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Information technology — Telecommunications and information exchange between systems — Local and metropolitan area networks — Specific requirements —

Part 3: Standard for Ethernet

Technologies de l'information — Télécommunications et échange d'information entre systèmes — Réseaux locaux et métropolitains — Prescriptions spécifiques —

Partie 3: Norme pour Ethernet

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ISO/IEC/IEEE 8802-3 was prepared by the LAN/MAN of the IEEE Computer Society (as IEEE Std 802.3-2015). It was adopted by Joint Technical Committee ISO/IEC JTC 1, Information technology, Subcommittee SC 6, Telecommunications and information exchange between systems, in parallel with its approval by the ISO/IEC national bodies, under the “fast-track procedure” defined in the Partner Standards Development Organization cooperation agreement between ISO and IEEE. IEEE is responsible for the maintenance of this document with participation and input from ISO/IEC national bodies.

This second edition cancels and replaces the first edition (ISO/IEC/IEEE 8802-3:2014), which has been technically revised.

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IEEE Std 802.3™-2015
(Revision of
IEEE Std 802.3-2012)

IEEE Standard for Ethernet

LAN/MAN Standards Committee
of the
IEEE Computer Society

Approved 3 September 2015

IEEE-SA Standards Board

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Abstract: Ethernet local area network operation is specified for selected speeds of operation from 1 Mb/s to 100 Gb/s using a common media access control (MAC) specification and management information base (MIB). The Carrier Sense Multiple Access with Collision Detection (CSMA/CD) MAC protocol specifies shared medium (half duplex) operation, as well as full duplex operation. Speed specific Media Independent Interfaces (MIIs) allow use of selected Physical Layer devices (PHY) for operation over coaxial, twisted pair or fiber optic cables, or electrical backplanes. System considerations for multisegment shared access networks describe the use of Repeaters which are defined for operational speeds up to 1000 Mb/s. Local Area Network (LAN) operation is supported at all speeds. Other specified capabilities include: various PHY types for access networks, PHYs suitable for metropolitan area network applications, and the provision of power over selected twisted pair PHY types.

Keywords: 10BASE; 100BASE; 1000BASE; 10GBASE; 40GBASE; 100GBASE; Fast Ethernet; 10 Gigabit Ethernet; 40 Gigabit Ethernet; 100 Gigabit Ethernet; attachment unit interface; AUI; Auto Negotiation; Backplane Ethernet; data processing; DTE Power via the MDI; EPON; Ethernet; Ethernet in the First Mile; Ethernet passive optical network; Fast Ethernet; Gigabit Ethernet; GMII; IEEE 802.3™; information exchange; local area network; management; medium dependent interface; media independent interface; MDI; MIB; MII; XGMII; PHY; physical coding sublayer; Physical Layer; physical medium attachment; PMA; Power over Ethernet; repeater; type field; VLAN TAG

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Participants

The following individuals were officers and members of the IEEE 802.3 working group at the beginning of the IEEE 802.3bx working group ballot.

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Adam Healey, *IEEE 802.3 Working Group Vice-Chair*
Pete Anslow, *IEEE 802.3 Working Group Secretary*
Steven B. Carlson, *IEEE 802.3 Working Group Executive Secretary*
Valerie Maguire, *IEEE 802.3 Working Group Treasurer*

Adam Healey, *IEEE P802.3 (IEEE 802.3bx) Task Force Chair and Editor-in-Chief*
Valerie Maguire, *IEEE P802.3 (IEEE 802.3bx) Task Force Recording Secretary and Section Editor*
Pete Anslow, *IEEE P802.3 (IEEE 802.3bx) Task Force Section Editor*
Marek Hajduczenia, *IEEE P802.3 (IEEE 802.3bx) Task Force Section Editor*

Historical participants

The following individuals participated in the IEEE 802.3 working group during various stages of the standard's development. Since the initial publication, many IEEE standards have added functionality or provided updates to material included in this standard. Included is a historical list of participants who have dedicated their valuable time, energy, and knowledge to the creation of this material:

IEEE Std 802.3 document	Date approved by IEEE and ANSI	Officers at the time of working group ballot
IEEE Std 802.3-1985, Original 10 Mb/s standard, MAC, PLS, AUI, 10BASE5	23 June 1983 (IEEE) 31 December 1984 (ANSI)	**Donald C. Loughry,** *Working Group Chair*
IEEE Std 802.3a-1988 (Clause 10), 10 Mb/s MAU 10BASE2	15 November 1985 (IEEE) 28 December 1987 (ANSI)	**Donald C. Loughry,** *Working Group Chair* **Alan Flatman,** *Task Force Chair*
IEEE Std 802.3b-1985 (Clause 11), 10 Mb/s Broadband MAU, 10BROAD36	19 September 1985 (IEEE) 28 February 1986 (ANSI)	**Donald C. Loughry,** *Working Group Chair* **Menachem Abraham,** *Task Force Chair*
IEEE Std 802.3c-1985 (9.1–9.8), 10 Mb/s Baseband Repeater	12 December 1985 (IEEE) 4 June 1986 (ANSI)	**Donald C. Loughry,** *Working Group Chair* **Geoffrey O. Thompson,** *Task Force Chair*
IEEE Std 802.3d-1987 (9.9), 10 Mb/s Fiber MAU, FOIRL	10 December 1987 (IEEE) 9 February 1989 (ANSI)	**Donald C. Loughry,** *Working Group Chair* **Steven Moustakas,** *Task Force Chair*
IEEE Std 802.3e-1987 (Clause 12), 1 Mb/s MAU and Hub 1BASE5	11 June 1987 (IEEE) 15 December 1987 (ANSI)	**Donald C. Loughry,** *Working Group Chair* **Robert Galin,** *Task Force Chair*
IEEE Std 802.3h-1990 (Clause 5), 10 Mb/s Layer Management, DTEs	28 September 1990 (IEEE) 11 March 1991 (ANSI)	**Donald C. Loughry,** *Working Group Chair* **Andy J. Luque,** *Task Force Chair*
IEEE Std 802.3i-1990 (Clauses 13 and 14), 10 Mb/s UTP MAU, 10 BASE-T	28 September 1990 (IEEE) 11 March 1991 (ANSI)	**Donald C. Loughry**, *Working Group Chair* **Patricia Thaler,** *Task Force Chair (initial)* **Richard Anderson,** *Task Force Chair (final)*
IEEE Std 802.3j-1993 (Clauses 15–18), 10 Mb/s Fiber MAUs 10BASE-FP, 10BASE-FB, and 10BASE-FL	15 September 1993 (IEEE) 15 March 1994 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Keith Amundsen,** *Task Force Chair (initial)* **Frederick Scholl,** *Task Force Chair (final)* **Michael E. Lee,** *Technical Editor*

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IEEE Std 802.3k-1993 (Clause 19), 10 Mb/s Layer Management, Repeaters	17 September 1992 (IEEE) 8 March 1993 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Joseph S. Skorupa,** *Task Force Chair* **Geoffrey O. Thompson,** *Vice Chair and Editor*
IEEE Std 802.3*l*-1992 (14.10), 10 Mb/s PICS Proforma 10BASE-T MAU	17 September 1992 (IEEE) 23 February 1993 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Mike Armstrong,** *Task Force Chair and Editor* **Paul Nikolich,** *Vice Chair* **William Randle,** *Editorial Coordinator*
IEEE Std 802.3m-1995, Maintenance 2	21 September 1995 (IEEE) 16 July 1996 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Gary Robinson,** *Maintenance Chair*
IEEE Std 802.3n-1995, Maintenance 3	21 September 1995 (IEEE) 4 April 1996 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Gary Robinson,** *Maintenance Chair*
IEEE Std 802.3p-1993 (Clause 20), Management, 10 Mb/s Integrated MAUs	17 June 1993 (IEEE) 4 January 1994 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Joseph S. Skorupa,** *Task Force Chair* **Geoffrey O. Thompson,** *Vice Chair and Editor*
IEEE Std 802.3q-1993 (Clause 5), 10 Mb/s Layer Management, GDMO Format	17 June 1993 (IEEE) 4 January 1994 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Joseph S. Skorupa,** *Task Force Chair* **Geoffrey O. Thompson,** *Vice Chair and Editor*
IEEE Std 802.3r-1996 (8.8), Type 10BASE5 Medium Attachment Unit PICS proforma	29 July 1996 (IEEE) 6 January 1997 (ANSI)	**Patricia Thaler,** *Working Group Chair* **Imre Juhász**, *Task Force Chair* **William Randle,** *Task Force Editor*
IEEE Std 802.3s-1995, Maintenance 4	21 September 1995 (IEEE) 8 April 1996 (ANSI)	**Geoffrey O. Thompson,** *Working Group Chair* **Gary Robinson,** *Maintenance Chair*
IEEE Std 802.3t-1995, 120 Ω informative annex to 10BASE-T	14 June 1995 (IEEE) 12 January 1996 (ANSI)	**Geoffrey O. Thompson,** *Working Group Chair* **Jacques Christ,** *Task Force Chair*
IEEE Std 802.3u-1995 (Clauses 21–30), Type 100BASE-T MAC parameters, Physical Layer, MAUs, and Repeater for 100 Mb/s Operation	14 June 1995 (IEEE) 4 April 1996 (ANSI)	**Geoffrey O. Thompson,** *Working Group Chair* **Peter Tarrant,** *Task Force Chair (Phase 1)* **Howard Frazier,** *Task Force Chair (Phase 2)* **Paul Sherer,** *Task Force Editor-in-Chief (Phase 1)* **Howard Johnson,** *Task Force Editor-in-Chief (Phase 2)* **Colin Mick,** *Task Force Comment Editor*
IEEE Std 802.3v-1995, 150 Ω informative annex to 10BASE-T	12 December 1995 (IEEE) 16 July 1996 (ANSI)	**Geoffrey O. Thompson,** *Working Group Chair* **Larry Nicholson,** *Task Force Chair*
IEEE Std 802.3x-1997 and IEEE Std 802.3y-1997 (Revisions to IEEE Std 802.3, Clauses 31 and 32), Full-Duplex Operation and Type 100BASE-T2	20 March 1997 (IEEE) 5 September 1997 (ANSI)	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Rich Seifert,** *Task Force Chair and Editor (802.3x)* **J. Scott Carter,** *Task Force Chair (802.3y)* **Colin Mick**, *Task Force Editor (802.3y)*
IEEE Std 802.3z-1998 (Clauses 34–39, 41–42), Type 1000BASE-X MAC Parameters, Physical Layer, Repeater, and Management Parameters for 1000 Mb/s Operation	25 June 1998 (IEEE)	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Howard M. Frazier, Jr.,** *Task Force Chair* **Howard W. Johnson,** *Task Force Editor*
IEEE Std 802.3aa-1998, Maintenance 5	25 June 1998 (IEEE)	**Geoffrey O. Thompson,** *Working Group Chair* **Colin Mick**, *Task Force Editor*
IEEE Std 802.3ab-1999 (Clause 40), Physical Layer Parameters and Specifications for 1000 Mb/s Operation Over 4 Pair of Category 5 Balanced Copper Cabling, Type 1000BASE-T	26 June 1999 (IEEE)	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Robert M. Grow,** *Working Group Secretary* **George Eisler**, *Task Force Chair* **Colin Mick**, *Task Force Editor*

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IEEE Std 802.3ac-1998, Frame Extensions for Virtual Bridged Local Area Network (VLAN) Tagging on IEEE 802.3 Networks	16 September 1998 (IEEE)	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Andy J. Luque,** *Working Group Secretary* **Ian Crayford,** *Task Force Chair* **Rich Seifert,** *Task Force Editor*
IEEE Std 802.3ad-2000 (Clause 43), Aggregation of Multiple Link Segments	30 March 2000 (IEEE)	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Robert M. Grow,** *Working Group Secretary* **Steven Haddock,** *Task Force Chair* **Tony Jeffree,** *Task Force Co-Editor* **Rich Seifert,** *Task Force CoEditor*
IEEE Std 802.3-2002 (IEEE 802.3ag, Maintenance 6, Revision of the base), Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and Physical Layer specifications	14 January 2002 (IEEE)	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Robert M. Grow,** *Working Group Secretary*
IEEE Std 802.3ae-2002, (Clauses 44–53) Media Access Control (MAC) Parameters, Physical Layers, and Management Parameters for 10 Gb/s Operation	13 June 2002 (IEEE)	**Geoffrey O. Thompson,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Robert M. Grow,** *Working Group Secretary* **R. Jonathan Thatcher,** *Task Force Chair* **Stephen Haddock,** *Task Force Vice Chair* **Bradley J. Booth,** *Task Force Editor* **Lacreshia Laningham,** *Task Force Assistant Editor* **Benjamin Brown,** *Logic Track Chair* **Walter Thirion,** *Optical Track Chair*
IEEE Std 802.3af-2003, (Clause 33) Data Terminal Equipment (DTE) Power via Media Dependent Interface (MDI)	12 June 2003 (IEEE)	**Geoffrey O. Thompson,** *Working Group Chair (Phase 1)* **Robert M. Grow,** *Working Group Chair (Phase 2)* **David J. Law,** *Working Group Vice Chair* **Robert M. Grow,** *Working Group Secretary (Phase 1)* **Steven B. Carlson,** *Working Group Secretary (Phase 2)* **Steven B. Carlson,** *Task Force Chair* **Michael S. McCormack,** *Task Force Editor (Phase 1)* **John J. Jetzt,** *Task Force Editor (Phase 2)* **Chad M. Jones,** *Task Force Comment Editor*
IEEE Std 802.3ah-2004, Media Access Control Parameters, Physical Layers, and Management Parameters for Subscriber Access Networks	6 April 2005 (IEEE)	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Steven B. Carlson,** *Working Group Secretary* **Howard Frazier,** *Task Force Chair* **Wael W. Diab,** *Task Force Editor-in-Chief* **Hugh Barrass,** *Task Force Vice-Chair* **Scott Simon,** *Task Force Recording Secretary* **Behrooz Rezvani,** *Task Force Executive Secretary*
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IEEE Std 802.3ak-2004, Physical Layer and Management Parameters for 10Gb/s Operation, Type 10GBASE-CX4	9 February 2004 (IEEE)	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Steven B. Carlson,** *Working Group Secretary* **Daniel J. Dove,** *Task Force Chair* **Howard A. Baumer,** *Task Force Editor*
IEEE Std 802.3-2005 (IEEE 802.3REVam, Revision of the base), Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and Physical Layer specifications	9 June 2005 (IEEE)	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Wael W. Diab,** *Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Piers Dawe,** *Review Editor*

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IEEE Std 802.3an-2006, Physical Layer and Management Parameter for 10 Gb/s Operation, Type 10GBASE-T	8 June 2006 (IEEE)	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Wael William Diab,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Bradley Booth,** *Task Force Chair* **Sanjay Kasturia,** *Task Force Editor-in Chief* **George Eisler,** *Task Force Recording Secretary*
IEEE Std 802.3ap-2007, Ethernet Operation over Electrical Backplanes	22 March 2007 (IEEE)	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice-Chair* **Wael W. Diab**, *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Bradley Booth,** *Working Group Treasurer* **Adam Healey,** *Task Force Chair* **John D'Ambrosia,** *Task Force Secretary* **Schelto vanDoorn,** *Task Force Editor-in-Chief (Phase 1)* **Ilango S. Ganga,** *Task Force Editor-in-Chief (Phase 2)*
IEEE Std 802.3aq-2006, Physical Layer and Management Parameters for 10 Gb/s Operation, Type 10GBASE-LRM	15 September 2006 (IEEE)	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair* **Wael William Diab,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **David G. Cunningham,** *Task Force Chair* **Nick Weiner,** *Task Force Editor* **Piers Dawe,** *Task Force Contributing Editor*
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IEEE Std 802.3-2005/Cor 1-2006 (IEEE 802.3au), DTE Power via MDI Isolation corrigendum	8 June 2006 (IEEE)	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair, Task Force Editor* **Wael W. Diab**, *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary*
IEEE Std 802.3-2005/Cor 2-2007 (IEEE 802.3aw), 10GBASE-T corrigendum	7 June 2007 (IEEE)	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair, Task Force Editor* **Wael W. Diab**, *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Bradley Booth,** *Working Group Treasurer*
IEEE Std 802.3-2008 (IEEE 802.3ay), Maintenance #9 (Revision of the base), Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and Physical Layer specifications	26 September 2008 (IEEE)	**Robert M. Grow,** *Working Group Chair* **David J. Law,** *Working Group Vice Chair, Task Force Editor* **Wael William Diab,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Bradley Booth,** *Working Group Treasurer*
IEEE Std 802.3at-2009 Data Terminal Equipment (DTE) Power via the Media Dependent Interface (MDI) Enhancements	11 September 2009 (IEEE)	**David J. Law,** *Working Group Chair* **Wael William Diab,** *Working Group Vice Chair* **Adam Healey,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Bradley Booth,** *Working Group Treasurer* **Mike McCormack,** *Task Force Chair* **D. Matthew Landry,** *Task Force Chief Editor* **Chad Jones,** *Task Force Comment Editor*
IEEE Std 802.3av-2009 Physical Layer Specifications and Management Parameters for 10 Gb/s Passive Optical Networks	11 September 2009 (IEEE)	**David J. Law,** *Working Group Chair* **Wael William Diab,** *Working Group Vice Chair* **Adam Healey,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Bradley Booth,** *Working Group Treasurer* **Glen Kramer,** *Task Force Chair* **Duane Remein,** *Task Force Chief Editor* **Marek Hajduczenia,** *Task Force Assistant Editor*

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IEEE Std 802.3 document	Date approved by IEEE and ANSI	Officers at the time of working group ballot
IEEE Std 802.3az-2010 Media Access Control Parameters, Physical Layers, and Management Parameters for Energy-Efficient Ethernet	30 September 2010 (IEEE)	**David J. Law,** *Working Group Chair* **Wael William Diab,** *Working Group Vice Chair* **Steven B. Carlson,** *Working Group Executive Secretary* **Adam Healey,** *Working Group Secretary* **Bradley Booth,** *Working Group Treasurer* **Michael Bennett,** *Task Force Chair* **Sanjay Kasturia,** *Task Force Editor-in-Chief*
IEEE Std 802.3ba Media Access Control Parameters, Physical Layers, and Management Parameters for 40 Gb/s and 100 Gb/s Operation	17 June 2010 (IEEE)	**David J. Law,** *Working Group Chair* **Wael William Diab,** *Working Group Vice-Chair* **Steven B. Carlson,** *Working Group Executive Secretary* **Adam Healey,** *Working Group Secretary* **Bradley Booth,** *Working Group Treasurer* **John D'Ambrosia,** *Task Force Chair* **Ilango S. Ganga,** *Task Force Editor-in-Chief*
IEEE Std 802.3-2008/Cor 1-2009 (IEEE 802.3bb) Pause Reaction Delay Corrigendum.	9 December 2009 (IEEE)	**David J. Law,** *Working Group Chair* **Wael William Diab,** *Working Group Vice-Chair* **Steven B. Carlson,** *Working Group Executive Secretary* **Adam Healey,** *Working Group Secretary* **Bradley Booth,** *Working Group Treasurer*
IEEE Std 802.3bc-2009 Ethernet Organizationally Specific Type, Length, Value (TLVs)	11 September 2009 (IEEE)	**David J. Law,** *Working Group Chair and Task Force Editor* **Wael W. Diab,** *Working Group Vice Chair, Task Force Chair* **Steven B. Carlson,** *Working Group Executive Secretary* **Adam Healey,** *Working Group Secretary* **Bradley Booth,** *Working Group Treasurer*
IEEE Std 802.3bd-2011 MAC Control Frame for Priority-based Flow Control	16 June 2011 (IEEE)	**Tony Jeffree,** *IEEE 802.1 Working Group Chair* **Paul Congdon,** *IEEE 802.1 Working Group Vice Chair* **David J. Law,** *IEEE 802.3 Working Group Chair* **Wael W. Diab,** *IEEE 802.3 Working Group Vice Chair* **Pat Thaler,** *Data Center Bridging Task Group Chair*
IEEE Std 802.3bf-2011 Media Access Control (MAC) Service Interface and Management Parameters to Support Time Synchronization Protocols	16 May 2011 (IEEE)	**David J. Law,** *Working Group Chair* **Wael William Diab,** *Working Group Vice-Chair* **Adam Healey,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasurer* **Steven B. Carlson,** *Task Force Chair* **Marek Hajduczenia,** *Task Force Editor-in-Chief*
IEEE Std 802.3bg-2011 Physical Layer and Management Parameters for Serial 40 Gb/s Ethernet Operation Over Single-Mode Fiber	31 March 2011 (IEEE)	**David J. Law,** *Working Group Chair* **Wael William Diab,** *Working Group Vice-Chair* **Adam Healey,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasurer* **Mark Nowell,** *Task Force Chair* **Pete Anslow,** *Task Force Editor-in-Chief*
IEEE Std 802.3-2012 (IEEE 802.3ah), Maintenance #10 (Revision of the base), Standard for Ethernet	28 December 2012 (IEEE)	**David J. Law,** *Working Group Chair* **Wael William Diab,** *Working Group Vice-Chair, Task Force Chair and Editor-in-Chief* **Adam Healey,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasure*
IEEE Std 802.3bk-2013 Physical Layer Specifications and Management Parameters for Extended Ethernet Passive Optical Networks	23 August 2013 (IEEE)	**David J. Law,** *Working Group Chair* **Wael William Diab,** *Working Group Vice-Chair* **Adam Healey,** *Working Group Secretary* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasurer* **Marek Hajduczenia,** *Task Force Chair* **Susumu Nishihara,** *Task Force Editor-in-Chief*

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IEEE Std 802.3bj-2014 Physical Layer Specifications and Management Parameters for 100 Gb/s Operation Over Backplanes and Copper Cables	12 June 2014 (IEEE)	**David J. Law,** *Working Group Chair* **Wael William Diab,** *Working Group Vice-Chair (initial)* **Adam Healey,** *Working Group Secretary, (initial), Task Force Editor-in-Chief (initial), Working Group Vice-Chair (final), Task Force Chair (final)* **Peter Anslow,** *Working Group Secretary (final)* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasurer* **John D'Ambrosia,** *Task Force Chair (initial)* **Matthew Brown,** *Task Force Editor-in-Chief (final)*
IEEE Std 802.3bm-2015 Physical Layer Specifications and Management Parameters for 40 Gb/s and 100 Gb/s Operation Over Fiber Optic Cables	16 February 2015 (IEEE)	**David J. Law,** *Working Group Chair* **Adam Healey,** *Working Group Vice-Chair* **Pete Anslow,** *Working Group Secretary and Task Force Editor-in-Chief* **Steven B. Carlson,** *Working Group Executive Secretary* **Valerie Maguire,** *Working Group Treasurer* **Dan Dove,** *Task Force Chair* **Kapil Shrikhande,** *Task Force Vice-Chair*

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Introduction

This introduction is not part of IEEE Std 802.3™-2015, IEEE Standard for Ethernet.

IEEE Std 802.3™ was first published in 1985. Since the initial publication, many projects have added functionality or provided maintenance updates to the specifications and text included in the standard. Each IEEE 802.3 project/amendment is identified with a suffix (e.g., IEEE Std 802.3ba™-2010).

The half duplex Media Access Control (MAC) protocol specified in IEEE Std 802.3-1985 is Carrier Sense Multiple Access with Collision Detection (CSMA/CD). This MAC protocol was key to the experimental Ethernet developed at Xerox Palo Alto Research Center, which had a 2.94 Mb/s data rate. Ethernet at 10 Mb/s was jointly released as a public specification by Digital Equipment Corporation (DEC), Intel and Xerox in 1980. Ethernet at 10 Mb/s was approved as an IEEE standard by the IEEE Standards Board in 1983 and subsequently published in 1985 as IEEE Std 802.3-1985. Since 1985, new media options, new speeds of operation, and new capabilities have been added to IEEE Std 802.3. A full duplex MAC protocol was added in 1997.

Some of the major additions to IEEE Std 802.3 are identified in the marketplace with their project number. This is most common for projects adding higher speeds of operation or new protocols. For example, IEEE Std 802.3u™ added 100 Mb/s operation (also called Fast Ethernet), IEEE Std 802.3z added 1000 Mb/s operation (also called Gigabit Ethernet), IEEE Std 802.3ae added 10 Gb/s operation (also called 10 Gigabit Ethernet), IEEE Std 802.3ah™ specified access network Ethernet (also called Ethernet in the First Mile) and IEEE Std 802.3ba added 40 Gb/s operation (also called 40 Gigabit Ethernet) and 100 Gb/s operation (also called 100 Gigabit Ethernet). These major additions are all now included in and are superseded by IEEE Std 802.3-2015 and are not maintained as separate documents.

At the date of IEEE Std 802.3-2015 publication, IEEE Std 802.3 is composed of the following documents:

IEEE Std 802.3-2015

Section One—Includes Clause 1 through Clause 20 and Annex A through Annex H and Annex 4A. Section One includes the specifications for 10 Mb/s operation and the MAC, frame formats and service interfaces used for all speeds of operation.

Section Two—Includes Clause 21 through Clause 33 and Annex 22A through Annex 33E. Section Two includes management attributes for multiple protocols and speed of operation as well as specifications for providing power over twisted pair cabling for multiple operational speeds. It also includes general information on 100 Mb/s operation as well as most of the 100 Mb/s Physical Layer specifications.

Section Three—Includes Clause 34 through Clause 43 and Annex 36A through Annex 43C. Section Three includes general information on 1000 Mb/s operation as well as most of the 1000 Mb/s Physical Layer specifications.

Section Four—Includes Clause 44 through Clause 55 and Annex 44A through Annex 55B. Section Four includes general information on 10 Gb/s operation as well as most of the 10 Gb/s Physical Layer specifications.

Section Five—Includes Clause 56 through Clause 77 and Annex 57A through Annex 76A. Clause 56 through Clause 67 and Clause 75 through Clause 77, as well as associated annexes, specify subscriber access and other Physical Layers and sublayers for operation from 512 kb/s to 10 Gb/s, and defines services and protocol elements that enable the exchange of IEEE Std 802.3 format frames between stations in a subscriber access network. Clause 68 specifies a 10 Gb/s Physical Layer specification.

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Clause 69 through Clause 74 and associated annexes specify Ethernet operation over electrical backplanes at speeds of 1000 Mb/s and 10 Gb/s.

Section Six—Includes Clause 78 through Clause 95 and Annex 83A through Annex 93C. Clause 78 specifies Energy-Efficient Ethernet. Clause 79 specifies IEEE 802.3 Organizationally Specific Link Layer Discovery Protocol (LLDP) type, length, and value (TLV) information elements. Clause 80 through Clause 95 and associated annexes includes general information on 40 Gb/s and 100 Gb/s operation as well the 40 Gb/s and 100 Gb/s Physical Layer specifications. Clause 90 specifies Ethernet support for time synchronization protocols.

A companion document IEEE Std 802.3.1 describes Ethernet management information base (MIB) modules for use with the Simple Network Management Protocol (SNMP). IEEE Std 802.3.1 is updated to add management capability for enhancements to IEEE Std 802.3 after approval of the enhancements.

IEEE Std 802.3 will continue to evolve. New Ethernet capabilities are anticipated to be added within the next few years as amendments to this standard.

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List of special symbols

For the benefit of users who have received this document by electronic means, what follows is a list of special symbols and operators. If any of these symbols or operators fail to print out correctly, the editors apologize and hope that this table will at least help to sort out the meaning of the resulting funny-shaped blobs and strokes.

Special symbols and operators

Printed character	Meaning	Font
*	Boolean AND	Symbol
+	Boolean OR, arithmetic addition	Symbol
^	Boolean XOR	Times New Roman
!	Boolean NOT	Symbol
x	Multiplication	Symbol
<	Less than	Symbol
≤	Less than or equal to	Symbol
>	Greater than	Symbol
≥	Greater than or equal to	Symbol
=	Equal to	Symbol
≈	Approximately equal to	Symbol
≠	Not equal to	Symbol
⇐	Assignment operator	Symbol
∈	Indicates membership	Symbol
∉	Indicates nonmembership	Symbol
±	Plus or minus (a tolerance)	Symbol
°	Degrees	Symbol
Σ	Summation	Symbol
√	Square root	Symbol
—	Big dash (em dash)	Times New Roman
–	Little dash (en dash), subtraction	Times New Roman
|	Vertical bar	Times New Roman
†	Dagger	Times New Roman
‡	Double dagger	Times New Roman
α	Lower case alpha	Symbol
β	Lower case beta	Symbol
γ	Lower case gamma	Symbol
δ	Lower case delta	Symbol
ε	Lower case epsilon	Symbol
λ	Lower case lambda	Symbol
μ	Lower case mu	Times New Roman
Π	Upper case pi	Symbol
Ω	Upper case omega	Symbol

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IEEE Standard for Ethernet

SECTION ONE

This section includes Clause 1 through Clause 20, Annex A through Annex H, and Annex 4A.

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IEEE Standard for Ethernet

Section One: This section includes Clause 1 through Clause 20, Annex A through Annex H, and Annex 4A.

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1. Introduction

1.1 Overview

This is an international standard for Local and Metropolitan Area Networks (LANs and MANs), employing CSMA/CD as the shared media access method and the IEEE 802.3 (Ethernet) protocol and frame format for data communication. This international standard is intended to encompass several media types and techniques for a variety of MAC data rates as shown in Figure 1–1 and in 4.4.2.

1.1.1 Scope

This standard defines Ethernet local area, access and metropolitan area networks. Ethernet is specified at selected speeds of operation; and uses a common media access control (MAC) specification and management information base (MIB). The Carrier Sense Multiple Access with Collision Detection (CSMA/CD) MAC protocol specifies shared medium (half duplex) operation, as well as full duplex operation. Speed specific Media Independent Interfaces (MIIs) provide an architectural and optional implementation interface to selected Physical Layer entities (PHY). The Physical Layer encodes frames for transmission and decodes received frames with the modulation specified for the speed of operation, transmission medium and supported link length. Other specified capabilities include: control and management protocols, and the provision of power over selected twisted pair PHY types.

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1.1.2 Basic concepts

This standard provides for two distinct modes of operation: half duplex and full duplex. A given IEEE 802.3 instantiation operates in either half or full duplex mode at any one time. The term "CSMA/CD MAC" is used throughout this standard synonymously with "802.3 MAC," and may represent an instance of either a half duplex or full duplex mode data terminal equipment (DTE), even though full duplex mode DTEs do not implement the CSMA/CD algorithms traditionally used to arbitrate access to shared-media LANs.

1.1.2.1 Half duplex operation

In half duplex mode, the CSMA/CD media access method is the means by which two or more stations share a common transmission medium. To transmit, a station waits (defers) for a quiet period on the medium (that is, no other station is transmitting) and then sends the intended message in bit-serial form. If, after initiating a transmission, the message collides with that of another station, then each transmitting station intentionally transmits for an additional predefined period to ensure propagation of the collision throughout the system. The station remains silent for a random amount of time (backoff) before attempting to transmit again. Each aspect of this access method process is specified in detail in subsequent clauses of this standard.

Half duplex operation can be used with certain media types and configurations as defined by this standard. For allowable configurations, see 4.4.2.

1.1.2.2 Full duplex operation

Full duplex operation allows simultaneous communication between a pair of stations using point-to-point media (dedicated channel). Full duplex operation does not require that transmitters defer, nor do they monitor or react to receive activity, as there is no contention for a shared medium in this mode. Full duplex mode can only be used when all of the following are true:

a) The physical medium is capable of supporting simultaneous transmission and reception without interference.
b) There are exactly two stations connected with a full duplex point-to-point link. Since there is no contention for use of a shared medium, the multiple access (i.e., CSMA/CD) algorithms are unnecessary.
c) Both stations on the LAN are capable of, and have been configured to use, full duplex operation.

The most common configuration envisioned for full duplex operation consists of a central bridge (also known as a switch) with a dedicated LAN connecting each bridge port to a single device. Repeaters as defined in this standard are outside the scope of full duplex operation.

Full duplex operation constitutes a proper subset of the MAC functionality required for half duplex operation.

1.1.3 Architectural perspectives

There are two important ways to view network design corresponding to the following:

a) *Architecture.* Emphasizing the logical divisions of the system and how they fit together.
b) *Implementation.* Emphasizing actual components, their packaging, and interconnection.

This standard is organized along architectural lines, emphasizing the large-scale separation of the system into two parts: the Media Access Control (MAC) sublayer of the Data Link Layer and the Physical Layer. These layers are intended to correspond closely to the lowest layers of the ISO/IEC Model for Open Systems Interconnection (see Figure 1–1). (See ISO/IEC 7498-1:1994.[1]) The Logical Link Control (LLC) sublayer and MAC sublayer together encompass the functions intended for the Data Link Layer as defined in the OSI model.

[1]For information about references, see 1.3.

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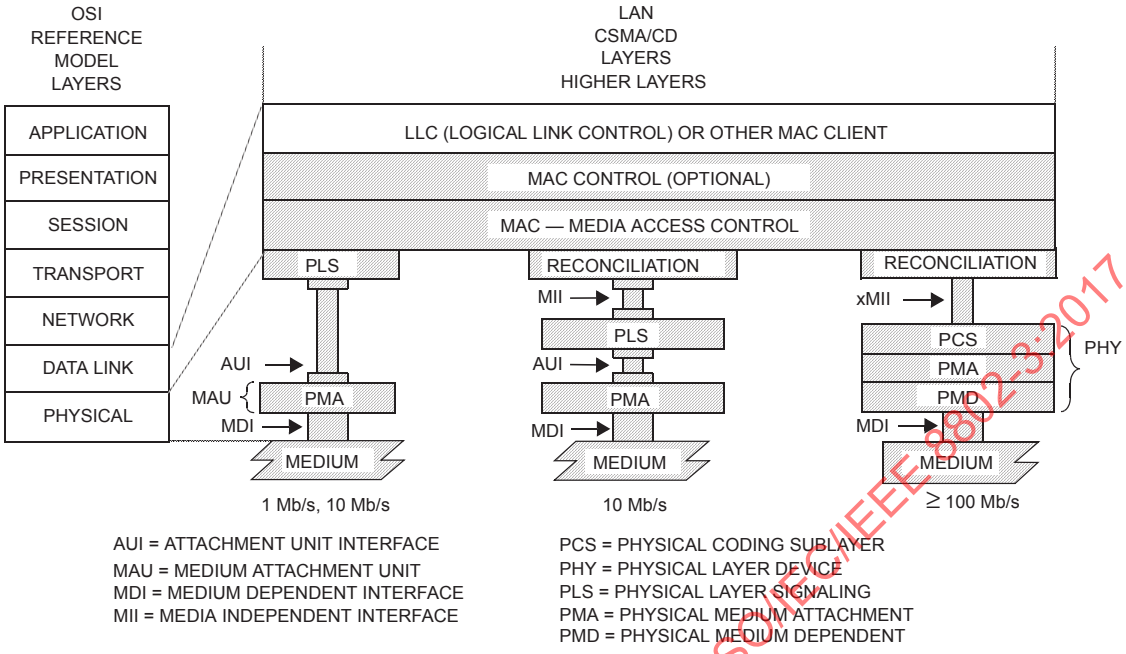

NOTE—In this figure, the xMII is used as a generic term for the Media Independent Interfaces for implementations of 100 Mb/s and above. For example: for 100 Mb/s implementations this interface is called MII; for 1 Gb/s implementations it is called GMII; for 10 Gb/s implementations it is called XGMII; etc.

Figure 1–1—IEEE 802.3 standard relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model

1.1.3.1 Architectural rationale

An architectural organization of the standard has two main advantages:

a) *Clarity.* A clean overall division of the design along architectural lines makes the standard clearer.
b) *Flexibility.* Segregation of medium-dependent aspects in the Physical Layer allows the LLC and MAC sublayers to apply to a family of transmission media.

Partitioning the Data Link Layer allows various media access methods within the family of LAN standards.

The architectural model is based on a set of interfaces that may be different from those emphasized in implementations. One critical aspect of the design, however, shall be addressed largely in terms of the implementation interfaces: compatibility.

1.1.3.2 Compatibility interfaces

The following important compatibility interfaces are defined within what is architecturally the Physical Layer.

a) *Medium Dependent Interfaces (MDI).* To communicate in a compatible manner, all stations shall adhere rigidly to the exact specification of physical media signals defined in the appropriate clauses in this standard, and to the procedures that define correct behavior of a station. The medium-independent aspects of the LLC sublayer and the MAC sublayer should not be taken as detracting from this point; communication in an Ethernet Local Area Network requires complete compatibility at the Physical Medium interface (that is, the physical cable interface).

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b) *Attachment Unit Interface (AUI).* Some DTEs are located some distance from their connection to the physical cable. A small amount of circuitry will exist in the Medium Attachment Unit (MAU) directly adjacent to the physical cable, while the majority of the hardware and all of the software will be placed within the DTE. The AUI is defined as a second compatibility interface. While conformance with this interface is not strictly necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing MAUs and DTEs. The AUI may be optional or not specified for some implementations of this standard that are expected to be connected directly to the medium and so do not use a separate MAU or its interconnecting AUI cable. The PLS and PMA are then part of a single unit, and no explicit AUI implementation is required.

c) *Media Independent Interface (MII).* It is anticipated that some DTEs will be connected to a remote PHY, and/or to different medium dependent PHYs. The MII is defined as a third compatibility interface. While conformance with implementation of this interface is not strictly necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing PHYs and DTEs. The MII is optional.

d) *Gigabit Media Independent Interface (GMII).* The GMII is designed to connect a 1 Gb/s capable MAC or repeater unit to a 1 Gb/s PHY. While conformance with implementation of this interface is not strictly necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing PHYs and DTEs at 1 Gb/s speeds. The GMII is intended for use as a chip-to-chip interface. No mechanical connector is specified for use with the GMII. The GMII is optional.

e) *Ten-bit Interface (TBI).* The TBI is provided by the 1000BASE-X PMA sublayer as a physical instantiation of the PMA service interface. The TBI is recommended for 1000BASE-X systems, since it provides a convenient partition between the high-frequency circuitry associated with the PMA sublayer and the logic functions associated with the PCS and MAC sublayers. The TBI is intended for use as a chip-to-chip interface. No mechanical connector is specified for use with the TBI. The TBI is optional.

f) *10 Gigabit Media Independent Interface (XGMII).* The XGMII is designed to connect a 10 Gb/s capable MAC to a 10 Gb/s PHY. While conformance with implementation of this interface is not necessary to ensure communication, it allows maximum flexibility in intermixing PHYs and DTEs at 10 Gb/s speeds. The XGMII is intended for use as a chip-to-chip interface. No mechanical connector is specified for use with the XGMII. The XGMII is optional.

g) *10 Gigabit Attachment Unit Interface (XAUI).* The XAUI is designed to extend the connection between a 10 Gb/s capable MAC and a 10 Gb/s PHY. While conformance with implementation of this interface is not necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing PHYs and DTEs at 10 Gb/s speeds. The XAUI is intended for use as a chip-to-chip interface. No mechanical connector is specified for use with the XAUI. The XAUI is optional.

h) *10 Gigabit Sixteen-Bit Interface (XSBI).* The XSBI is provided as a physical instantiation of the PMA service interface for 10GBASE-R and 10GBASE-W PHYs. While conformance with implementation of this interface is not necessary to ensure communication, it provides a convenient partition between the high-frequency circuitry associated with the PMA sublayer and the logic functions associated with the PCS and MAC sublayers. No mechanical connector is specified for use with the XSBI. The XSBI is optional.

i) *40 Gb/s Media Independent Interface (XLGMII).* The XLGMII is designed to connect a 40 Gb/s capable MAC to a 40 Gb/s PHY. While conformance with implementation of this interface is not necessary to ensure communication, it allows flexibility in intermixing PHYs and DTEs at 40 Gb/s speeds. The XLGMII is a logical interconnection intended for use as an intra-chip interface. No mechanical connector is specified for use with the XLGMII. The XLGMII is optional.

j) *40 Gb/s Attachment Unit Interface (XLAUI).* The XLAUI is a physical instantiation of the PMA service interface to extend the connection between 40 Gb/s capable PMAs. While conformance with implementation of this interface is not necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing PHYs and DTEs at 40 Gb/s speeds. The XLAUI is

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intended for use as a chip-to-chip or a chip-to-module interface. No mechanical connector is specified for use with the XLAUI. The XLAUI is optional.

k) *40 Gb/s Parallel Physical Interface (XLPPI)*. The XLPPI is provided as a physical instantiation of the PMD service interface for 40GBASE-SR4 and 40GBASE-LR4 PMDs. The XLPPI has four lanes. While conformance with implementation of this interface is not necessary to ensure communication, it allows flexibility in connecting the 40GBASE-SR4 or 40GBASE-LR4 PMDs. The XLPPI is intended for use as a chip-to-module interface. No mechanical connector is specified for use with the XLPPI. The XLPPI is optional.

l) *100 Gb/s Media Independent Interface (CGMII)*. The CGMII is designed to connect a 100 Gb/s capable MAC to a 100 Gb/s PHY. While conformance with implementation of this interface is not necessary to ensure communication, it allows flexibility in intermixing PHYs and DTEs at 100 Gb/s speeds. The CGMII is a logical interconnection intended for use as an intra-chip interface. No mechanical connector is specified for use with the CGMII. The CGMII is optional.

m) *100 Gb/s Attachment Unit Interface (CAUI-n)*. The CAUI-n is a physical instantiation of the PMA service interface to extend the connection between 100 Gb/s capable PMAs. While conformance with implementation of this interface is not necessary to ensure communication, it is recommended, since it allows maximum flexibility in intermixing PHYs and DTEs at 100 Gb/s speeds. The CAUI-n is intended for use as a chip-to-chip or a chip-to-module interface. Two widths of CAUI-n are defined: a ten-lane version (CAUI-10) in Annex 83A and Annex 83B, and a four-lane version (CAUI-4) in Annex 83D and Annex 83E. No mechanical connector is specified for use with the CAUI-n. The CAUI-n is optional.

n) *100 Gb/s Parallel Physical Interface (CPPI)*. The CPPI is provided as a physical instantiation of the PMD service interface for 100GBASE-SR10 PMDs. The CPPI has ten lanes. While conformance with implementation of this interface is not necessary to ensure communication, it allows flexibility in connecting the 100GBASE-SR10 PMDs. The CPPI is intended for use as a chip-to-module interface. No mechanical connector is specified for use with the CPPI. The CPPI is optional.

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1.1.4 Layer interfaces

In the architectural model used here, the layers interact by way of well-defined interfaces, providing services as specified in Clause 2 and Clause 6. In general, the interface requirements are as follows:

a) The interface between the MAC sublayer and its client includes facilities for transmitting and receiving frames, and provides per-operation status information for use by higher-layer error recovery procedures.
b) The interface between the MAC sublayer and the Physical Layer includes signals for framing (carrier sense, receive data valid, transmit initiation) and contention resolution (collision detect), facilities for passing a pair of serial bit streams (transmit, receive) between the two layers, and a wait function for timing.

These interfaces are described more precisely in 4.3. Additional interfaces are necessary to provide for MAC Control services, and to allow higher level network management facilities to interact with these layers to perform operation, maintenance, and planning functions. Network management functions are described in Clause 30.

1.1.5 Application areas

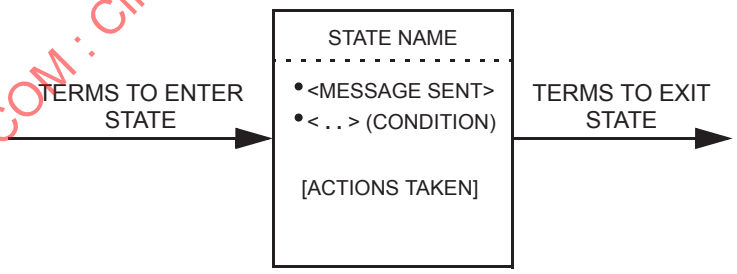
Use of this standard is not restricted to any specific environments or applications.

In the context of this standard, the term “LAN” is used to indicate all networks that utilize the IEEE 802.3 (Ethernet) protocol for communication. These may include (but are not limited to) LANs and MANs.

1.2 Notation

1.2.1 State diagram conventions

The operation of a protocol can be described by subdividing the protocol into a number of interrelated functions. The operation of the functions can be described by state diagrams. Each diagram represents the domain of a function and consists of a group of connected, mutually exclusive states. Only one state of a function is active at any given time (see Figure 1–2).



Key: ( ) = condition, for example, (if no_collision)
[ ] = action, for example, [reset PLS functions]
* = logical AND
+ = logical OR, arithmetic addition
Tw = Wait Time, implementation dependent
Td = Delay Timeout
Tb = Backoff Timeout
UCT = unconditional transition

Figure 1–2—State diagram notation example

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Each state that the function can assume is represented by a rectangle. These are divided into two parts by a horizontal line. In the upper part the state is identified by a name in capital letters. The lower part contains the name of any ON signal that is generated by the function. Actions are described by short phrases and enclosed in brackets.

All permissible transitions between the states of a function are represented graphically by arrows between them. A transition that is global in nature (for example, an exit condition from all states to the IDLE or RESET state) is indicated by an open arrow. Labels on transitions are qualifiers that must be fulfilled before the transition will be taken. The label UCT designates an unconditional transition. Qualifiers described by short phrases are enclosed in parentheses.

State transitions and sending and receiving of messages occur instantaneously. When a state is entered and the condition to leave that state is not immediately fulfilled, the state executes continuously, sending the messages and executing the actions contained in the state in a continuous manner.

Some devices described in this standard (e.g., repeaters) are allowed to have two or more ports. State diagrams that are capable of describing the operation of devices with an unspecified number of ports require a qualifier notation that allows testing for conditions at multiple ports. The notation used is a term that includes a description in parentheses of which ports must meet the term for the qualifier to be satisfied (e.g., ANY and ALL). It is also necessary to provide for term-assignment statements that assign a name to a port that satisfies a qualifier. The following conventions are used to describe a term-assignment statement that is associated with a transition:

a) The character ":" (colon) is a delimiter used to denote that a term assignment statement follows.
b) The character "⇐" (left arrow) denotes assignment of the value following the arrow to the term preceding the arrow.

The state diagrams contain the authoritative statement of the functions they depict; when apparent conflicts between descriptive text and state diagrams arise, the state diagrams are to take precedence. This does not override, however, any explicit description in the text that has no parallel in the state diagrams.

The models presented by state diagrams are intended as the primary specifications of the functions to be provided. It is important to distinguish, however, between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, while any realistic implementation may place heavier emphasis on efficiency and suitability to a particular implementation technology. It is the functional behavior of any unit that must match the standard, not its internal structure. The internal details of the model are useful only to the extent that they specify the external behavior clearly and precisely.

1.2.2 Service specification method and notation

The service of a layer or sublayer is the set of capabilities that it offers to a user in the next higher (sub)layer. Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition of service is independent of any particular implementation (see Figure 1–3).

Specific implementations may also include provisions for interface interactions that have no direct end-to-end effects. Examples of such local interactions include interface flow control, status requests and indications, error notifications, and layer management. Specific implementation details are omitted from this service specification both because they will differ from implementation to implementation and because they do not impact the peer-to-peer protocols.

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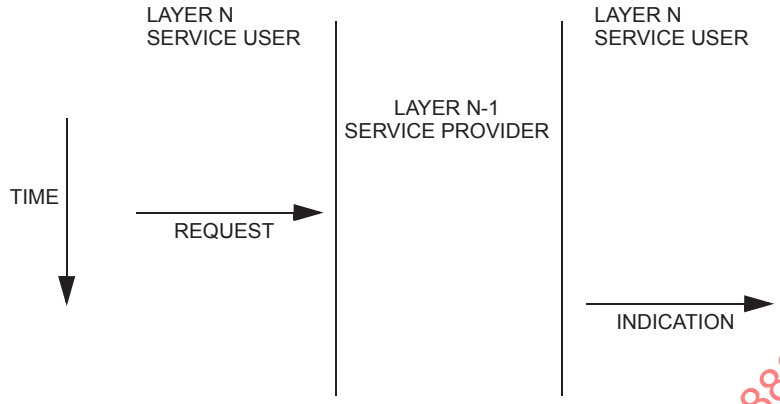

Figure 1–3—Service primitive notation

1.2.2.1 Classification of service primitives

Primitives are of two generic types:

a) REQUEST. The request primitive is passed from layer N to layer N-1 to request that a service be initiated.
b) INDICATION. The indication primitive is passed from layer N-1 to layer N to indicate an internal layer N-1 event that is significant to layer N. This event may be logically related to a remote service request, or may be caused by an event internal to layer N-1.

The service primitives are an abstraction of the functional specification and the user-layer interaction. The abstract definition does not contain local detail of the user/provider interaction. For instance, it does not indicate the local mechanism that allows a user to indicate that it is awaiting an incoming call. Each primitive has a set of zero or more parameters, representing data elements that shall be passed to qualify the functions invoked by the primitive. Parameters indicate information available in a user/provider interaction; in any particular interface, some parameters may be explicitly stated (even though not explicitly defined in the primitive) or implicitly associated with the service access point. Similarly, in any particular protocol specification, functions corresponding to a service primitive may be explicitly defined or implicitly available.

1.2.3 Physical Layer and media notation

Users of this standard need to reference which particular implementation is being used or identified. Therefore, a means of identifying each implementation is given by a simple, three-field, type notation that is explicitly stated at the beginning of each relevant clause. In general, the Physical Layer type is specified by these fields:

<data rate> <modulation type> <additional distinction>

The data rate, if only a number, is in Mb/s, and if suffixed by a “G”, is in Gb/s. The modulation type (e.g., BASE) indicates how encoded data is transmitted on the medium. The additional distinction may identify characteristics of transmission or medium and, in some cases, the type of PCS encoding used (examples of additional distinctions are “T” for twisted pair, “B” for bidirectional optics, and “X” for a block PCS coding used for that speed of operation). Expansions for defined Physical Layer types are included in 1.4.

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1.2.4 Physical Layer message notation

Messages generated within the Physical Layer, either within or between PLS and the MAU (that is, PMA circuitry), are designated by an italic type to designate either form of physical or logical message used to execute the Physical Layer signaling process (for example, *input_idle* or *mau_available*).

1.2.5 Hexadecimal notation

Numerical values designated by the 0x prefix indicate a hexadecimal interpretation of the corresponding number. For example: 0x0F represents an 8-bit hexadecimal value of the decimal number 15; 0x00000000 represents a 32-bit hexadecimal value of the decimal number 0; etc.

Numerical values designated with a 16 subscript indicate a hexadecimal interpretation of the corresponding number. For example: $0F_{16}$ represents an 8-bit hexadecimal value of the decimal number 15.

1.2.6 Accuracy and resolution of numerical quantities

Unless otherwise stated, numerical limits in this standard are to be taken as exact, with the number of significant digits and trailing zeros having no significance.

1.3 Normative references

The following standards contain provisions that, through reference in this text, constitute provisions of this standard. Standards may be subject to revision, and parties subject to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid international standards. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI T1.269-2000, Information Interchange—Structure and Representation of Trace Message Formats For The North American Telecommunications System.[2]

ANSI T1.417-2001, Spectrum Management for Loop Transmission Systems.

ANSI T1.424-2004, Interface between networks and customer installations—Very-high Speed Digital Subscriber Lines (VDSL) Metallic Interface (DMT based).

ANSI T1.601-1992, Telecommunications—Integrated Services Digital Network (ISDN)—Basic Access Interface for Use on Metallic Loops for Application on the Network Side of the NT (Layer 1 Specification).

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[2]ANSI publications are available from the American National Standards Institute (http://www.ansi.org).

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IEC 60060 (all parts), High-voltage test techniques.[7]

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IEC 60603-7:1990, Connectors for frequencies below 3 MHz for use with printed boards, Part 7: Detail specification for connectors, 8-way, including fixed and free connectors with common mating features, with assessed quality.

IEC 60793-1:1992, Optical fibres—Part 1: Generic specification.

IEC 60793-1:1995, Optical fibres—Part 1: Generic specification.

IEC 60793-1-41:2001, Optical fibres—Part 1-41: Measurement methods and test procedures—Bandwidth.

[3]ATIS publication are available from the Alliance for Telecommunications Industry Solutions (http://atis.org).

[4]CISPR documents are available from the International Electrotechnical Commission (http://www.iec.ch/). CISPR documents are also available in the United States from the American National Standards Institute (http://www.ansi.org).

[5]EIA publications are available from the IHS Standards Store (http://global.ihs.com/). JEDEC publications are available from the JEDEC Solid State Technology Association (http://www.jedec.org).

[6]ETSI publications are available the European Telecommunications Standards Institute (http://www.etsi.org).

[7]IEC publications are available from the International Electrotechnical Commission (http://www.iec.ch/). IEC publications are also available in the United States from the American National Standards Institute (http://www.ansi.org).

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IEC 60874-10:1992, Connectors for optical fibres and cables—Part 10: Sectional specification, Fibre optic connector type BFOC/2,5.

IEC 60950:1991, Safety of information technology equipment.

IEC 60950-1, Information technology equipment—Safety—Part 1: General requirements.

IEC 61076-3-101:1997, Connectors with assessed quality, for use in d.c., low-frequency analogue and in digital high-speed data applications—Part 3: Rectangular connectors—Section 101: Detail specification for a range of shielded connectors with trapezoidal shaped shells and non-removable rectangular contacts on a 1.27 mm × 2.54 mm centre-line.

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IEC 61076-3-113, Ed. 1.0 (draft, 48B/1437/CD, 2 April 2004.) [48B Secretariat 1327] Connectors for electronic equipment—Part 3-113: Screened, serial multi-conductor cable to board connectors suitable for 10 Gbit/sec data rates.[8]

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[8]At the time IEEE Std 802.3-2015 was published, IEC 61076-3-113 is a committee draft. This document is available at (http://www.iec.ch/dyn/www/f?p=103:29:0::::FSP_ORG_ID,FSP_LANG_ID:1373,25#3.

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[9]IEEE publications are available from The Institute of Electrical and Electronics Engineers (http://standards.ieee.org/).

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[11]IEEE Std 802.1F-1993 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181 (http://global.ihs.com/).

[12]IEEE Std 802.5v-2001 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181 (http://global.ihs.com/).

[13]IEEE Std 802.9a-1995 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181 (http://global.ihs.com/).

[14]IETF RFCs are available from the Internet Engineering Task Force (http://www.ietf.org/rfc.html).

[15]ISO/IEC publications are available from the International Organization for Standardization (http://www.iso.ch/) and the International Electrotechnical Commission (http://www.iec.ch/). ISO/IEC publications are also available in the United States from the American National Standards Institute (http://www.ansi.org/).

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ISO/IEC 9314-1:1989, Information processing systems—Fibre Distributed Data Interface (FDDI)—Part 1: Token Ring Physical Layer Protocol (PHY).

ISO/IEC 9314-2:1989, Information processing systems—Fibre Distributed Data Interface (FDDI)—Part 2: Token Ring Media Access Control (MAC).

ISO/IEC 9314-3:1990, Information processing systems—Fibre Distributed Data Interface (FDDI)—Part 3: Physical Layer Medium Dependent (PMD).

ISO/IEC 9646-1:1994, Information technology—Open Systems Interconnection—Conformance testing methodology and framework—Part 1: General concepts.

ISO/IEC 9646-2:1994, Information technology—Open Systems Interconnection—Conformance testing methodology and framework—Part 2: Abstract test suite specification.

ISO/IEC 10040:1992, Information technology—Open Systems Interconnection—Systems management overview.

ISO/IEC 10165-2:1992, Information technology—Open Systems Interconnection—Structure of management information: Definition of management information.

ISO/IEC 10165-4:1992, Information technology—Open Systems Interconnection—Management information services—Structure of management information—Part 4: Guidelines for the definition of managed objects.

ISO/IEC 11801:1995, Information technology—Generic cabling for customer premises.[16]

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ISO/IEC 15802-1:1995, Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Common specifications—Part 1: Medium Access Control (MAC) service definition.

ISO/IEC TR 24750:2007, Information technology—Assessment and mitigation of installed balanced cabling channels in order to support of 10GBASE-T.

ITU-T Recommendation G.650.1, 2010—Definitions and test methods for linear, deterministic attributes of single-mode fibre and cable.[17]

ITU-T Recommendation G.652, 2009—Characteristics of a single-mode optical fibre and cable.

[16]Previous editions of ISO/IEC standards are available from Deutsches Institut für Normung (http://www.din.de).
[17]ITU-T publications are available from the International Telecommunications Union (http://www.itu.int/).

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ITU-T Recommendation G.657, 2009—Characteristics of a bending-loss insensitive single-mode optical fibre and cable for the access network.

ITU-T Recommendation G.671, 2009—Transmission characteristics of optical components and subsystems.

ITU-T Recommendation G.691, 2006—Optical interfaces for single channel STM-64 and other SDH systems with optical amplifiers.

ITU-T Recommendation G.694.1—Spectral grids for WDM applications: DWDM frequency grid.

ITU-T Recommendation G.694.2—Spectral grids for WDM applications: CWDM wavelength grid.

ITU-T Recommendation G.695, 2010—Optical interfaces for coarse wavelength division multiplexing applications.

ITU-T Recommendation G.957, 2006—Optical interfaces for equipments and systems relating to the synchronous digital hierarchy.

ITU-T Recommendation G.959.1, 2009—Optical transport network physical layer interfaces.

ITU-T Recommendation G.975—Forward error correction for submarine systems.

ITU-T Recommendation G.991.2, 2001—Amendment 1.

ITU-T Recommendation G.991.2, 2001—Single-pair high-speed digital subscriber line (SHDSL) transceivers.

ITU-T Recommendation G.993.1, 2003—Amendment 1.

ITU-T Recommendation G.993.1, 2001—Very high speed digital subscriber line foundation.

ITU-T Recommendation G.994.1, 2004—Handshake procedures for digital subscriber line (DSL) transceivers.

ITU-T Recommendation I.430, 1995—Basic user-network interface—Layer 1 specification.

ITU-T Recommendation O.150, 1996—General requirements for instrumentation for performance measurements on digital transmission equipment.

ITU-T Recommendation O.153, 1992—Basic parameters for the measurement of error performance at bit rates below the primary rate.

ITU-T Recommendation O.172, 2005—Jitter and wander measuring equipment for digital systems which are based on the synchronous digital hierarchy (SDH).

MATLAB Matrix Laboratory Software.[18]

SFF-8436, Rev 4.1, August 24, 2011, Specification for QSFP+ 10 Gbs 4X Pluggable Transceiver.[19]

SFF-8642, Rev 2.7, February 26, 2010, Specification for Mini Multilane 12 Gbs 12X Shielded Connector.

[18]For information on MatLab, contact The MathWorks (http://www.mathworks.com).
[19]SFF specifications are available at ftp://ftp.seagate.com/sff.

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TIA-455-127-A-2006, FOTP-127-A, Basic Spectral Characterization of Laser Diodes.[20]

TIA TSB-155-A-2010, Guidelines for the Assessment and Mitigation of Installed Category 6 Cabling to Support 10GBASE-T.

NOTE—Local and national standards such as those supported by ANSI, EIA, MIL, NFPA, and UL are not a formal part of this standard except where no international standard equivalent exists. A number of local and national standards are referenced as resource material; these bibliographical references are located in the bibliography in Annex A.[21]

1.4 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be referenced for terms not defined in this clause.[22]

1.4.1 10BASE2: IEEE 802.3 Physical Layer specification for a 10 Mb/s CSMA/CD local area network over RG 58 coaxial cable. (See IEEE Std 802.3, Clause 10.)

1.4.2 10BASE5: IEEE 802.3 Physical Layer specification for a 10 Mb/s CSMA/CD local area network over coaxial cable (i.e., thicknet). (See IEEE Std 802.3, Clause 8.)

1.4.3 10BASE-F: IEEE 802.3 Physical Layer specification for a 10 Mb/s CSMA/CD local area network over multimode fiber optic cable. (See IEEE Std 802.3, Clause 15.)

1.4.4 10BASE-FB port: A port on a repeater that contains an internal 10BASE-FB Medium Attachment Unit (MAU) that can connect to a similar port on another repeater. (See IEEE Std 802.3, Clause 9, Figure 15–1b, and Clause 17.)

1.4.5 10BASE-FB segment: A fiber optic link segment providing a point-to-point connection between two 10BASE-FB ports on repeaters. (See link segment IEEE Std 802.3, Figure 15–1b and Figure 15–2.)

1.4.6 10BASE-FL segment: A fiber optic link segment providing point-to-point connection between two 10BASE-FL Medium Attachment Units (MAUs). (See link segment IEEE Std 802.3, Figure 15–1c and Figure 15–2.)

1.4.7 10BASE-FP segment: A fiber optic mixing segment, including one 10BASE-FP Star and all of the attached fiber pairs. (See IEEE Std 802.3, Figure 15–1a, Figure 1–3, and mixing segment.)

1.4.8 10BASE-FP Star: A passive device that is used to couple fiber pairs together to form a 10BASE-FP segment. Optical signals received at any input port of the 10BASE-FP Star are distributed to all of its output ports (including the output port of the optical interface from which it was received). A 10BASE-FP Star is typically comprised of a passive-star coupler, fiber optic connectors, and a suitable mechanical housing. (See IEEE Std 802.3, 16.5.)

1.4.9 10BASE-T: IEEE 802.3 Physical Layer specification for a 10 Mb/s CSMA/CD local area network over two pairs of twisted-pair telephone wire. (See IEEE Std 802.3, Clause 14.)

1.4.10 10BASE-Te: IEEE 802.3 Physical Layer specification for an energy-efficient version of 10BASE-T for a 10 Mb/s CSMA/CD local area network over two pairs of Category 5 or better-balanced cabling. (See IEEE Std 802.3, Clause 14.)

[20]TIA publications are available from the IHS Standards Store (http://global.ihs.com/) or from the Telecommunications Industry Association (http://www.tiaonline.org).

[21]Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement this standard.

[22]The *IEEE Standards Dictionary Online* subscription is available at http://dictionary.ieee.org/.

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1.4.11 10BROAD36: IEEE 802.3 Physical Layer specification for a 10 Mb/s CSMA/CD local area network over single broadband cable. (See IEEE Std 802.3, Clause 11.)

1.4.12 10PASS-TS: IEEE 802.3 Physical Layer specification up to 100 Mb/s point-to-point link over single copper wire pair. (See IEEE Std 802.3, Clause 61 and Clause 62.)

1.4.13 100BASE-BX10: IEEE 802.3 Physical Layer specification for a 100 Mb/s point-to-point link over one single-mode fiber. The link includes two different specifications for 100BASE-BX10-D and 100BASE-BX10-U. (See IEEE Std 802.3, Clause 58 and Clause 66.)

1.4.14 100BASE-FX: IEEE 802.3 Physical Layer specification for a 100 Mb/s CSMA/CD local area network over two multimode optical fibers. (See IEEE Std 802.3, Clause 24 and Clause 26.)

1.4.15 100BASE-LX10: IEEE 802.3 Physical Layer specification for a 100 Mb/s point-to-point link over two single-mode optical fibers. (See IEEE Std 802.3, Clause 58 and Clause 66.)

1.4.16 100BASE-T: IEEE 802.3 Physical Layer specification for a 100 Mb/s CSMA/CD local area network. (See IEEE Std 802.3, Clause 22 and Clause 28.)

1.4.17 100BASE-T2: IEEE 802.3 specification for a 100 Mb/s CSMA/CD local area network over two pairs of Category 3 or better balanced cabling. (See IEEE Std 802.3, Clause 32.)

1.4.18 100BASE-T4: IEEE 802.3 Physical Layer specification for a 100 Mb/s CSMA/CD local area network over four pairs of Category 3, 4, and 5 twisted-pair cabling. (See IEEE Std 802.3 Clause 23.)

1.4.19 100BASE-TX: IEEE 802.3 Physical Layer specification for a 100 Mb/s CSMA/CD local area network over two pairs of Category 5 twisted-pair cabling. (See IEEE Std 802.3, Clause 24 and Clause 25.)

1.4.20 100BASE-X: IEEE 802.3 Physical Layer specification for a 100 Mb/s CSMA/CD local area network that uses the Physical Medium Dependent (PMD) sublayer and Medium Dependent Interface (MDI) of the ISO/IEC 9314 group of standards developed by ASC X3T12 (FDDI). (See IEEE Std 802.3, Clause 24.)

1.4.21 1000BASE-BX10: IEEE 802.3 Physical Layer specification for a 1000 Mb/s point-to-point link over one single-mode optical fiber. (See IEEE Std 802.3, Clause 59 and Clause 66.)

1.4.22 1000BASE-CX: 1000BASE-X over specialty shielded balanced copper jumper cable assemblies. (See IEEE Std 802.3, Clause 39.)

1.4.23 1000BASE-KX: IEEE 802.3 Physical Layer specification for 1 Gb/s using 1000BASE-X encoding over an electrical backplane. (See IEEE Std 802.3 Clause 70.)

1.4.24 1000BASE-LX: 1000BASE-X using long wavelength laser devices over multimode and single-mode fiber. (See IEEE Std 802.3, Clause 38.)

1.4.25 1000BASE-LX10: IEEE 802.3 Physical Layer specification for a 1000 Mb/s point-to-point link over two single-mode or multimode optical fibers. (See IEEE Std 802.3, Clause 59 and Clause 66.)

1.4.26 1000BASE-PX: A collection of IEEE 802.3 Physical Layer specifications for a 1000 Mb/s point-to-multipoint link over one single-mode optical fiber. (See IEEE Std 802.3, Table 56–1, Clause 60, Clause 65, and Clause 64.)

1.4.27 1000BASE-SX: 1000BASE-X using short wavelength laser devices over multimode fiber. (See IEEE Std 802.3, Clause 38.)

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1.4.28 1000BASE-T: IEEE 802.3 Physical Layer specification for a 1000 Mb/s CSMA/CD LAN using four pairs of Category 5 balanced copper cabling. (See IEEE Std 802.3, Clause 40.)

1.4.29 1000BASE-X: IEEE 802.3 Physical Layer specification for a 1000 Mb/s CSMA/CD LAN that uses a Physical Layer derived from ANSI X3.230-1994 (FC-PH) [B21][23]. (See IEEE Std 802.3, Clause 36.)

1.4.30 10GBASE-CX4: IEEE 802.3 Physical Layer specification for 10 Gb/s using 10GBASE-X encoding over four lanes over shielded balanced copper cabling. (See IEEE Std 802.3, Clause 54.)

1.4.31 10GBASE-E: IEEE 802.3 PMD specifications for 10 Gb/s serial transmission using extra long wavelength. (See IEEE Std 802.3, Clause 52.)

1.4.32 10GBASE-ER: IEEE 802.3 Physical Layer specification for 10 Gb/s using 10GBASE-R encoding and 10GBASE-E optics. (See IEEE Std 802.3, Clause 49 and Clause 52.)

1.4.33 10GBASE-EW: IEEE 802.3 Physical Layer specification for 10Gb/s using 10GBASE-W encoding and 10GBASE-E optics. (See IEEE Std 802.3, Clause 50 and Clause 52.)

1.4.34 10GBASE-KR: IEEE 802.3 Physical Layer specification for 10 Gb/s using 10GBASE-R encoding over an electrical backplane. (See IEEE Std 802.3 Clause 72.)

1.4.35 10GBASE-KX4: IEEE 802.3 Physical Layer specification for 10 Gb/s using 10GBASE-X encoding over an electrical backplane. (See IEEE Std 802.3 Clause 71.)

1.4.36 10GBASE-L: IEEE 802.3 PMD specifications for 10 Gb/s serial transmission using long wavelength. (See IEEE Std 802.3, Clause 52)

1.4.37 10GBASE-LR: IEEE 802.3 Physical Layer specification for 10 Gb/s using 10GBASE-R encoding and 10GBASE-L optics. (See IEEE Std 802.3, Clause 49 and Clause 52.)

1.4.38 10GBASE-LRM: IEEE 802.3 Physical Layer specification for 10 Gb/s using 10GBASE-R encoding and long wavelength optics for multimode fiber (See IEEE Std 802.3 Clause 68).

1.4.39 10GBASE-LW: IEEE 802.3 Physical Layer specification for 10 Gb/s using 10GBASE-W encoding and 10GBASE-L optics. (See IEEE Std 802.3, Clause 50 and Clause 52.)

1.4.40 10GBASE-LX4: IEEE 802.3 Physical Layer specification for 10 Gb/s using 10GBASE-X encoding over four WWDM lanes over multimode fiber. (See IEEE Std 802.3, Clause 54.)

1.4.41 10GBASE-PR: A collection of IEEE 802.3 Physical Layer specifications for a 10 Gb/s (10/10G-EPON) point-to-multipoint link over one single-mode optical fiber. (See IEEE Std 802.3, Table 56–1, Clause 75, Clause 76, and Clause 77.)

1.4.42 10/1GBASE-PRX: A collection of IEEE 802.3 Physical Layer specifications for a 10 Gb/s downstream, 1 Gb/s upstream (10/1G-EPON) point-to-multipoint link over one single-mode optical fiber. (See IEEE Std 802.3, Table 56–1, Clause 75, Clause 76, and Clause 77.)

1.4.43 10GBASE-R: An IEEE 802.3 physical coding sublayer for serial 10 Gb/s operation. (See IEEE Std 802.3, Clause 49.)

1.4.44 10GBASE-S: IEEE 802.3 PMD specifications for 10 Gb/s serial transmission using short wavelength. (See IEEE Std 802.3, Clause 52.)

[23]The numbers in brackets preceded by the letter B correspond to those of the bibliography in Annex A.

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1.4.45 10GBASE-SR: IEEE 802.3 Physical Layer specification for 10 Gb/s using 10GBASE-R encoding and 10GBASE-S optics. (See IEEE Std 802.3, Clause 49 and Clause 52.)

1.4.46 10GBASE-SW: IEEE 802.3 Physical Layer specification for 10 Gb/s using 10GBASE-W encoding and 10GBASE-S optics. (See IEEE Std 802.3, Clause 50 and Clause 52.)

1.4.47 10GBASE-T: IEEE 802.3 Physical Layer specification for a 10 Gb/s LAN using four pairs of Class E or Class F balanced copper cabling. (See IEEE Std 802.3, Clause 55.)

1.4.48 10GBASE-W: An IEEE 802.3 physical coding sublayer for serial 10 Gb/s operation that is data-rate and format compatible with SONET STS-192c. (See IEEE Std 802.3, Clause 49.)

1.4.49 10GBASE-X: An IEEE 802.3 physical coding sublayer for 10 Gb/s operation over XAUI and four lane PMDs. (See IEEE Std 802.3, Clause 48.)

1.4.50 100GBASE-P: An IEEE 802.3 family of Physical Layer devices using 100GBASE-R encoding and a PMD that employs pulse amplitude modulation with more than 2 levels. (See IEEE Std 802.3, Clause 80.)

1.4.51 100GBASE-R: An IEEE 802.3 family of Physical Layer devices using 100GBASE-R encoding and a PMD that employs 2-level pulse amplitude modulation. (See IEEE Std 802.3, Clause 80.)

1.4.52 100GBASE-R encoding: The physical coding sublayer encoding defined in Clause 82 for 100 Gb/s operation. (See IEEE Std 802.3, Clause 82.)

1.4.53 100GBASE-CR4: IEEE 802.3 Physical Layer specification for 100 Gb/s using 100GBASE-R encoding and Clause 91 RS-FEC over four lanes of shielded balanced copper cabling, with reach up to at least 5 m. (See IEEE Std 802.3, Clause 92.)

1.4.54 100GBASE-CR10: IEEE 802.3 Physical Layer specification for 100 Gb/s using 100GBASE-R encoding over ten lanes of shielded balanced copper cabling, with reach up to at least 7 m. (See IEEE Std 802.3, Clause 85.)

1.4.55 100GBASE-KP4: IEEE 802.3 Physical Layer specification for 100 Gb/s using 100GBASE-R encoding, Clause 91 RS-FEC, and 4-level pulse amplitude modulation over four lanes of an electrical backplane, with a total insertion loss up to 33 dB at 7 GHz. (See IEEE Std 802.3, Clause 94.)

1.4.56 100GBASE-KR4: IEEE 802.3 Physical Layer specification for 100 Gb/s using 100GBASE-R encoding, Clause 91 RS-FEC, and 2-level pulse amplitude modulation over four lanes of an electrical backplane, with a total insertion loss up to 35 dB at 12.9 GHz. (See IEEE Std 802.3, Clause 93.)

1.4.57 100GBASE-ER4: IEEE 802.3 Physical Layer specification for 100 Gb/s using 100GBASE-R encoding over four WDM lanes on single-mode fiber, with reach up to at least 40 km. (See IEEE Std 802.3, Clause 88.)

1.4.58 100GBASE-LR4: IEEE 802.3 Physical Layer specification for 100 Gb/s using 100GBASE-R encoding over four WDM lanes on single-mode fiber, with reach up to at least 10 km. (See IEEE Std 802.3, Clause 88.)

1.4.59 100GBASE-SR4: IEEE 802.3 Physical Layer specification for 100 Gb/s using 100GBASE-R encoding over four lanes of multimode fiber, with reach up to at least 100 m. (See IEEE Std 802.3, Clause 95.)

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1.4.60 100GBASE-SR10: IEEE 802.3 Physical Layer specification for 100 Gb/s using 100GBASE-R encoding over ten lanes of multimode fiber, with reach up to at least 100 m. (See IEEE Std 802.3, Clause 86.)

1.4.61 1G-EPON: An EPON architecture operating at 1 Gb/s in both downstream and upstream directions.

1.4.62 10G-EPON: An EPON architecture operating at 10 Gb/s in either downstream or both downstream and upstream directions. This term collectively refers to 10/10G-EPON and 10/1G-EPON architectures.

1.4.63 10/1G-EPON: An EPON architecture operating at 10 Gb/s in downstream direction and at 1 Gb/s data rate in upstream direction (asymmetric rate).

1.4.64 10/10G-EPON: An EPON architecture operating at 10 Gb/s in both downstream and upstream directions (symmetric rate).

1.4.65 40GBASE-R: An IEEE 802.3 family of Physical Layer devices using 40GBASE-R encoding. (See IEEE Std 802.3, Clause 80.)

1.4.66 40GBASE-R encoding: The physical coding sublayer encoding defined in Clause 82 for 40 Gb/s operation. (See IEEE Std 802.3, Clause 82.)

1.4.67 40GBASE-CR4: IEEE 802.3 Physical Layer specification for 40 Gb/s using 40GBASE-R encoding over four lanes of shielded balanced copper cabling, with reach up to at least 7 m. (See IEEE Std 802.3, Clause 85.)

1.4.68 40GBASE-ER4: IEEE 802.3 Physical Layer specification for 40 Gb/s using 40GBASE-R encoding over four WDM lanes on single-mode fiber, with reach up to at least 40 km. (See IEEE Std 802.3, Clause 87.)

1.4.69 40GBASE-FR: IEEE 802.3 Physical Layer specification for 40 Gb/s serial transmission using 40GBASE-R encoding over one wavelength on single-mode fiber, with reach up to at least 2 km (See IEEE Std 802.3, Clause 89.)

1.4.70 40GBASE-KR4: IEEE 802.3 Physical Layer specification for 40 Gb/s using 40GBASE-R encoding over four lanes of an electrical backplane, with reach up to at least 1 m. (See IEEE Std 802.3, Clause 84.)

1.4.71 40GBASE-LR4: IEEE 802.3 Physical Layer specification for 40 Gb/s using 40GBASE-R encoding over four WDM lanes on single-mode fiber, with reach up to at least 10 km. (See IEEE Std 802.3, Clause 87.)

1.4.72 40GBASE-SR4: IEEE 802.3 Physical Layer specification for 40 Gb/s using 40GBASE-R encoding over four lanes of multimode fiber, with reach up to at least 100 m. (See IEEE Std 802.3, Clause 86.)

1.4.73 1BASE5: IEEE 802.3 Physical Layer specification for a 1 Mb/s CSMA/CD local area network over two pairs of twisted-pair telephone wire. (See IEEE Std 802.3, Clause 12.)

1.4.74 2BASE-TL: IEEE 802.3 Physical Layer specification up to 5.696 Mb/s point-to-point link over single copper wire pair. (See IEEE Std 802.3, Clause 61 and Clause 63.)

1.4.75 10 Gigabit Attachment Unit Interface (XAUI): The interface between two 10 Gigabit Extender Sublayers (XGXS) to extend the reach of the XGMII for 10 Gb/s operation. (See IEEE Std 802.3, Clause 47.)

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1.4.76 10 Gigabit Media Independent Interface (XGMII): The interface between the Reconciliation Sublayer (RS) and the Physical Coding Sublayer (PCS) for 10 Gb/s operation. (See IEEE Std 802.3, Clause 46.)

1.4.77 10 Gigabit Sixteen-Bit Interface (XSBI): The interface between the Physical Coding Sublayer (PCS) in 10GBASE-R or the WAN Interface Sublayer (WIS) in 10GBASE-W and the Physical Medium Attachment (PMA) sublayer for 10 Gb/s operation. (See IEEE Std 802.3, Clause 51.)

1.4.78 40 Gb/s Attachment Unit Interface (XLAUI): A physical instantiation of the PMA service interface to extend the connection between 40 Gb/s capable PMAs, used for chip-to-chip or chip-to-module interconnections. (See IEEE Std 802.3, Annex 83A and Annex 83B.)

1.4.79 40 Gb/s Media Independent Interface (XLGMII): The interface between the Reconciliation Sublayer (RS) and the Physical Coding Sublayer (PCS) for 40 Gb/s operation. (See IEEE Std 802.3, Clause 81.)

1.4.80 40 Gb/s Parallel Physical Interface (XLPPI): The interface between the Physical Medium Attachment (PMA) sublayer and the Physical Medium Dependent (PMD) sublayer for 40GBASE-SR4 and 40GBASE-LR4 PHYs. (See IEEE Std 802.3, Annex 86A.)

1.4.81 100 Gb/s Attachment Unit Interface (CAUI-n): A physical instantiation of the PMA service interface to extend the connection between 100 Gb/s capable PMAs over n lanes, used for chip-to-chip or chip-to-module interconnections. Two widths of CAUI-n are defined: a ten-lane version (CAUI-10) and a four-lane version (CAUI-4). (See IEEE Std 802.3, Annex 83A and Annex 83B for CAUI-10, or Annex 83D and Annex 83E for CAUI-4.)

1.4.82 100 Gb/s Media Independent Interface (CGMII): The interface between the Reconciliation Sublayer (RS) and the Physical Coding Sublayer (PCS) for 100 Gb/s operation. (See IEEE Std 802.3, Clause 81.)

1.4.83 100 Gb/s Parallel Physical Interface (CPPI): The interface between the Physical Medium Attachment (PMA) sublayer and the Physical Medium Dependent (PMD) sublayer for 100GBASE-SR10 PHYs. (See IEEE Std 802.3, Annex 86A.)

1.4.84 1-Event class signature: The response of the PD to 1-Event classification (see IEEE Std 802.3, Clause 33).

1.4.85 1-Event classification: The application of a single class event during PI probing (see IEEE Std 802.3, Clause 33, 33.2.6).

1.4.86 2-Event class signature: The response of the PD to 2-Event classification (see IEEE Std 802.3, Clause 33).

1.4.87 2-Event classification: The application of two class events during PI probing (see IEEE Std 802.3, Clause 33, 33.2.6).

1.4.88 4D-PAM5: The symbol encoding method used in 1000BASE-T. The four-dimensional quinary symbols (4D) received from the 8B1Q4 data encoding are transmitted using five voltage levels (PAM5). Four symbols are transmitted in parallel each symbol period. (See IEEE Std 802.3, Clause 40.)

1.4.89 8B/10B transmission code: A DC-balanced octet-oriented data encoding specified in IEEE Std 802.3, Table 36–1a–e and Table 36–2.

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1.4.90 8B1Q4: For IEEE 802.3, the data encoding technique used by 1000BASE-T when converting GMII data (8B-8 bits) to four quinary symbols (Q4) that are transmitted during one clock (1Q4). (See IEEE Std 802.3, Clause 40.)

1.4.91 64B/65B transmission code: A block oriented encoding where 64-bit blocks are prepended with a single bit to indicate whether the block contains only data or a mix of data and control information. (See IEEE Std 802.3, Clause 55.)

1.4.92 ability: A mode that a device can advertise using Auto-Negotiation. For modes that represent a type of data service, a device shall be able to operate that data service before it may advertise this ability. A device may support multiple abilities. (See IEEE Std 802.3, 28.2.1.2.2.)

1.4.93 Acknowledge Bit: A bit used by IEEE 802.3 Auto-Negotiation to indicate that a station has successfully received multiple identical copies of the link codeword. This bit is only set after an identical link codeword has been received three times in succession. (See IEEE Std 802.3, 28.2.1.2.5.)

1.4.94 advertised ability: An operational mode that is advertised using Auto-Negotiation. (See IEEE Std 802.3, 28.2.1.2.2.)

1.4.95 agent: A term used to refer to the managed nodes in a network. Managed nodes are those nodes that contain a network management entity (NME), which can be used to configure the node and/or collect data describing operation of that node. The agent is controlled by a network control host or manager that contains both an NME and network management application (NMA) software to control the operations of agents. Agents include systems that support user applications as well as nodes that provide communications services such as front-end processors, bridges, and routers. (See IEEE Std 802.3, Clause 30.)

1.4.96 agent code: A term used to refer to network management entity software residing in a node that can be used to remotely configure the host system based on commands received from the network control host, collect information documenting the operation of the host, and communicate with the network control host. (See IEEE Std 802.3, Clause 30.)

1.4.97 Aggregation group: A collection of PMEs that may be aggregated according to a particular implementation of the PME aggregation function. (See IEEE Std 802.3, 61.2.2.)

1.4.98 agile device: A device that supports automatic switching between multiple Physical Layer technologies. (See IEEE Std 802.3, Clause 28.)

1.4.99 anomaly: A discrepancy between the actual and desired characteristics of an item. This definition is derived from ATIS-0600416.1999(R2010) and ATIS-0900105.2008, which take precedence.

1.4.100 arbitration: In 1000BASE-X, Auto-Negotiation process that ensures proper sequencing of configuration information between link partners using the Physical Coding Sublayer (PCS) Transmit and Receive functions. (See IEEE Std 802.3, Clause 36 and Clause 37.)

1.4.101 Attachment Unit Interface (AUI): In 10 Mb/s CSMA/CD, the interface between the Medium Attachment Unit (MAU) and the data terminal equipment (DTE) within a data station. Note that the AUI carries encoded signals and provides for duplex data transmission. (See IEEE Std 802.3, Clause 7 and Clause 8.)

1.4.102 Auto-Negotiation: The algorithm that allows two devices at either end of a link segment to negotiate common data service functions. (See IEEE Std 802.3, Clause 28, Clause 37, and Clause 73.)

1.4.103 balanced cable: A cable consisting of one or more metallic symmetrical cable elements (twisted pairs or quads). (From ISO/IEC 11801.)

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1.4.104 Bandplan: The set of parameters that control the lowest and highest frequencies and power at which 10PASS-TS and 2BASE-TL may operate.

1.4.105 baseband coaxial system: A system whereby information is directly encoded and impressed upon the transmission medium. At any point on the medium only one information signal at a time can be present without disruption.

1.4.106 Base link codeword: The first 16-bit message exchanged during IEEE 802.3 Auto-Negotiation. (See IEEE Std 802.3, 28.2.1.2.)

1.4.107 BASE-R: An IEEE 802.3 family of Physical Layer devices using the 64B/66B encoding defined in Clause 49 or Clause 82. (See IEEE Std 802.3, Clause 49 and Clause 82.)

1.4.108 Base Page: *See:* **Base link codeword**.

1.4.109 basic frame: A MAC frame that carries a Length/Type field with the Length or Type interpretation and has a maximum length of 1518 octets. The basic frame is not intended to allow inclusion of additional tags (i.e., untagged) or encapsulations required by higher layer protocols. (See IEEE Std 802.3, 3.2.7.)

1.4.110 baud (Bd): A unit of signaling speed, expressed as the number of times per second the signal can change the electrical state of the transmission line or other medium.

NOTE—Depending on the encoding strategies, a signal event may represent a single bit, more, or less than one bit. *Contrast with:* **bit rate**; **bits per second**. (From IEEE Std 610.7-1995 [B42].)

1.4.111 Binary Phase Shift Keying (Binary PSK or BPSK): A form of modulation in which binary data are transmitted by changing the carrier phase by 180 degrees. (See IEEE Std 802.3, Clause 11.)

1.4.112 bit cell: The time interval used for the transmission of a single data (CD0 or CD1) or control (CVH or CVL) symbol.

1.4.113 bit error ratio (BER): The ratio of the number of bits received in error to the total number of bits received.

1.4.114 bit interleaved parity N (BIP-N): A method of error monitoring using even (or odd) parity, such that an N-bit codeword is generated over a specified portion of an input data stream in such a manner that the i-th bit of the codeword provides even (or odd) parity over the i-th bit of all N-bit sequences in the covered portion of the data stream. This definition is derived from ATIS-0600416.1999(R2010) and ATIS-0900105.2008, which take precedence.

1.4.115 bit rate (BR): The total number of bits per second transferred to or from the Media Access Control (MAC). For example, 100BASE-T has a bit rate of one hundred million bits per second (10^8 b/s).

1.4.116 bit rate (BR)/2: One-half of the BR in hertz.

1.4.117 bit time (BT): The duration of one bit as transferred to and from the Media Access Control (MAC). The bit time is the reciprocal of the bit rate. For example, for 100BASE-T the bit time is 10^{-8} s or 10 ns.

1.4.118 BR/2: *See:* **bit rate (BR)/2.**

1.4.119 branch cable: In 10BROAD36, the Attachment Unit Interface (AUI) cable interconnecting the data terminal equipment and Medium Attachment Unit (MAU) system components.

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1.4.120 bridge: A layer 2 interconnection device that does not form part of a CSMA/CD collision domain but conforms to IEEE Std 802.1D. A bridge does not form part of a CSMA/CD collision domain but, rather appears as a Media Access Control (MAC) to the collision domain. (See also IEEE 100.)

1.4.121 broadband local area network (LAN): A local area network in which information is transmitted on modulated carriers, allowing coexistence of multiple simultaneous services on a single physical medium by frequency division multiplexing. (See IEEE Std 802.3, Clause 11.)

1.4.122 bundle: A group of signals that have a common set of characteristics and differ only in their information content.

1.4.123 carrier extension: The addition of non-data symbols to the end of frames that are less than slotTime bits in length so that the resulting transmission is at least one slotTime in duration.

1.4.124 carrier sense: In a local area network, an ongoing activity of a data station to detect whether another station is transmitting.

NOTE—The carrier sense signal indicates that one or more DTEs are currently transmitting.

1.4.125 Category 3 balanced cabling: Balanced 100 Ω cables and associated connecting hardware whose transmission characteristics are specified up to 16 MHz (i.e., performance meets the requirements of a Class C link as per ISO/IEC 11801:1995). Commonly used by IEEE 802.3 10BASE-T installations. In addition to the requirements outlined in ISO/IEC 11801:1995, IEEE Std 802.3 Clause 14, Clause 23, and Clause 32 specify additional requirements for cabling when used with 10BASE-T, 100BASE-TX, and 1000BASE-T.

1.4.126 Category 4 balanced cabling: Balanced 100 Ω cables and associated connecting hardware whose transmission characteristics are specified up to 20 MHz as per ISO/IEC 11801:1995. In addition to the requirements outlined in ISO/IEC 11801:1995, IEEE Std 802.3 Clause 14, Clause 23, and Clause 32 specify additional requirements for this cabling when used with 10BASE-T, 100BASE-T4, and 100BASE-T2, respectively.

1.4.127 Category 5 balanced cabling: Balanced 100 Ω cables and associated connecting hardware whose transmission characteristics are specified up to 100 MHz (i.e., cabling components meet the performance specified in ISO/IEC 11801:1995 and ANSI/EIA/TIA-568-A-1995). In addition to the requirements outlined in ISO/IEC 11801:1995 and ANSI/EIA/TIA-568-A-1995, IEEE Std 802.3 Clause 14, Clause 23, Clause 25, and Clause 40 specify additional requirements for this cabling when used with 10BASE-T and 100BASE-T.

1.4.128 Category 6 balanced cabling: Balanced 100 Ω cables and associated connecting hardware whose transmission characteristics are specified up to 250 MHz (i.e., cabling components meet the performance specified in ISO/IEC 11801:2002 and ANSI/TIA-568-C.2). In addition to the requirements outlined in ISO/IEC 11801:1995 and ANSI/TIA-568-C.2, IEEE Std 802.3 Clause 14, Clause 23, Clause 25, Clause 40, and Clause 55 specify additional requirements for this cabling when used with 10BASE-T, 100BASE-T, and 10GBASE-T.

1.4.129 Category 6A balanced cabling: Balanced 100 Ω cables and associated connecting hardware whose transmission characteristics are specified up to 500 MHz (i.e., cabling components meet the performance specified in ISO/IEC 11801:2002 Amendment 2 and ANSI/TIA-568-C.2). In addition to the requirements outlined in ISO/IEC 11801:2002 Amendment 2 and ANSI/TIA-568-C.2, IEEE Std 802.3 Clause 14, Clause 23, Clause 25, Clause 40, and Clause 55 specify additional requirements for this cabling when used with 10BASE-T, 100BASE-T, and 10GBASE-T.

1.4.130 Category 7 balanced cabling: Balanced 100 Ω cables and associated connecting hardware whose transmission characteristics are specified up to 600 MHz (i.e., cabling components meet the performance

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specified in ISO/IEC 11801:2002). In addition to the requirements outlined in ISO/IEC 11801:2002, IEEE Std 802.3 Clause 14, Clause 23, Clause 25, Clause 40, and Clause 55 specify additional requirements for this cabling when used with 10BASE-T, 100BASE-T, and 10GBASE-T.

1.4.131 Category 7A balanced cabling: Balanced 100 Ω cables and associated connecting hardware whose transmission characteristics are specified up to 1000 MHz (i.e., cabling components meet the performance specified in ISO/IEC 11801:2002 Amendment 2). In addition to the requirements outlined in ISO/IEC 11801:2002 Amendment 2, IEEE Std 802.3 Clause 14, Clause 23, Clause 25, Clause 40, and Clause 55 specify additional requirements for this cabling when used with 10BASE-T, 100BASE-T, and 10GBASE-T.

1.4.132 CATV-type broadband medium: *See:* **Community Antenna Television (CATV)-type broadband medium.**

1.4.133 center wavelength: The average of two optical wavelengths at which the spectral radiant intensity is 50% of the maximum value. (See IEEE Std 802.3, Clause 11.)

1.4.134 channel: In 10BROAD36, a band of frequencies dedicated to a certain service transmitted on the broadband medium. (See IEEE Std 802.3, Clause 11.)

1.4.135 channel insertion loss: As used in IEEE 802.3 for fiber optic links, the static loss of light through a link between a transmitter and receiver. It includes the loss of the fiber, connectors, and splices and, for EPON links, optional power splitter/combiner.

1.4.136 Channel Operating Margin (COM): A figure of merit for a channel derived from a measurement of its scattering parameters. (See IEEE Std 802.3, Clause 93A.1.)

1.4.137 chassis ground: The electrical node that contains the chassis (see IEEE 100).

1.4.138 circuit: The physical medium on which signals are carried across the Attachment Unit Interface (AUI) for 10BASE-T or Media Independent Interface (MII) for 100BASE-T. For 10BASE-T, the data and control circuits consist of an A circuit and a B circuit forming a balanced transmission system so that the signal carrier on the B circuit is the inverse of the signal carried on the A circuit.

1.4.139 Class I repeater: A type of 100BASE-T repeater set with internal delay such that only one repeater set may exist between any two DTEs within a single collision domain when two maximum length copper cable segments are used. (See IEEE Std 802.3, Clause 27.)

1.4.140 Class II repeater: A type of IEEE 802.3 100BASE-T repeater set with internal delay such that only two or fewer such repeater sets may exist between any two DTEs within a single collision domain when two maximum length copper cable segments are used. (See IEEE Std 802.3, Clause 27.)

1.4.141 Clocked Data One (CD1): A Manchester-encoded data 1. A CD1 is encoded as a LO for the first half of the bit-cell and a HI for the second half of the bit-cell. (See IEEE Std 802.3, Clause 12.)

1.4.142 Clocked Data Zero (CD0): A Manchester-encoded data 0. A CD0 is encoded as a HI for the first half of the bit-cell and a LO for the second half of the bit-cell. (See IEEE Std 802.3, Clause 12.)

1.4.143 Clocked Violation HI (CVH): A symbol that deliberately violates Manchester-encoding rules, used as a part of the Collision Presence signal. A CVH is encoded as a transition from LO to HI at the beginning of the bit cell, HI for the entire bit cell, and a transition from HI to LO at the end of the bit cell. (See IEEE Std 802.3, Clause 12.)

1.4.144 Clocked Violation LO (CVL): A symbol that deliberately violates Manchester-encoding rules, used as a part of the Collision Presence signal. A CVL is encoded as a transition from HI to LO at the begin-

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ning of the bit cell, LO for the entire bit cell, and a transition from LO to HI at the end of the bit cell. (See IEEE Std 802.3, Clause 12.)

1.4.145 coaxial cable: A two-conductor (center conductor, shield system), concentric, constant impedance transmission line used as the trunk medium in the baseband system.

1.4.146 coaxial cable interface: The electrical and mechanical interface to the shared coaxial cable medium either contained within or connected to the Medium Attachment Unit (MAU). Also known as the Medium Dependent Interface (MDI).

1.4.147 coaxial cable section: A single length of coaxial cable, terminated at each end with a male BNC connector. Cable sections are joined to other cable sections via BNC plug/receptacle barrel or Type T adapters.

1.4.148 coaxial cable segment: A length of coaxial cable made up from one or more coaxial cable sections and coaxial connectors, and terminated at each end in its characteristic impedance.

1.4.149 code-bit: Within IEEE 802.3, in 100BASE-T, the unit of data passed across the Physical Medium Attachment (PMA) service interface, and the smallest signaling element used for transmission on the medium. A group of five code-bits constitutes a code-group in the 100BASE-X Physical Coding Sublayer (PCS). (See IEEE Std 802.3, Clause 24.)

1.4.150 code-group: For IEEE 802.3, a set of encoded symbols representing encoded data or control information. For 100BASE-T4, a set of six ternary symbols that, when representing data, conveys an octet. For 100BASE-TX and 100BASE-FX, a set of five code-bits that, when representing data, conveys a nibble. For 100BASE-T2, a pair of PAM5×5 symbols that, when representing data, conveys a nibble. For 1000BASE-X, a set of ten bits that, when representing data, conveys an octet. For 1000BASE-T, a vector of four 8B1Q4 coded quinary symbols that, when representing data, conveys an octet. (See IEEE Std 802.3, Clause 23, Clause 24, Clause 32, Clause 36, and Clause 40.)

1.4.151 code-group alignment: In 1000BASE-X, the receiver action that resets the existing code-group boundary to that of the comma or K28.5 character currently being received. (See IEEE Std 802.3, Clause 36.)

1.4.152 code-group slipping: In 1000BASE-X, the receiver action to align the correct receive clock and code-group containing a comma. (See IEEE Std 802.3, Clause 36.)

1.4.153 Code Rule Violation (CRV): An analog waveform that is not the result of the valid Manchester-encoded output of a single optical transmitter. The collision of two or more 10BASE-FB optical transmissions will cause multiple CRVs. The preamble encoding of a single 10BASE-FP optical transmission contains a single CRV. (See IEEE Std 802.3, 16.3.1.1.)

1.4.154 collision: A condition that results from concurrent transmissions from multiple data terminal equipment (DTE) sources within a single collision domain.

1.4.155 collision domain: A single, half duplex mode CSMA/CD network. If two or more Media Access Control (MAC) sublayers are within the same collision domain and both transmit at the same time, a collision will occur. MAC sublayers separated by a repeater are in the same collision domain. MAC sublayers separated by a bridge are within different collision domains. (See IEEE Std 802.3.)

1.4.156 collision presence: A signal generated within the Physical Layer by an end station or hub to indicate that multiple stations are contending for access to the transmission medium. (See IEEE Std 802.3, Clause 8 and Clause 12.)

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1.4.157 comma: In 1000BASE-X, the seven-bit sequence that is part of an 8B/10B code-group that is used for the purpose of code-group alignment. (See IEEE Std 802.3, Clause 36.)

1.4.158 comma-: In 1000BASE-X, the seven-bit sequence (1100000) of an encoded data stream. (See IEEE Std 802.3, Clause 36.)

1.4.159 comma+: In 1000BASE-X, the seven-bit sequence (0011111) of an encoded data stream. (See IEEE Std 802.3, Clause 36.)

1.4.160 common-mode voltage: The instantaneous algebraic average of two signals applied to a balanced circuit, with both signals referenced to a common reference. Also called *longitudinal voltage* in the telephone industry.

1.4.161 Community Antenna Television (CATV)-type broadband medium: A broadband system comprising coaxial cables, taps, splitters, amplifiers, and connectors the same as those used in CATV or cable television installations. (See IEEE Std 802.3, Clause 11.)

1.4.162 Company ID (CID): A 24-bit unique number that identifies a manufacturer or other organization. A CID is used as a globally unique identifier on its own, and may be included as part of a context dependent identifier, as part of a protocol identifier, in other management data, etc. Any MAC addresses created from a CID are by definition, locally administered and not guaranteed to be unique in any MAC address context. OUI (see 1.4.306) and CID are non-overlapping and therefore mutually unique.

NOTE—See http://standards.ieee.org/develop/regauth/

1.4.163 compatibility interfaces: Several hardware points of attachment have been defined by this standard to allow connection of independently designed and manufactured components to the transmission medium. (See IEEE Std 802.3, 1.1.3.2.)

1.4.164 container: An SDH term that is equivalent to the payload capacity of a synchronous payload envelope. This definition is derived from ATIS-0900105.2008 and ATIS-0600416.1999(R2010), which take precedence.

1.4.165 continuous wave (CW): A carrier that is not modulated or switched.

1.4.166 Control mode: In 1000BASE-T, the period of operation in which the PHY is transmitting code-groups that represent control information. The end of a frame is accompanied by a transition to the Control mode, which immediately follows the Data mode and precedes the Idle mode. This occurs when the GMII signal TX_EN is set FALSE. During this time, several control fields are transmitted as code-groups to complete a stream. These include two convolutional encoder reset code-groups, two End-of-Stream delimiter (ESD) code-groups and, possibly, carrier extend code-groups. (See IEEE Std 802.3, Clause 40.)

1.4.167 Control Signal One (CS1): An encoded control signal used on the Control In and Control Out circuits. A CS1 is encoded as a signal at half the bit rate (BR)/2). (See IEEE Std 802.3, Clause 7.)

1.4.168 Control Signal Zero (CS0): An encoded control signal used on the Control In and Control Out circuits. A CS0 is encoded as a signal at the bit rate (BR). (See IEEE Std 802.3, Clause 7.)

1.4.169 Coupled Power Ratio (CPR): The ratio (in dB) of the total power coupled into a multimode fiber to the optical power that can be coupled into a single-mode fiber.

1.4.170 cross connect: A group of connection points, often wall- or rack-mounted in a wiring closet, used to mechanically terminate and interconnect twisted-pair building wiring.

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1.4.171 data frame: Use of this term is restricted to Clause 9, 27 and 41 (*See:* **MAC Frame**).

1.4.172 Data mode: In 1000BASE-T, the period of operation in which the PHY is transmitting code-groups that represent data. This mode is preceded by a start of a frame during which the GMII signal TX_EN is set TRUE for data transmission. This mode begins with transmission of two Start-of-Stream delimiter code-groups followed by code-groups encoded from the data octets arriving on TXD<7:0> via the GMII. (See IEEE Std 802.3 Clause 40.)

1.4.173 data terminal equipment (DTE): Any source or destination of data connected to the local area network.

1.4.174 dBm: Decibels referenced to 1.0 mW.

1.4.175 dBmV: Decibels referenced to 1.0 mV measured at the same impedance. Used to define signal levels in Community Antenna Television (CATV)-type broadband systems. (See IEEE Std 802.3 Clause 11.)

1.4.176 dedicated service: A CSMA/CD network in which the collision domain consists of two and only two DTEs so that the total network bandwidth is dedicated to supporting the flow of information between them.

1.4.177 deep sleep: One of the two modes of operation for Energy-Efficient Ethernet. Deep sleep refers to the mode for which the transmitter ceases transmission during Low Power Idle to maximize the energy saving potential. (See IEEE Std 802.3, Figure 78–3).

1.4.178 defect: A limited interruption in the ability of an item to perform a required function. This definition is derived from ATIS-0600416.1999(R2010) and ATIS-0900105.2008, which take precedence.

1.4.179 differential Manchester encoding: Data encoding system used in Backplane Ethernet for Auto-Negotiation signaling and 10GBASE-KR training frame control channel encoding. (See IEEE Std 802.3 72.6.10.2.2 and 73.5.)

1.4.180 differential-mode voltage: The instantaneous algebraic difference between the potential of two signals applied to the two sides of a balanced circuit. Also called *metallic voltage* in the telephone industry.

1.4.181 differential skew: The difference in time between the midpoint voltage crossings of the true and complement components of a differential signal.

1.4.182 dispersion slope: The rate of change of the chromatic dispersion of a fiber with wavelength.

1.4.183 Downstream: In an access network, where there is a clear indication in each deployment as to which end of a link is closer to a subscriber, transmission toward the subscriber end of the link.

1.4.184 drop cable: In 10BROAD36, the small diameter flexible coaxial cable of the broadband medium that connects to a Medium Attachment Unit (MAU). (*See:* **trunk cable**.)

1.4.185 DSQ128: The 128 point double square (DSQ) constellation mapping used in 10GBASE-T. This constellation is obtained by taking a 2D constellation with 16-level pulse amplitude modulation (PAM16) on each dimension and eliminating half the points to create a checkerboard pattern. This constellation is based on a lattice called RZ^2 in the literature. (See IEEE Std 802.3, Clause 55.)

NOTE—See also Forney [B28A]

1.4.186 dual duplex: Within IEEE 802.3, a signaling system that supports simultaneous duplex communication over two cabling pairs.

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1.4.187 duplex channel: Within IEEE 802.3, a communications channel capable of simultaneous duplex communication.

1.4.188 eight-pin modular: An eight-wire connector. (From IEC 60603-7.)

1.4.189 encapsulation: In 1000BASE-X, the process by which a MAC packet is enclosed within a PCS code-group stream. (See IEEE Std 802.3, Clause 36.)

1.4.190 encircled flux: The optical power within a specified radius of a fiber center, as a percentage of that within 36 µm (for 62.5 µm fiber) or 29 µm (for 50 µm fiber).

1.4.191 Endpoint PSE: Power Sourcing Equipment (PSE) that is located at an endpoint.

1.4.192 End_of_Packet Delimiter (EPD): In 1000BASE-X, a defined sequence of three single code-group 8B/10B ordered sets used to delineate the ending boundary of a data transmission sequence for a single packet. (See IEEE Std 802.3, Clause 36.)

1.4.193 End-of-Stream Delimiter (ESD): Within IEEE 802.3, a code-group pattern used to terminate a normal data transmission. For 100BASE-T4, the ESD is indicated by the transmission of five predefined ternary code-groups named eop1-5. For 100BASE-X, the ESD is indicated by the transmission of the code-group/T/R. For 100BASE-T2, the ESD is indicated by two consecutive pairs of predefined PAM5×5 symbols (see Table 32–15), which are generated using unique Start-of-Stream Delimiter (SSD)/ESD coding rules. For 1000BASE-T, the ESD is indicated by two consecutive vectors of four quinary symbols as specified in Table 40–1. (See IEEE Std 802.3, Clause 22, Clause 23, Clause 32, and Clause 40.)

1.4.194 Energy-Efficient Ethernet (EEE): Provides a protocol for PHYs to coordinate transitions to or from a lower level of power consumption, without changing the link status and without dropping or corrupting frames. (See IEEE Std 802.3, Clause 78).

1.4.195 envelope frame: A MAC frame that carries a Length/Type field with the Type interpretation that may indicate additional encapsulation information within the MAC client data and has a maximum length of 2000 octets. The envelope frame is intended to allow inclusion of additional prefixes and suffixes required by higher layer encapsulation protocols. The encapsulation protocols may use up to 482 octets. (See IEEE 802.3, 3.2.7.)

1.4.196 Ethertype: A 2 octet value that indicates the nature of the MAC client protocol. Type values are assigned by the IEEE Registration Authority. (See: IEEE Std 802.3, 3.2.6.)

1.4.197 Exception Window: A time interval during which the impedance of a mated connector and associated transmission line is allowed to exceed the impedance tolerance specification for signals passed through that connector.

1.4.198 extension bit: A bit decoded from the received carrier stream that does not map into the data space but nonetheless denotes the presence of carrier for the purposes of CSMA/CD.

1.4.199 extinction ratio: The ratio of the low optical power level to the high optical power level on an optical segment. (See IEEE Std 802.3, Clause 15.)

1.4.200 eye-opening penalty: The difference, in dB, between (a) the optical power measured at the center of the data eye, and (b) the optical power measured at a point defined by the total worst-case peak-to-peak jitter at the receiver.

1.4.201 Fast Link Pulse (FLP) Burst: A group of no more than 33 and not less than 17 10BASE-T compatible link integrity test pulses. Each FLP Burst encodes 16 bits of data using an alternating clock and

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data pulse sequence. (See Figure 14–15, IEEE Std 802.3, Clause 14 and Figure 28–4, IEEE Std 802.3, Clause 28.)

1.4.202 Fast Link Pulse (FLP) Burst Sequence: The sequence of FLP Bursts transmitted by the local station. This term is intended to differentiate the spacing between FLP Bursts from the individual pulse spacings within an FLP Burst. (See IEEE Std 802.3, Clause 28.)

1.4.203 fast wake: One of the two modes of operation for Energy-Efficient Ethernet (EEE). Fast wake refers to the mode for which the transmitter continues to transmit signals during Low Power Idle so that the receiver can resume operation with a shorter wake time. (See IEEE Std 802.3, Figure 78–4.)

1.4.204 fiber optic cable: A cable containing one or more optical fibers as specified in IEEE Std 802.3, 15.3.1.

1.4.205 Fiber Optic Inter-Repeater Link (FOIRL): A Fiber Optic Inter-Repeater Link segment and its two attached Medium Attachment Units (MAUs). (See IEEE Std 802.3, Clause 15.)

1.4.206 Fiber Optic Inter-Repeater Link (FOIRL) bit error ratio (BER): For 10BASE-F, the mean bit error ratio of the FOIRL. (See IEEE Std 802.3, Clause 9.)

1.4.207 Fiber Optic Inter-Repeater Link (FOIRL) collision: For 10BASE-F, the simultaneous transmission and reception of data in a Fiber Optic Medium Attachment Unit (FOMAU). (See IEEE Std 802.3, Clause 9.)

1.4.208 Fiber Optic Inter-Repeater Link (FOIRL) Compatibility Interface: For 10BASE-F, the FOMDI and Attachment Unit Interface (AUI) (optional); the two points at which hardware compatibility is defined to allow connection of independently designed and manufactured components to the baseband optical fiber cable link segment. (See IEEE Std 802.3, Clause 9.)

1.4.209 Fiber Optic Inter-Repeater Link (FOIRL) Segment: A fiber optic link segment providing a point-to-point connection between two FOIRL Medium Attachment Units (MAUs) or between one FOIRL MAU and one 10BASE-FL MAU. *See:* **link segment**.

1.4.210 Fiber Optic Medium Attachment Unit (FOMAU): A MAU for fiber applications. (See IEEE Std 802.3, Clause 9.)

1.4.211 Fiber Optic Medium Attachment Unit's (FOMAU's) Receive Optical Fiber: For 10BASE-F, the optical fiber from which the local FOMAU receives signals. (See IEEE Std 802.3, Clause 9.)

1.4.212 Fiber Optic Medium Attachment Unit's (FOMAU's) Transmit Optical Fiber: For 10BASE-F, the optical fiber into which the local FOMAU transmits signals. (See IEEE Std 802.3, Clause 9.)

1.4.213 Fiber Optic Medium Dependent Interface (FOMDI): For 10BASE-F, the mechanical and optical interface between the optical fiber cable link segment and the Fiber Optic Medium Attachment Unit (FOMAU). (See IEEE Std 802.3, Clause 9.)

1.4.214 Fiber Optic Physical Medium Attachment (FOPMA): For 10BASE-F, the portion of the Fiber Optic Medium Attachment Unit (FOMAU) that contains the functional circuitry. (See IEEE Std 802.3 Clause 9.)

1.4.215 fiber pair: Optical fibers interconnected to provide two continuous light paths terminated at each end in an optical connector. Any intermediate optical connections must have insertion and return loss characteristics that meet or exceed IEEE Std 802.3, 15.3.2.1 and 15.3.2.2, respectively. (See IEEE Std 802.3, 15.3.1.)

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1.4.216 Fibre Channel (FC-PH): Name used to refer to ANSI X3.230-1994 [B21]. (See IEEE Std 802.3, Clause 36.)

1.4.217 Fibre Distributed Data Interface (FDDI): A 100 Mb/s, fiber optic-based, token-ring local area network standard (ISO/IEC 9314 series of standards).

1.4.218 fixed stuff: Null or padding octets inserted to compensate for the bandwidth differences between the byte interleaving and the concatenation rules of SONET/SDH. This definition is derived from ATIS-0600416.1999(R2010) and ATIS-0900105.2008, which take precedence.

1.4.219 FLP Burst: *See:* **Fast Link Pulse (FLP) Burst.**

1.4.220 FOIRL: *See:* **Fiber Optic Inter-Repeater Link (FOIRL).**

1.4.221 FOMAU: *See:* **Fiber Optic Medium Attachment Unit (FOMAU).**

1.4.222 frame ground: *See:* **chassis ground**.

1.4.223 frame loss ratio: The number of transmitted frames not received as valid by the MAC divided by the total number of transmitted frames.

1.4.224 full duplex: A mode of operation of a network, DTE, or Medium Attachment Unit (MAU) that supports duplex transmission as defined in IEEE 100. Within the scope of this standard, this mode of operation allows for simultaneous communication between a pair of stations, provided that the Physical Layer is capable of supporting simultaneous transmission and reception without interference. (See IEEE Std 802.3.)

1.4.225 Gigabit Media Independent Interface (GMII): The interface between the Reconciliation sublayer and the physical coding sublayer (PCS) for 1000 Mb/s operation. (See IEEE Std 802.3, Clause 35.)

1.4.226 grant: Within P2MP protocols, a permission to transmit at a specific time, for a specific duration. Grants are issued by the OLT (master) to ONUs (slaves) by means of GATE messages.

1.4.227 group: A repeater port or a collection of repeater ports that can be related to the logical arrangement of ports within a repeater.

1.4.228 group delay: In 10BROAD36, the rate of change of total phase shift, with respect to frequency, through a component or system. Group delay variation is the maximum difference in delay as a function of frequency over a band of frequencies. (See IEEE Std 802.3, Clause 11.)

1.4.229 half duplex: A mode of operation of a CSMA/CD local area network (LAN) in which DTEs contend for access to a shared medium. Multiple, simultaneous transmissions in a half duplex mode CSMA/CD LAN result in interference, requiring resolution by the CSMA/CD access control protocol. (See IEEE Std 802.3.)

1.4.230 headend: In 10BROAD36, the location in a broadband system that serves as the root for the branching tree comprising the physical medium; the point to which all inbound signals converge and the point from which all outbound signals emanate. (See IEEE Std 802.3, Clause 11.)

1.4.231 header hub (HH): The highest-level hub in a hierarchy of hubs. The HH broadcasts signals transmitted to it by lower-level hubs or DTEs such that they can be received by all DTEs that may be connected to it either directly or through intermediate hubs. (See IEEE Std 802.3, 12.2.1.)

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1.4.232 hub: A device used to provide connectivity between DTEs. Hubs perform the basic functions of restoring signal amplitude and timing, collision detection, and notification and signal broadcast to lower-level hubs and DTEs. (See IEEE Std 802.3, Clause 12.)

1.4.233 hybrid: A circuit (implementable with active or passive components) that enables full duplex transmission by allowing symbols to be transmitted and received on the same wire pair at the same time. It is often used together with an echo canceller to get adequate separation of transmit and receive signals.

1.4.234 I_{Port}: The total power-pair current going into the PI (see IEEE 802.3, Clause 33).

1.4.235 idle (IDL): A signal condition where no transition occurs on the transmission line, that is used to define the end of a frame and ceases to exist after the next LO or HI transition on the Attachment Unit Interface (AUI) or Media Independent Interface (MII) circuits. An IDL always begins with a HI signal level. A driver is required to send the IDL signal for at least 2 bit times and a receiver is required to detect IDL within 1.6 bit times. (See IEEE Std 802.3, 7.3 and 12.3.2.4.4 for additional details.)

1.4.236 Idle mode: In 1000BASE-T, the period of operation in which the PHY is transmitting special code-groups that use only the values {2, 0, –2}. Idle mode occurs during start-up when the PHYs at each end of a link are attempting to establish adaptive filter parameters and then synchronize both phase and timing so that normal operation can begin. Idle mode also occurs during normal operation between frames. Idle mode occurs after a control mode ends and before another Data mode begins. The Idle mode is not used between frames in a packet burst. (See IEEE Std 802.3, Clause 40.)

1.4.237 in-band signaling: The transmission of a signal using a frequency that is within the bandwidth of the information channel. *Contrast with:* **out-of-band signaling**. *Syn:* **in-channel signaling**. (From IEEE Std 610.7-1995 [B42].)

1.4.238 intermediate hub (IH): A hub that occupies any level below the header hub in a hierarchy of hubs. (See IEEE Std 802.3, 12.2.1 for details.)

1.4.239 interpacket gap (IPG): A delay or time gap between Ethernet packets intended to provide inter-frame recovery time for other Ethernet sublayers and for the Physical Medium. (See IEEE Std 802.3, 4.2.3.2.1 and 4.2.3.2.2.) The minimum length of IPG at the transmitting MAC is enforced by the MAC parameter interPacketGap; the actual interpacket gap may change between the transmitting MAC and receiving MAC.

1.4.240 Inter-Repeater Link (IRL): A mechanism for connecting two and only two repeater sets.

1.4.241 intersymbol interference penalty: The power penalty due to the finite bandwidth of the link. (See IEEE Std 802.3, Clause 38.)

1.4.242 jabber: A condition wherein a station transmits for a period of time longer than the maximum permissible packet length, usually due to a fault condition.

1.4.243 Jabber function: A mechanism for controlling abnormally long transmissions (i.e., jabber).

1.4.244 jitter: The variations of signal transitions from their ideal positions in time. Jitter may be characterized by its spectral properties and its distribution in time.

1.4.245 jumper cable assembly: An electrical or optical assembly, used for the bidirectional transmission and reception of information, consisting of a pair of transmission lines terminated at their ends with plug connectors. This assembly may or may not contain additional components, located between the plug connectors, to perform equalization. (See IEEE Std 802.3, Clause 39.)

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1.4.246 lane: A bundle of signals that constitutes a logical subset of a point-to-point interconnect. A lane contains enough signals to communicate a quantum of data and/or control information between the two end-points.

1.4.247 LDPC(1723,2048) frame: 64B/65B transmission code blocks mapped into a low density parity check (LDPC) frame with 1723 coded bits, 325 check bits and 1536 uncoded bits. (See IEEE Std 802.3, Clause 55.)

1.4.248 link: The transmission path between any two interfaces of generic cabling. (From ISO/IEC 11801.)

1.4.249 Link codeword: The 16 bits of data encoded into a Fast Link Pulse (FLP) Burst. (See IEEE Std 802.3, Clause 28.)

1.4.250 Link Layer Discovery Protocol (LLDP): A media-independent protocol intended to run on any IEEE 802® LAN station and to allow an LLDP agent to learn the connectivity and management information from adjacent stations (see IEEE Std 802.1AB-2009).

1.4.251 link partner: The device at the opposite end of a link segment from the local station. The link partner device may be either a DTE or a repeater. (See IEEE Std 802.3, Clause 28.)

1.4.252 link penalties: For fiber optic links, the power penalties of a link not attributed to link attenuation. These power penalties include modal noise, relative intensity noise (RIN), intersymbol interference (ISI), mode partition noise, extinction ratio, and eye-opening penalties.

1.4.253 link pulse: Communication mechanism used in 10BASE-T and 100BASE-T networks to indicate link status and (in Auto-Negotiation-equipped devices) to communicate information about abilities and negotiate communication methods. 10BASE-T uses Normal Link Pulses (NLPs), which indicate link status only. 10BASE-T and 100BASE-T nodes equipped with Auto-Negotiation exchange information using a Fast Link Pulse (FLP) mechanism that is compatible with NLP. (See IEEE Std 802.3, Clause 14 and Clause 28.)

1.4.254 link section: The portion of the link from the PSE to the PD.

1.4.255 link segment: The point-to-point full-duplex medium connection between two and only two Medium Dependent Interfaces (MDIs).

1.4.256 Link Segment Delay Value (LSDV): A number associated with a given segment that represents the delay on that segment used to assess path delays for 100 Mb/s CSMA/CD networks. LSDV is similar to SDV; however, LSDV values do not include the delays associated with attached end stations and/or repeaters. (See IEEE Std 802.3, 29.3.)

1.4.257 local ability: *See:* **ability**.

1.4.258 local device: The local device that may attempt to perform Auto-Negotiation with a link partner. The local device may be either a DTE or repeater. (See IEEE Std 802.3, Clause 28.)

1.4.259 Logical Link Identifier (LLID): A numeric identifier assigned to a P2MP association between an OLT and ONU established through the Point-to-Point Emulation sublayer. Each P2MP association is assigned a unique LLID. The P2MP association is bound to an ONU DTE, where a MAC would observe a private association.

1.4.260 Low Power Idle (LPI) mode: An optional mode intended to save power that may be enabled during periods of low link utilization in which either side of a link may disable portions of device or system functionality.

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1.4.261 MAC frame: Consists of the Destination Address, Source Address, Length/Type field, MAC Client Data, Pad (if required), and Frame Check Sequence.

1.4.262 Management Information Base (MIB): A repository of information to describe the operation of a specific network device.

1.4.263 management interface: An interface provided by both the Media Independent Interface (MII) or Gigabit Media Independent Interface (GMII) that provides access to management parameters and services.

1.4.264 master Physical Layer (PHY): Within IEEE 802.3, in a 100BASE-T2 or 1000BASE-T link containing a pair of PHYs, the PHY that uses an external clock for generating its clock signals to determine the timing of transmitter and receiver operations. It also uses the master transmit scrambler generator polynomial for side-stream scrambling. Master and slave PHY status is determined during the Auto-Negotiation process that takes place prior to establishing the transmission link. *See also:* **slave Physical Layer (PHY).**

1.4.265 maximum differential input: The largest value of peak-to-peak differential (ppd) amplitude at which a receiver is expected to operate, under worst-case conditions, without exceeding the objective bit error ratio.

1.4.266 Media Access Control (MAC): The data link sublayer that is responsible for transferring data to and from the Physical Layer.

1.4.267 Media Independent Interface (MII): A transparent signal interface at the bottom of the Reconciliation sublayer. (See IEEE Std 802.3, Clause 22.)

1.4.268 Medium Attachment Unit (MAU): A device containing an Attachment Unit Interface (AUI), Physical Medium Attachment (PMA), and Medium Dependent Interface (MDI) that is used to connect a repeater or data terminal equipment (DTE) to a transmission medium.

1.4.269 Medium Dependent Interface (MDI): The mechanical and electrical or optical interface between the transmission medium and the MAU (e.g., 10BASE-T) or the PHY (e.g., 1000BASE-T) and also between the transmission medium and any associated (optional per IEEE Std 802.3, Clause 33) Powered Device (PD) or Endpoint Power Sourcing Equipment (PSE).

1.4.270 Message Code (MC): The predefined 12-bit code contained in an Auto-Negotiation Message Page. (See IEEE Std 802.3, Clause 28.)

1.4.271 Message Page (MP): An Auto-Negotiation Next Page encoding that contains a predefined 12-bit Message Code. (See IEEE Std 802.3, Clause 28.)

1.4.272 midspan: An entity located within a link segment that is distinctly separate from and between the Medium Dependent Interfaces (MDIs).

1.4.273 Midspan PSE: Power Sourcing Equipment (PSE) that is located in the midspan.

1.4.274 Midspan PSE, 1000BASE-T: A Midspan PSE that results in a link that can support 10BASE-T, 100BASE-TX, and 1000BASE-T operation (see IEEE 802.3, Clause 33).

1.4.275 Midspan PSE, 10BASE-T/100BASE-TX: A Midspan PSE that results in a link that can only support 10BASE-T and 100BASE-TX operation (see IEEE 802.3, Clause 33).

1.4.276 minimum differential sensitivity: The smallest value of peak-to-peak differential (ppd) amplitude at which a receiver is expected to operate, under worst-case conditions, without exceeding the objective bit error ratio.

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1.4.277 mixing segment: A medium that may be connected to more than two Medium Dependent Interfaces (MDIs).

1.4.278 multiport device: A device with multiple instances of MDI. (See IEEE Std 802.3, Clause 40 and Clause 42.)

1.4.279 network control host: A network management central control center that is used to configure agents, communicate with agents, and display information collected from agents.

1.4.280 network interface device (NID): A device that contains a MDI or a PI.

1.4.281 Next Page: General class of pages optionally transmitted by Auto-Negotiation able devices following the base link codeword negotiation. (See IEEE Std 802.3, Clause 28.)

1.4.282 Next Page algorithm (NPA): The algorithm that governs Next Page communication. (See IEEE Std 802.3, Clause 28.)

1.4.283 Next Page bit: A bit in the Auto-Negotiation base link codeword or Next Page encoding(s) that indicates that further link codeword transfer is required. (See IEEE Std 802.3, Clause 28.)

1.4.284 nibble: A group of four data bits. The unit of data exchange on the Media Independent Interface (MII). (See IEEE Std 802.3, Clause 22.)

1.4.285 NLP: *See:* **Normal Link Pulse (NLP).**

1.4.286 Non-Return-to-Zero, Invert on Ones (NRZI): An encoding technique used in FDDI (ISO/IEC 9314-1:1989, ISO/IEC 9314-2:1989, ISO/IEC 9314-3:1989) where a polarity transition represents a logical ONE. The absence of a polarity transition denotes a logical ZERO.

1.4.287 Non-Return-to-Zero, Invert on Ones (NRZI)-bit: A code-bit transferred in NRZI format. The unit of data passed across the Physical Medium Dependent (PMD) service interface in 100BASE-X.

1.4.288 normalized amplitude: The amplitude of a signal when driving its steady-state value; i.e., not under the influence of ringing or other dynamic influences.

1.4.289 Normal Link Pulse (NLP): An out-of-band communications mechanism used in 10BASE-T to indicate link status. (See IEEE Std 802.3, Figure 14–13.)

1.4.290 Normal Link Pulse (NLP) Receive Link Integrity Test function: A test function associated with Auto-Negotiation that allows backward compatibility with the 10BASE-T Link Integrity Test function of IEEE Std 802.3 Figure 14–6. (See IEEE Std 802.3, Clause 28.)

1.4.291 Normal Link Pulse (NLP) sequence: A Normal Link Pulse sequence, defined in IEEE Std 802.3, 14.2.1.1 as TP_IDL.

1.4.292 nPPI: The term “nPPI” denotes either XLPPI or CPPI or both. (See IEEE Std 802.3, Annex 86A.)

1.4.293 NRZI: *See:* **Non-Return-to-Zero, Invert on Ones**.

1.4.294 OAM Discovery: Process that detects the presence and configuration of the OAM sublayer in the remote DTE.

1.4.295 offline: In 1000BASE-X, a DTE in its nonfunctional state. (See IEEE Std 802.3, Clause 37.)

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1.4.296 Operations, Administration, and Maintenance (OAM): A group of network support functions that monitor and sustain segment operation, activities that are concerned with, but not limited to, failure detection, notification, location, and repairs that are intended to eliminate faults and keep a segment in an operational state and support activities required to provide the services of a subscriber access network to users/subscribers.

1.4.297 optical fiber: A filament-shaped optical waveguide made of dielectric materials.

1.4.298 Optical Fiber Cable Interface: *See:* **Fiber Optic Medium Dependent Interface (FOMDI)**.

1.4.299 optical fiber cable link segment: A length of optical fiber cable that contains two optical fibers and is comprised of one or more optical fiber cable sections and their means of interconnection, with each optical fiber terminated at each end in the optical connector plug. (See IEEE Std 802.3, 9.9.5.1 and 9.9.5.1.)

1.4.300 Optical Idle Signal: The signal transmitted by the Fiber Optic Medium Attachment Unit (FOMAU) into its transmit optical fiber during the idle state of the DO circuit. (See IEEE Std 802.3, Clause 9.)

1.4.301 optical interface: The optical input and output connection interface to a 10BASE-FP Star. (See IEEE Std 802.3, Clause 15.)

1.4.302 Optical Line Terminal (OLT): The network-end DTE for an optical access network. The OLT is the master entity in a P2MP network with regard to the MPCP protocol.

1.4.303 Optical Modulation Amplitude (OMA): The absolute difference between the optical power of a logic one level and the optical power of a logic zero level.

1.4.304 Optical Network Unit (ONU): The subscriber-end DTE to an optical access network. An ONU is a slave entity in a P2MP network with regard to the MPCP protocol.

1.4.305 ordered set: A single special code-group, a combination of special and data code-groups, or a combination of a control character and data characters that are used to send control and status information such as remote fault and local fault status over the link. Also used by the 1000BASE-X and 10GBASE-X PCS for delineation of a packet and synchronization between the transmitter and receiver circuits at opposite ends of a link. (See IEEE Std 802.3, Clause 36, Clause 48, Clause 49, Clause 55, and Clause 82.)

1.4.306 Organizationally Unique Identifier (OUI): A 24-bit unique number that identifies a manufacturer or other organization. While an OUI may be used as a globally unique identifier on its own, its primary purpose is to be extended to form universally administered, globally unique MAC addresses or other extended globally-unique identifiers. It may also be used as part of a context dependent identifier, as part of a protocol identifier, in other management data, etc. OUI and CID (see 1.4.162) are non-overlapping and therefore mutually unique.

NOTE—See http://standards.ieee.org/develop/regauth/

1.4.307 out-of-band signaling: The transmission of a signal using a frequency that is within the pass band of the transmission facility but outside a frequency range normally used for data transmission. *Contrast with:* **in-band signaling**. (From IEEE Std 610.7-1995 [B42].)

1.4.308 overfilled launch: The overfilled launch condition that excites both radial and azimuthal modes defined in ANSI/EIA/TIA 455-54A-1990 [B7].

1.4.309 P2MP Discovery: Process by which the OLT finds a newly attached and active ONU in the P2MP network, and by which the OLT and ONU exchange registration information. The OLT sends a GATE flagged for discovery.

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1.4.310 P2MP Discovery window: A time period in a given wavelength band reserved by the OLT exclusively for the discovery process.

1.4.311 P2MP Timestamp: The timestamp used to synchronize slaves (e.g., ONUs) with the master (OLT) and for the ranging process.

1.4.312 packet: Consists of a MAC frame as defined previously, preceded by the Preamble and the Start Frame Delimiter, encoded, as appropriate, for the Physical Layer (PHY) type.

1.4.313 page: In Auto-Negotiation, the encoding for a link codeword. Auto-Negotiation can support an arbitrary number of link codeword encodings. The Base Page has a constant encoding as defined in 28.2.1.2. Additional pages may have a predefined encoding *(see:* **Message Page**) or may be custom encoded *(see:* **Unformatted Page**).

1.4.314 PAM5×5: Within IEEE 802.3, a block coding technique utilizing a 5×5 matrix (representing two 5-level signals) to generate pairs of quinary codes representing data nibbles and control characters. In 100BASE-T2, PAM5×5 code pairs are sent in parallel across two wire pairs. (See IEEE Std 802.3, Clause 32.)

1.4.315 parallel detection: In Auto-Negotiation, the ability to detect 100BASE-TX and 100BASE-T4 technology specific link signaling while also detecting the Normal Link Pulse (NLP) sequence or Fast Link Pulse (FLP) Burst sequence. (See IEEE Std 802.3, Clause 28.)

1.4.316 Passive-Star Coupler: A component of a 10BASE-FP fiber optic mixing segment that divides optical power received at any of N input ports among all N output ports. The division of optical power is approximately uniform. (See IEEE Std 802.3, Clause 15.)

1.4.317 patch cord: Flexible cable unit or element with connector(s) used to establish connections on a patch panel. (From ISO/IEC 11801:1995.)

1.4.318 patch panel: A cross-connect designed to accommodate the use of patch cords. It facilitates administration for moves and changes. (From ISO/IEC 11801:1995.)

1.4.319 path: The sequence of segments and repeaters providing the connectivity between two DTEs in a single collision domain. In CSMA/CD networks there is one and only one path between any two DTEs.

1.4.320 Path Delay Value (PDV): The sum of all Segment Delay Values for all segments along a given path. (See IEEE Std 802.3, Clause 13 and Clause 29.)

1.4.321 Path Variability Value (PVV): The sum of all Segment Variability Values for all the segments along a given path. (See IEEE Std 802.3, Clause 13.)

1.4.322 pause: A mechanism for full duplex flow control. (See IEEE Std 802.3, Annex 31B.)

1.4.323 pause_quantum: The unit of measurement for pause time specified; 512 MAC bit times.

NOTE—See IEEE Std 802.3, Annex 31B.

1.4.324 payload pointer: An indicator of the location of the beginning of the synchronous payload envelope. This definition is derived from ATIS-0600416.1999(R2010) and ATIS-0900105.2008, which take precedence.

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1.4.325 PCS lane (PCSL): In 40GBASE-R and 100GBASE-R, the PCS distributes encoded data to multiple logical lanes, these logical lanes are called PCS lanes. One or more PCS lanes can be multiplexed and carried on a physical lane together at the PMA service interface. (See IEEE Std 802.3, Clause 83.)

1.4.326 Physical Coding Sublayer (PCS): Within IEEE 802.3, a sublayer used in certain port types to couple the Media Independent Interface (MII), Gigabit Media Independent Interface (GMII) or 10 Gigabit Media Independent Interface (XGMII) and the Physical Medium Attachment (PMA). The PCS contains the functions to encode data bits for transmission via the PMA and to decode the received conditioned signal from the PMA. There are several PCS structures. (For example, See IEEE Std 802.3, Clause 23, Clause 24, Clause 32, Clause 36, Clause 40, Clause 48, Clause 49, and Clause 82.)

1.4.327 Physical Layer entity (PHY): Within IEEE 802.3, the portion of the Physical Layer between the Medium Dependent Interface (MDI) and the Media Independent Interface (MII), Gigabit Media Independent Interface (GMII) or 10 Gigabit Media Independent Interface (XGMII), consisting of the Physical Coding Sublayer (PCS), the Physical Medium Attachment (PMA), and, if present, the WAN Interface Sublayer (WIS) and Physical Medium Dependent (PMD) sublayers. The PHY contains the functions that transmit, receive, and manage the encoded signals that are impressed on and recovered from the physical medium. (For example, See IEEE Std 802.3, Clauses 23 to 26, Clause 32, Clause 36, Clause 40, Clauses 48 to 54, Clauses 58 to 63, Clause 65, Clause 66, and Clauses 82 to 89.)

1.4.328 Physical Medium Attachment (PMA) sublayer: Within 802.3, that portion of the Physical Layer that contains the functions for transmission, reception, and (depending on the PHY) collision detection, clock recovery and skew alignment. (For example, See IEEE Std 802.3, Clauses 7, 12, 14, 16, 17, 18, 23, 24, 32, 36, 40, 51, 62, 63, 66, and 83.)

1.4.329 Physical Medium Dependent (PMD) sublayer: Within 802.3, that portion of the Physical Layer responsible for interfacing to the transmission medium. The PMD is located just above the Medium Dependent Interface (MDI). (For example, See IEEE Std 802.3, Clause 25, Clause 26, Clause 38, Clause 39, Clause 54, Clauses 58 to 60, Clause 62, Clause 63, and Clauses 84 to 89.)

1.4.330 Physical Signaling Sublayer (PLS): In 10BASE-T, that portion of the Physical Layer contained within the data terminal equipment (DTE) that provides the logical and functional coupling between the Medium Attachment Unit (MAU) and the Data Link Layer.

1.4.331 Point-to-Multipoint network (P2MP): A passive optical network providing transport of Ethernet frames (See IEEE Std 802.3, Clause 64 and Clause 65).

1.4.332 pointer: *See:* **payload pointer.**

1.4.333 Point-to-point emulation (P2PE): Emulation of private communication between two end-stations (e.g., ONU) in a P2MP. Emulation creates the equivalent of a star topology with the OLT in the nexus, and is required for compliance with IEEE 802.1D bridging.

1.4.334 port: A segment or Inter-Repeater Link (IRL) interface of a repeater unit.

1.4.335 postamble: In 10BROAD36, the bit pattern appended after the last bit of the Frame Check Sequence by the Medium Attachment Unit (MAU). The Broadband End-of-Frame Delimiter (BEOFD). (See IEEE Std 802.3, Clause 11.)

1.4.336 power budget: The minimum optical power available to overcome the sum of attenuation plus power penalties of the optical path between the transmitter and receiver calculated as the difference between the transmitter launch power (min) and the receive power (min).

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1.4.337 Power Interface (PI): The mechanical and electrical interface between the Power Sourcing Equipment (PSE) or Powered Device (PD) and the transmission medium. In an Endpoint PSE and in a PD the Power Interface is the MDI.

1.4.338 Power Sourcing Equipment (PSE): A DTE or midspan device that provides the power to a single link section. DTE powering is intended to provide a single 10BASE-T, 100BASE-TX, or 1000BASE-T device with a unified interface for both the data it requires and the power to process these data.

1.4.339 Powered Device (PD): A device that is either drawing power or requesting power from a PSE.

1.4.340 prepend: To append to the beginning. For example, a Media Access Control (MAC) frame is prepended with a preamble, and appended with a frame check sequence (FCS).

1.4.341 Priority-based Flow Control (PFC): A mechanism for applying flow control to frames with a given priority on a full duplex link. (See IEEE Std 802.1Q.)

1.4.342 priority resolution: A mechanism that allows a local device and its link partner to resolve to a single mode of operation given a set of prioritized rules governing resolution. (See IEEE Std 802.3, Clause 28 and Clause 37.)

1.4.343 Priority Resolution Table: The look-up table used by Auto-Negotiation to select the network connection type where more than one common network ability exists (100BASE-TX, 100BASE-T4, 10BASE-T, etc.) The priority resolution table defines the relative hierarchy of connection types from the highest common denominator to the lowest common denominator. (See IEEE Std 802.3, Clause 28.)

1.4.344 PSE Group: A PSE or a collection of PSEs that can be related to the logical arrangement for management within an encompassing system.

1.4.345 Q: In the context of a fiber optic communication system, one-half of the ratio of peak-to-peak signal to rms noise.

1.4.346 QTag Prefix: The first four octets of an Ethernet-encoded Tag Header. The Ethernet-encoded Tag Header is defined in IEEE Std 802.1Q.

1.4.347 Q-tagged frame: A MAC frame with a specific Ethertype value, and that has a maximum length of 1522 octets. (See IEEE Std 802.3, 3.2.7 and IEEE Std 802.1Q, Annex G.)

1.4.348 quad: *See:* **star quad**.

1.4.349 quinary: Five-level.

1.4.350 quinary symbol: In 1000BASE-T, one of five numeric values corresponding to five voltage levels on a single balanced twisted pair. The values come from the set {2, 1, 0, –1, –2}. Table 40–1 lists groups of four quinary symbols. Idle is a special case where numeric values are limited to the set {2, 0, and –2}. (See IEEE Std 802.3, Clause 40.)

1.4.351 radial overfilled launch: A launch condition created when a multimode optical fiber is illuminated by the coherent optical output of a source operating in its lowest-order transverse mode in a manner that excites predominantly the radial modes of the multimode fiber.

1.4.352 ranging: A procedure by which the propagation delay between a master (e.g., OLT) and slave (e.g., ONU) is measured. The round trip delay computation is performed by the OLT, using the timestamp in MPCP messages from the ONU.

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1.4.353 receiver training: Within IEEE 802.3, a start-up routine in 100BASE-T2 and 1000BASE-T used to acquire receiver parameters and synchronize the scramblers of two connected Physical Layers (PHYs).

1.4.354 Reconciliation Sublayer (RS): A mapping function that reconciles the signals at the Media Independent Interface (MII) to the Media Access Control (MAC)-Physical Signaling Sublayer (PLS) service definitions. (See IEEE Std 802.3, Clause 22.)

1.4.355 reflectance: Ratio of reflected to incident power. This is the inverse of return loss.

1.4.356 relative intensity noise: The ratio of the variance in the optical power to the average optical power.

1.4.357 remote fault: The generic ability of a link partner to signal its status even in the event that it may not have an operational receive link. (See IEEE Std 802.3, Clause 28 and Clause 37.)

1.4.358 renegotiation: Restart of the Auto-Negotiation algorithm caused by management or user interaction. (See IEEE Std 802.3, Clause 28.)

1.4.359 repeater: Within IEEE 802.3, a device as specified in Clause 9 and Clause 27 that is used to extend the length, topology, or interconnectivity of the physical medium beyond that imposed by a single segment, up to the maximum allowable end-to-end transmission line length. Repeaters perform the basic actions of restoring signal amplitude, waveform, and timing applied to the normal data and collision signals. For wired star topologies, repeaters provide a data distribution function. In 100BASE-T, a device that allows the interconnection of 100BASE-T Physical Layer (PHY) network segments using similar or dissimilar PHY implementations (e.g., 100BASE-X to 100BASE-X, 100BASE-X to 100BASE-T4). Repeaters are only for use in half duplex mode networks. (See IEEE Std 802.3, Clause 9 and Clause 27.)

1.4.360 repeater port: *See:* **port**.

1.4.361 repeater set: A repeater unit plus its associated Physical Layer interfaces [Medium Attachment Units (MAUs) or PHYs] and, if present, Attachment Unit (AU) or Media Independent (MI) interfaces (i.e., AUIs, MIIs).

1.4.362 repeater unit: The portion of a repeater that is inboard of its Physical Medium Attachment (PMA)/Physical Signaling Sublayer (PLS), or PMA/Physical Coding Sublayer (PCS) interfaces.

1.4.363 retraining: Within IEEE 802.3, the process of re-acquiring receiver parameters and synchronizing the scramblers of two connected 100BASE-T2 PHYs or 1000BASE-T. *See:* **receiver training, blind mode.**

1.4.364 return loss: In 10BROAD36, the ratio in decibels of the power reflected from a port to the power incident to the port. An indicator of impedance matching in a broadband system. (See IEEE Std 802.3, Clause 11.)

1.4.365 RIN$_x$OMA: Relative intensity noise. Laser noise in dB/Hz with x dB optical return loss, with respect to the optical modulation amplitude.

1.4.366 rising edge: A rising edge for a differential signal pair, e.g., signal(P,N) is when, signal(P) transitions from logic low to high and signal(N) transitions from logic high to low.

1.4.367 RMS spectral width: A measure of the optical wavelength range as defined by TIA 455-127-A (FOTP-127-A).

1.4.368 router: A layer 3 interconnection device that appears as a Media Access Control (MAC) to a CSMA/CD collision domain. (See IEEE Std 610.7-1995 [B42].)

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1.4.369 run length: The number of consecutive identical bits in a code-group. For example, the pattern 0011111010 has a run length of five. (See IEEE Std 802.3 Clause 36.)

1.4.370 run-length-limited code: Any transmission code that has limited run-length for its transmission. (See IEEE Std 802.3 Clause 36.)

1.4.371 running disparity: A binary parameter having a value of + or –, representing the imbalance between the number of ones and zeros in a sequence of 8B/10B code-groups. (See IEEE Std 802.3, 36.2.4.3.)

1.4.372 scrambler: A randomizing mechanism that is used to eliminate long strings of consecutive identical transmitted symbols and avoid the presence of spectral lines in the signal spectrum without changing the signaling rate. A self-synchronous scrambler is one in which the current state of the scrambler is the prior n bits of the scrambled output. Therefore, the descrambler can acquire the correct state directly from the received stream. A side-stream scrambler is one in which the current state of the scrambler is dependent only on the prior state of the scrambler and not on the transmitted data. Therefore, the descrambler must acquire state either by searching for a state that decodes a known pattern or by agreement to start at a known state in synchronization with the scrambler. A frame-synchronous scrambler is a side-stream scrambler that begins each frame in a known state. This definition is derived from ATIS-0600416.1999(R2010) and ATIS-0900105.2008, which take precedence.

1.4.373 Seed: In 10BROAD36, the 23 bits residing in the scrambler shift register prior to the transmission of a packet. (See IEEE Std 802.3, Clause 11.)

1.4.374 segment: The medium connection, including connectors, between Medium Dependent Interfaces (MDIs) in a CSMA/CD local area network.

1.4.375 Segment Delay Value (SDV): A number associated with a given segment that represents the delay on that segment including repeaters and end stations, if present, used to assess path delays for 10 Mb/s CSMA/CD networks. (See IEEE Std 802.3, 13.4.)

1.4.376 Segment Variability Value (SVV): A number associated with a given segment that represents the delay variability on that segment (including a repeater) for 10 Mb/s CSMA/CD networks. The SVVs for different segment types are specified in IEEE Std 802.3, Table 13–3. (See IEEE Std 802.3, 13.4.)

1.4.377 shared service: A CSMA/CD network in which the collision domain consists of more than two DTEs so that the total network bandwidth is shared among them.

1.4.378 shielded twisted-pair (STP) cable: An electrically conducting cable, comprising one or more elements, each of which is individually shielded. There may be an overall shield, in which case the cable is referred to as shielded twisted-pair cable with an overall shield (from ISO/IEC 11801:1995). Specifically for IEEE 802.3 100BASE-TX, 150 Ω balanced inside cable with performance characteristics specified to 100 MHz (i.e., performance to Class D link standards as per ISO/IEC 11801:1995). In addition to the requirements specified in ISO/IEC 11801:1995, IEEE Std 802.3, Clause 23 and Clause 25, provide additional performance requirements for 100BASE-T operation over STP.

1.4.379 simplex fiber optic link segment: A single fiber path between two Medium Attachment Units (MAUs) or PHYs, including the terminating connectors, consisting of one or more fibers joined serially with appropriate connection devices, for example, patch cables and wall plates. (See IEEE Std 802.3, Clause 15.)

1.4.380 simplex link segment: A path between two Medium Dependent Interfaces (MDIs), including the terminating connectors, consisting of one or more segments of twisted pair cable joined serially with appropriate connection devices, for example, patch cords and wall plates. (See IEEE Std 802.3, Figure 14–2.)

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1.4.381 single-port device: A device with a single instance of MDI. (See IEEE Std 802.3, Clause 40.)

1.4.382 skew between pairs: The difference in arrival times of two initially coincident signals propagated over two different pairs, as measured at the receiving end of the cable. Total skew includes contributions from transmitter circuits as well as the cable.

1.4.383 slave Physical Layer (PHY): Within IEEE 802.3, in a 100BASE-T2 or 1000BASE-T link containing a pair of PHYs, the PHY that recovers its clock from the received signal and uses it to determine the timing of transmitter operations. It also uses the slave transmit scrambler generator polynomial for side-stream scrambling. Master and slave PHY status is determined during the Auto-Negotiation process that takes place prior to establishing the transmission link. *See also:* **master Physical Layer (PHY).**

1.4.384 sliver: A pulse with a duration less than that specified for that signal (e.g., truncated clock signal).

1.4.385 special link (SL): A transmission system that replaces the normal medium. (See IEEE Std 802.3, 12.8.)

1.4.386 spectral width, full-width half maximum (FWHM): The absolute difference between the wavelengths at which the spectral radiant intensity is 50% of the maximum. (See IEEE Std 802.3, Clause 15.)

1.4.387 spectrum mask: A graphic representation of the required power distribution as a function of frequency for a modulated transmission.

1.4.388 star quad: A cable element that comprises four insulated connectors twisted together. Two diametrically facing conductors form a transmission pair.

NOTE—Cables containing star quads can be used interchangeably with cables consisting of pairs, provided the electrical characteristics meet the same specifications. (From ISO/IEC 11801.)

1.4.389 Start_of_Packet Delimiter (SPD): In 1000BASE-X, a single code-group 8B/10B ordered set used to delineate the starting boundary of a data transmission sequence for a single packet. (See IEEE Std 802.3, Clause 36.)

1.4.390 Start-of-Stream Delimiter (SSD): Within IEEE 802.3, a pattern of defined codewords used to delineate the boundary of a data transmission sequence on the Physical Layer stream. The SSD is unique in that it may be recognized independent of previously defined code-group boundaries and it defines subsequent code-group boundaries for the stream it delimits. For 100BASE-T4, SSD is a pattern of three predefined sosb code-groups (one per wire pair) indicating the positions of the first data code-group on each wire pair. For 100BASE-X, SSD consists of the code-group sequence /J/K/. For 100BASE-T2, the SSD is indicated by two consecutive pairs of predefined PAM5×5 symbols (±2, ±2) (±2, 0) which are generated using unique SSD/ESD coding rules. For 1000BASE-T, the SSD is indicated by two consecutive vectors of four quinary symbols as specified in Table 40–1.

1.4.391 stream: The Physical Layer (PHY) encapsulation of a Media Access Control (MAC) frame. Depending on the particular PHY, the MAC frame may be modified or have information appended or prepended to it to facilitate transfer through the Physical Medium Attachment (PMA). Any conversion from a MAC frame to a PHY stream and back to a MAC frame is transparent to the MAC. (See IEEE Std 802.3, Clause 23 and Clause 24.)

1.4.392 switch: A layer 2 interconnection device that conforms to the ISO/IEC 10038 [ANSI/IEEE 802.1D-1998]. *Syn:* **bridge.**

1.4.393 symbol: Within IEEE 802.3, the smallest unit of data transmission on the medium. Symbols are unique to the coding system employed. For example, 100BASE-T4 uses ternary symbols; 10BASE-T uses

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Manchester symbols; 100BASE-X uses binary symbols or code-bits; 100BASE-T2 and 1000BASE-T uses quinary symbols. For 1000BASE-X PMDs operating at 1.25 GBd, a symbol corresponds to a code-bit after the 8B/10B encoding operation i.e. has the duration of 0.8 ns. For 10GBASE-R PMDs operating at 10.3125 GBd, a symbol corresponds to a code-bit after the 64B/66B encoding operation i.e. has the duration of approximately 0.097 ns.

1.4.394 symbol period: In 1000BASE-T, the time interval for transmission of one code-group. This is equivalent to 8 ns. (See IEEE Std 802.3, Clause 40.)

1.4.395 symbol rate (SR): Within IEEE 802.3, the total number of symbols per second transferred to or from the Medium Dependent Interface (MDI) on a single wire pair. For 100BASE-T4, the symbol rate is 25 MBd; for 100BASE-X, the symbol rate is 125 MBd; for 100BASE-T2, the symbol rate is 25 MBd; for 1000BASE-T, the symbol rate is 125 MBd.

1.4.396 symbol time (ST): The duration of one symbol as transferred to and from the Medium Dependent Interface (MDI) via a single wire pair. The symbol time is the reciprocal of the symbol rate.

1.4.397 Synchronous Payload Envelope (SPE): A 125 μs frame structure composed of STS Path Overhead and bandwidth for payload (payload capacity). The equivalent SDH term is Virtual Container (VC). This definition is derived from ATIS-0600416.1999(R2010) and ATIS-0900105.2008, which take precedence.

1.4.398 ternary symbol: In 100BASE-T4, a ternary data element. A ternary symbol can have one of three values: –1, 0, or +1. (See IEEE Std 802.3, Clause 23.)

1.4.399 Time Synchronization Service Interface (TSSI): Time Synchronization Service Interface (TSSI) between the generic Reconciliation Sublayer and a TimeSync client. (See IEEE Std 802.3, Clause 90).

1.4.400 time_quantum: The unit of measurement for time related parameters specified in Multipoint MAC Control.

NOTE—See Clause 64 and Clause 77. The value of time_quantum is defined in 64.2.2.1.

1.4.401 Tomlinson-Harashima precoder (THP): A precoding technique for intersymbol interference mitigation. (See IEEE Std 802.3, Clause 55.)

1.4.402 transition density: The number of times the stream of bits within an 8B/10B code-group changes its value. (See IEEE Std 802.3, Clause 36.)

1.4.403 translation: In a single-cable 10BROAD36 system, the process by which incoming transmissions at one frequency are converted into another frequency for outgoing transmission. The translation takes place at the headend. (See IEEE Std 802.3, Clause 11.)

1.4.404 transmitter and dispersion penalty: A measure of the performance of a transmitter relative to an ideal transmitter. (See IEEE Std 802.3, 52.9.10 and 58.7.9.)

1.4.405 truncation loss: In a modulated data waveform, the power difference before and after implementation filtering necessary to constrain its spectrum to a specified frequency band.

1.4.406 trunk cable: The main (often large diameter) cable of a coaxial cable system. (*See:* **drop cable**.)

1.4.407 twinaxial cable: A cable similar to coaxial cable in construction but containing two insulated inner conductors rather than one.

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1.4.408 twinaxial cable assembly: An assembly containing multiple twinaxial cables, terminated in a connector at each end, for use as a link segment between MDIs, such as that used in 10GBASE-CX4.

1.4.409 twisted pair: A cable element that consists of two insulated conductors twisted together in a regular fashion to form a balanced transmission line. (From ISO/IEC 11801:1995.)

1.4.410 twisted-pair cable: A bundle of multiple twisted pairs within a single protective sheath. The bundle may be unshielded or enclosed by an overall shield.

1.4.411 twisted-pair cable binder group: A group of twisted pairs within a cable that are bound together. Large telephone cables have multiple binder groups with high interbinder group near-end crosstalk loss.

1.4.412 twisted-pair link: A twisted-pair cable plus connecting hardware. (From ISO/IEC 11801:1995.) (See also IEEE Std 802.3, 14.1.2.)

1.4.413 twisted-pair link segment: In 100BASE-T, a twisted-pair link for connecting two Physical Layers (PHYs). (See also IEEE Std 802.3, 14.1.2.)

1.4.414 Twisted Pair Medium Dependent Interface (TP MDI): The mechanical and electrical interface between the transmission medium and the Medium Attachment Unit (MAU) or PHY, e.g., 10BASE-T, 100BASE-TX, or 1000BASE-T.

1.4.415 Type 1 PD: A PD that does not provide a Class 4 signature during Physical Layer classification (see IEEE 802.3, Clause 33).

1.4.416 Type 1 PSE: A PSE that supports only a Type 1 PD (see IEEE 802.3, Clause 33).

1.4.417 Type 2 PD: A PD that provides a Class 4 signature during Physical Layer classification, understands 2-Event classification, and is capable of Data Link Layer classification (see IEEE 802.3, Clause 33).

1.4.418 Type 2 PSE: A PSE that supports both a Type 1 and a Type 2 PD (see IEEE 802.3, Clause 33).

1.4.419 type, length, value (TLV): A short, variable length encoding of an information element consisting of sequential type, length, and value fields where the type field identifies the type of information, the length field indicates the length of the information field in octets, and the value field contains the information, itself (See IEEE Std 802.3, 57.5.2 and 57.5.3).

1.4.420 uncorrelated jitter: Jitter that is not associated with the sequence being transmitted. (See IEEE Std 802.3, 68.6.8.)

1.4.421 Unformatted Page (UP): A Next Page encoding that contains an unformatted 12-bit message field. Use of this field is defined through message codes and information contained in the UP. (See IEEE Std 802.3, 28.2.1.2.)

1.4.422 unit interval (UI): A period of time, usually allocated for the transmission of one symbol on one channel; the inverse of the modulation rate. Generally not the same as bit time (BT).

1.4.423 unshielded twisted-pair cable (UTP): An electrically conducting cable, comprising one or more pairs, none of which are shielded.

1.4.424 upstream: In an access network, transmission away from the subscriber end of the link. Applicable to networks where there is a clear indication in each deployment as to which end of a link is closer to a subscriber.

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1.4.425 V_{PD}: The voltage at the PD PI measured between any conductor of one power pair and any conductor of the other power pair (see IEEE 802.3, Clause 33).

1.4.426 V_{PSE}: The voltage at the PSE PI measured between any conductor of one power pair and any conductor of the other power pair (see IEEE 802.3, Clause 33).

1.4.427 WAN Interface Sublayer (WIS): Within 10GBASE-W, a sublayer used to couple the Physical Coding Sublayer (PCS) and the Physical Medium Attachment (PMA) sublayer. The WIS contains functions to perform SONET STS-192c/SDH VC-4-64c framing and scrambling. (See IEEE Std 802.3, Clause 50.)

1.4.428 weight of 6T code group: The algebraic sum of the logical ternary symbol values listed in the 100BASE-T4 8B6T code table. (See IEEE Std 802.3, Clause 23.)

1.4.429 worst-case modal bandwidth (WCMB): The lowest value of the modal bandwidth found when measured using either an overfilled launch (OFL) or a radial overfilled launch (ROFL).

1.4.430 zero dispersion wavelength: That wavelength where the chromatic dispersion of a fiber is zero.

1.5 Abbreviations

This standard contains the following abbreviations:

10P	label to indicate “pertains to 10PASS-TS port-type”
10P/2B	label to indicate “pertains to 10PASS-TS and 2BASE-TL port-types”
2B	label to indicate “pertains to 2BASE-TL port-type”
2-PAM	two level pulse amplitude modulation
8802-3	ISO/IEC 8802-3 (IEEE Std 802.3)
8802-5	ISO/IEC 8802-5 (IEEE Std 802.5)
AIS	Alarm Indication Signal
AN	Auto-Negotiation
ANSI	American National Standards Institute
ASIC	application-specific integrated circuit
ASN.1	Abstract Syntax Notation One as defined in ISO/IEC 8824:1990
AUI	attachment unit interface
BER	bit error ratio
BERT	bit error ratio tester
BIP	Bit Interleaved Parity
BP	backplane
BPSK	binary phase shift keying
BR	bit rate
BT	bit time
CAT3	Category 3 balanced cable
CAT4	Category 4 balanced cable
CAT5	Category 5 balanced cable
CAT6	Category 6 balanced cabling
CAUI-n	100 Gb/s Attachment Unit Interface over n lanes
CD0	clocked data zero
CD1	clocked data one
CDR	clock and data recovery
CGMII	100 Gb/s Media Independent Interface
CID	Company ID (in Clause 50, Consecutive Identical Digit)
CJPAT	continuous jitter test pattern
CMIP	common management information protocol as defined in ISO/IEC 9596-1:1991

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CMIS	common management information service as defined in ISO/IEC 9595:1991
CMOS	complementary metal oxide semiconductor
CO	central office
COM	Channel Operating Margin
CPE	customer premises equipment
CPPI	100 Gb/s Parallel Physical Interface
CPR	coupled power ratio
CRC	cyclic redundancy check
CRPAT	continuous random test pattern
CRU	clock recovery unit
CRV	code rule violation
CS0	control signal zero
CS1	control signal one
CVH	clocked violation high
CVL	clocked violation low
CW	continuous wave
DA	destination address
DCD	duty cycle distortion
DDJ	data dependent jitter
DFB	distributed feedback
DFE	decision feedback equalizer
DIC	deficit idle count
DGD	differential group delay
DJ	deterministic jitter
DLL	Data Link Layer
DME	Differential Manchester encoding
DMT	discrete multi-tone
DSL	digital subscriber line
DSQ	double square
DTE	data terminal equipment
EEE	Energy-Efficient Ethernet
EFM	Ethernet in the first mile
EIA	Electronic Industries Association
ELFEXT	equal-level far-end crosstalk
EMI	electromagnetic interference
EOB	end of burst delimiter
EPD	End_of_Packet delimiter
EPON	Ethernet Passive Optical Network
ERDI	Enhanced Remote Defect Indication
ESD	end of stream delimiter
FC-PH	Fibre Channel—Physical and Signaling Interface
FCS	frame check sequence
FDDI	fibre distributed data interface
FEC	forward error correction
FEXT	far-end crosstalk
FIFO	first in, first out
FIR	finite impulse response
FLP	fast link pulse
FOIRL	fiber optic inter-repeater link
FOMAU	fiber optic medium attachment unit
FOMDI	fiber optic medium dependent interface
FOPMA	fiber optic physical medium attachment
FOTP	fiber optic test procedure
FSW	frame synchronization word

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GMII	Gigabit Media Independent Interface
gRS	generic Reconciliation Sublayer
HCB	Host Compliance Board
HH	header hub
IB	indicator bits
IEC	International Electrotechnical Commission
IH	intermediate hub
IPG	interpacket gap
IRL	inter-repeater link
ISI penalty	intersymbol interference penalty
ISO	International Organization for Standardization
LACP	Link Aggregation Control Protocol
LACPDU	Link Aggregation Control Protocol Data Unit
LAG ID	Link Aggregation Group Identifier
LAN	local area network
LCD	Loss Of Code-Group Delineation
LD	local device
LDPC	low density parity check
LLC	logical link control
LLDP	Link Layer Discovery Protocol (see IEEE Std 802.1AB-2009)
LLDPDU	LLDP data unit (see IEEE Std 802.1AB-2009)
LLID	logical link identifier
LOF	Loss Of Framing
LOP	Loss Of Pointer
LOS	Loss Of Signal
LP	link partner
LPI	Low Power Idle
LSB	least significant bit
LSDV	link segment delay value
LT	line termination
LVDS	Low-Voltage Differential Signals
MAC	medium access control
MAN	Metropolitan Area Network
MAU	medium attachment unit
MC	message code
MCB	Module Compliance Board
MDELFEXT	multiple-disturber equal-level far-end crosstalk
MDFEXT	multiple-disturber far-end crosstalk
MDI	medium dependent interface
MDIO	management data input/output
MDNEXT	multiple-disturber near-end crosstalk
MIB	management information base
MII	media independent interface
MMD	MDIO Manageable Device
MMF	multimode fiber
MP	message page
MPCP	multipoint control protocol
MPS	Maintain Power Signature
MSB	most significant bit
Mux	multiplexer
NEXT	Near-end Crosstalk
NID	network interface device
NLP	normal link pulse
NP	Next Page

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NPA	Next Page algorithm
NRZI	non return to zero and invert on ones
NT	network termination
NTT	Need To Transmit
OAM	operations, administration, and maintenance
OAMPDU	operations, administration, and maintenance protocol data unit
ODN	optical distribution network
OFL	overfilled launch
OFSTP	optical fiber system test procedure
OH	overhead
OIF	Optical Internetworking Forum
OLT	optical line terminal
OMA	Optical Modulation Amplitude
ONU	optical network unit
OPU3	Optical channel Payload Unit 3
ORLT	optical return loss tolerance
OTN	Optical Transport Network
OUI	Organizationally Unique Identifier
P2MP	point to multipoint
P2P	point to point
P2PE	point-to-point emulation
PAF	PME aggregation function
PAM	pulse amplitude modulation
PCB	printed circuit board
PCS	physical coding sublayer
PCSL	PCS lane
PD	Powered Device
PDU	Protocol Data Unit
PDV	path delay value
PFC	Priority-based Flow Control
PHY	Physical Layer entity
PI	Power Interface
PICS	protocol implementation conformance statement
PIPO	parallel in parallel out
PISO	parallel in serial out
pk-pk	peak-to-peak
PLL	phase-locked loop
PLM	Path Label Mismatch
PLS	physical signaling sublayer
PMA	physical medium attachment
PMD	physical medium dependent
PME	physical medium entity
PMI	physical medium independent
PMS-TC	physical media specific - transmission convergence
ppd	peak-to-peak differential
PRBS	pseudo random bit sequence
PSD	power spectral density
PSE	Power Sourcing Equipment
PVV	path variability value
RD	running disparity
REI	Remote Error Indication
RFI	radio frequency interference
RIN	relative intensity noise
RJ	random jitter

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ROFL	radial overfilled launch
RS	reconciliation sublayer
RS-FEC	Reed-Solomon Forward Error Correction
SA	source address
SCB	single copy broadcast
SDH	Synchronous Digital Hierarchy
SDV	segment delay value
SEF	Severely Errored Frame
SELV	Safety Extra Low Voltage
SERDES	serializer and deserializer circuit
SES	Severely Errored Second
SFD	start-of-frame delimiter
SFDR	spurious free dynamic range
SHDSL	single-pair high-speed digital subscriber line
SIPO	serial in parallel out
SLD	Start of LLID Delimiter
SMF	single-mode fiber
SMSR	side mode suppression ratio
SNR	signal-to-noise ratio
SONET	Synchronous Optical Network
SPD	Start_of_Packet delimiter
SPE	Synchronous Payload Envelope
SR	symbol rate
SSD	start-of-stream delimiter
ST	symbol time
STA	station management entity
STP	shielded twisted pair (copper)
STS	Synchronous Transport Signal
SVV	segment variability value
TBI	Ten-Bit Interface
TC	transmission convergence
TCM	trellis coded modulation
TDMA	time division multiple access
TDP	transmitter and dispersion penalty
TDR	time domain reflectometer
THP	Tomlinson-Harashima precoder
TIA	Telecommunications Industry Association
TLV	Type/Length/Value
TP-PMD	Twisted Pair, Physical Medium Dependent (ANSI X3.263-1995)
TPS-TC	transport protocol specific transmission convergence sublayer
TQ	time_quantum
TSS	Test Signal Structure
TSSI	Time Synchronization Service Interface
TWDP	transmitter waveform and dispersion penalty
UCT	unconditional transition
UI	unit interval
UJ	uncorrelated jitter
UP	unformatted page
UPBO	upstream power backoff
UTP	unshielded twisted pair
VC	Virtual Container
VDSL	very high speed digital subscriber line
VECP	vertical eye closure penalty
VLAN	Virtual Bridged Local Area Network (see IEEE Std 802.1Q)

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VTU	VDSL transceiver unit
VTU-O	VTU at the central office end
VTU-R	VTU at the remote end
WAN	Wide Area Network
WCMB	worst-case modal bandwidth
WDM	wavelength division multiplexing
WIS	WAN Interface Sublayer
WWDM	wide wavelength division multiplexing
XAUI	10 Gigabit Attachment Unit Interface
xDSL	generic term covering the family of all DSL technologies
XGMII	10 Gigabit Media Independent Interface
XGXS	XGMII Extender Sublayer
XLAUI	40 Gb/s Attachment Unit Interface
XLGMII	40 Gb/s Media Independent Interface
XLPPI	40 Gb/s Parallel Physical Interface
xMII	generic Media Independent Interface
XNP	Extended Next Page
XS	Extender Sublayer
XSBI	10 Gigabit Sixteen-Bit Interface

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2. Media Access Control (MAC) service specification

2.1 Scope and field of application

This clause specifies the services provided by the Media Access Control (MAC) sublayer to the client of the MAC (see Figure 1–1). MAC clients may include the Logical Link Control (LLC) sublayer, Bridge Relay Entity, or other users of ISO/IEC LAN International Standard MAC services (see Figure 2–1). The services are described in an abstract way and do not imply any particular implementation or any exposed interface. Other clauses in this standard may add optional protocol sublayers directly above the MAC that preserve the service interface to the MAC client. Any augmentations to the MAC client interface are specified in the relevant sublayer clause (e.g., Clause 31).

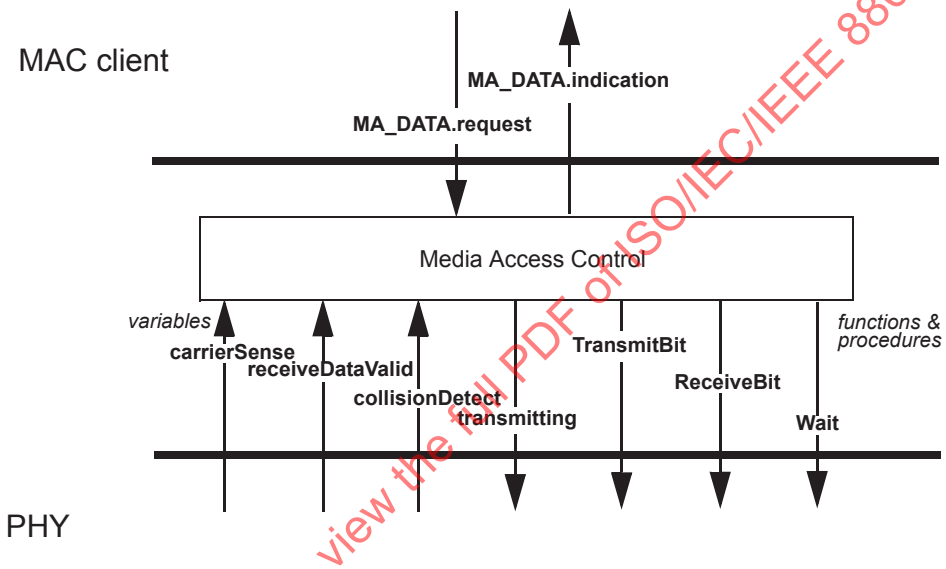

Figure 2–1—Service specification primitive relationships

2.2 Overview of the service

2.2.1 General description of services provided by the layer

The services provided by the MAC sublayer allow the local MAC client entity to exchange LLC data units with peer LLC sublayer entities. Optional support may be provided for resetting the MAC sublayer entity to a known state.

2.2.2 Model used for the service specification

The model used in this service specification is identical to that used in 1.2.2.

2.2.3 Overview of interactions

MA_DATA.request
MA_DATA.indication

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2.2.4 Basic services

The MA_DATA.request and MA_DATA.indication service primitives described in this subclause are mandatory.

2.3 Detailed service specification

2.3.1 MA_DATA.request

2.3.1.1 Function

This primitive defines the transfer of data from a MAC client entity to a single peer entity or multiple peer entities in the case of group addresses.

2.3.1.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
MA_DATA.request     (
                    destination_address,
                    source_address,
                    mac_service_data_unit,
                    frame_check_sequence
                    )
```

The destination_address parameter may specify either an individual or a group MAC entity address. It must contain sufficient information to create the DA field that is prepended to the frame by the local MAC sublayer entity and any physical information. The source_address parameter, if present, must specify an individual MAC address. If the source_address parameter is omitted, the local MAC sublayer entity will insert a value associated with that entity. The mac_service_data_unit parameter specifies the MAC service data unit to be transmitted by the MAC sublayer entity. There is sufficient information associated with the mac_service_data_unit for the MAC sublayer entity to determine the length of the data unit. The frame_check_sequence parameter, if present, must specify the frame check sequence field for the frame (see 3.2.9). If the frame_check_sequence parameter is omitted, the local MAC sublayer entity will compute this field and append it to the end of the frame.

2.3.1.3 When generated

This primitive is generated by the MAC client entity whenever data shall be transferred to a peer entity or entities. This can be in response to a request from higher protocol layers or from data generated internally to the MAC client, such as required by Type 2 LLC service.

2.3.1.4 Effect of receipt

The receipt of this primitive will cause the MAC entity to insert all MAC specific fields, including DA, SA, and any fields that are unique to the particular media access method, and pass the properly formed frame to the lower protocol layers for transfer to the peer MAC sublayer entity or entities.

2.3.1.5 Additional comments

If this primitive contains the frame_check_sequence parameter, the MAC client entity must take into account this parameter's special bit-transmission order requirements, as specified in 3.3.

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The mapping between the MA_UNITDATA.request primitive specified in ISO/IEC 15802-1 (for end stations) and the MA_DATA.request primitive specified here is as follows:

a) The user_priority parameter specified for MA_UNITDATA.request is not relevant for IEEE 802.3 operation and is ignored by MA_DATA.request.
b) The access_priority parameter specified for MA_UNITDATA.request is not relevant for IEEE 802.3 operation and is ignored by MA_DATA.request.
c) The frame_check_sequence parameter is not present for MA_UNITDATA.request.

The mapping between the M_UNITDATA.request primitive specified in IEEE Std 802.1D (for MAC Bridges) and the MA_DATA.request primitive specified here is as follows:

d) The frame_type parameter specified for M_UNITDATA.request is not relevant for IEEE 802.3 operation and is ignored by MA_DATA.request.
e) The mac_action parameter specified for M_UNITDATA.request is not relevant for IEEE 802.3 operation and is ignored by MA_DATA.request.
f) The user_priority parameter specified for M_UNITDATA.request is not relevant for IEEE 802.3 operation and is ignored by MA_DATA.request.
g) The access_priority parameter specified for M_UNITDATA.request is not relevant for IEEE 802.3 operation and is ignored by MA_DATA.request.

2.3.2 MA_DATA.indication

2.3.2.1 Function

This primitive defines the transfer of data from the MAC sublayer entity (through the optional MAC Control sublayer, if implemented) to the MAC client entity or entities in the case of group addresses.

2.3.2.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
MA_DATA.indication      (
                        destination_address,
                        source_address,
                        mac_service_data_unit,
                        frame_check_sequence,
                        reception_status
                        )
```

The destination_address parameter may be either an individual or a group address as specified by the DA field of the incoming frame. The source_address parameter is an individual address as specified by the SA field of the incoming frame. The mac_service_data_unit parameter specifies the MAC service data unit as received by the local MAC entity. The frame_check_sequence parameter is the cyclic redundancy check value (see 3.2.9) as specified by the FCS field of the incoming frame. This parameter may be either omitted or (optionally) passed by the MAC sublayer entity to the MAC client. The reception_status parameter is used to pass status information to the MAC client entity.

2.3.2.3 When generated

The MA_DATA.indication is passed from the MAC sublayer entity (through the optional MAC Control sublayer, if implemented) to the MAC client entity or entities to indicate the arrival of a frame to the local MAC sublayer entity that is destined for the MAC client. Such frames are reported only if they are validly formed, received without error, and their destination address designates the local MAC entity. Frames destined

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for the optional MAC Control sublayer are not passed to the MAC client if the MAC Control sublayer is implemented.

2.3.2.4 Effect of receipt

The effect of receipt of this primitive by the MAC client is unspecified.

2.3.2.5 Additional comments

If the local MAC sublayer entity is designated by the destination_address parameter of an MA_DATA.request, the indication primitive will also be invoked by the MAC entity to the MAC client entity. This characteristic of the MAC sublayer may be due to unique functionality within the MAC sublayer or characteristics of the lower layers (for example, all frames transmitted to the broadcast address will invoke MA_DATA.indication at all stations in the network including the station that generated the request).

If this primitive contains the frame_check_sequence parameter, the MAC client entity must take into account this parameter's special bit-transmission order requirements, as specified in 3.3.

The mapping between the MA_DATA.indication primitive specified here and the MA_UNITDATA.indication primitive specified in ISO/IEC 15802-1 (for end stations) is as follows:

a) The user_priority parameter specified for MA_UNITDATA.indication is not relevant for IEEE 802.3 operation.
b) The frame_check_sequence parameter is not present for MA_UNITDATA.indication.
c) The reception_status parameter is not mapped to any parameter and is ignored by MA_UNITDATA.indication.

The mapping between the MA_DATA.indication primitive and the M_UNITDATA.indication primitive specified in IEEE Std 802.1D (for MAC Bridges) is as follows:

a) The frame_type parameter specified for M_UNITDATA.indication is not relevant for IEEE 802.3 operation and is always assigned the value of user_data_frame.
b) The mac_action parameter specified for M_UNITDATA.indication is not relevant for IEEE 802.3 operation and is always assigned the value of request_with_no_response.
c) The user_priority parameter specified for M_UNITDATA.indication is not relevant for IEEE 802.3 operation.
d) The reception_status parameter is not mapped to any parameter and is ignored by M_UNITDATA.indication.

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3. Media Access Control (MAC) frame and packet specifications

3.1 Overview

This clause defines the mapping between MAC service interface primitives and Ethernet packets, including the syntax and semantics of the various fields of MAC frames and the fields used to form those MAC frames into packets.

During Ethernet's history, capabilities have been added to allow data link layer (layer 2) protocol encapsulations within the MAC Client Data field. As a result, there are now more than one type of MAC frame.

The frame format specified in this clause includes the following three types of MAC frames:

a) A basic frame
b) A Q-tagged frame
c) An envelope frame

All three frame types use the same Ethernet frame format.

3.1.1 Packet format

Figure 3–1 shows the fields of a packet: the Preamble, Start Frame Delimiter (SFD), the addresses of the MAC frame's destination and source, a length or type field to indicate the length or protocol type of the following field that contains the MAC client data, a field that contains padding if required, and the Frame Check Sequence (FCS) field containing a cyclic redundancy check value to detect errors in a received MAC frame. An Extension field is added, if required (for 1000 Mb/s half duplex operation only). Of these fields, all are of fixed size except for the MAC Client Data, Pad and Extension fields, which may contain an integer number of octets between the minimum and maximum values that are determined by the specific implementation of the MAC. See 4.4 for particular MAC parameters.

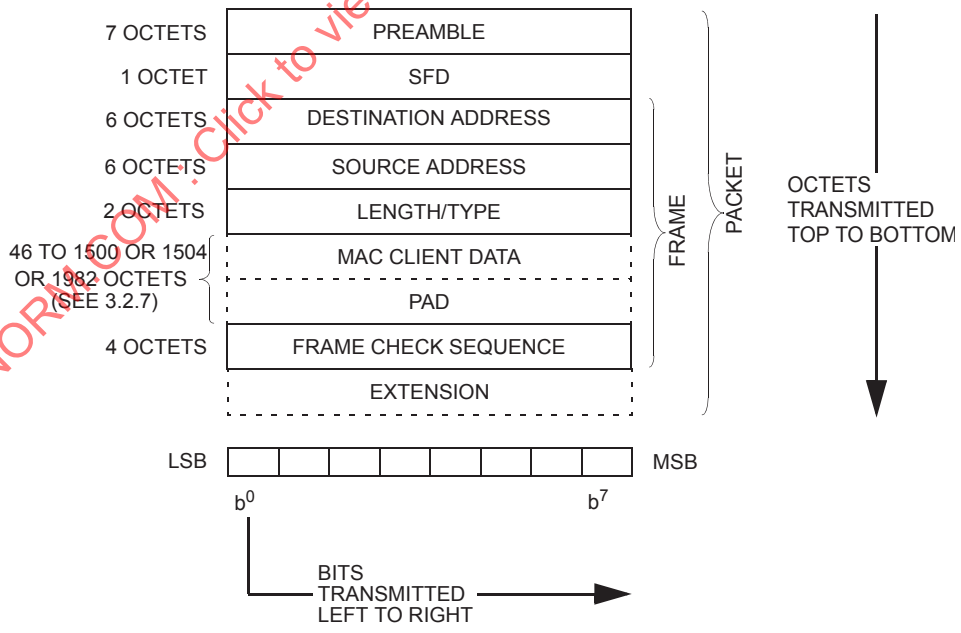

Figure 3–1—Packet format

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The minimum and maximum MAC frame size limits in 4.4 refer to that portion of the packet from the Destination Address field through the Frame Check Sequence field, inclusive (i.e., the MAC frame).

Relative to Figure 3–1, the octets of a packet are transmitted from top to bottom, and the bits of each octet are transmitted from left to right.

3.1.2 Service interface mappings

Figure 3–2 shows the mapping of service interface parameters to the fields of a MAC frame within a packet. The MAC client may or may not supply Pad and FCS. For this reason the mappings for Pad and FCS are shown with dashed lines.

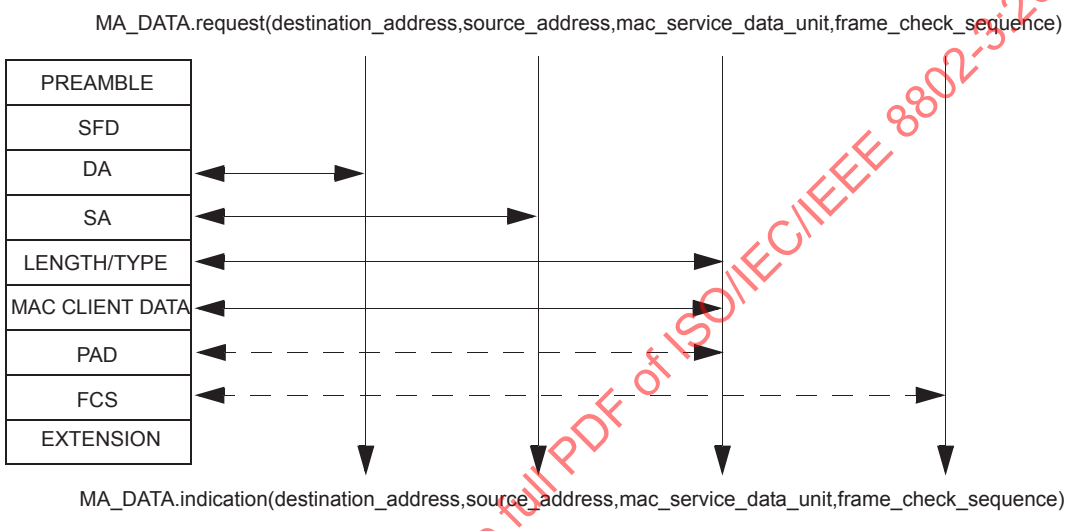

Figure 3–2—Service primitive mappings

3.2 Elements of the MAC frame and packet

A MAC frame is encapsulated in a packet by the MAC. This subclause describes in detail the fields of the MAC frame and the additional fields that the MAC creates to encapsulate the MAC frame. These fields are described in order of transmission.

3.2.1 Preamble field

The Preamble field is a 7-octet field that is used to allow the PLS circuitry to reach its steady-state synchronization with the received packet's timing (see 4.2.5).

3.2.2 Start Frame Delimiter (SFD) field

The SFD field is the sequence 10101011. It immediately follows the preamble pattern. A MAC frame starts immediately after the SFD.

3.2.3 Address fields

Each MAC frame shall contain two address fields: the Destination Address field and the Source Address field, in that order. The Destination Address field shall specify the destination addressee(s) for which the MAC frame is intended. The Source Address field shall identify the station from which the MAC frame was initiated. The representation of each address field shall be as follows (see Figure 3–3):

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a) Each address field shall be 48 bits in length.
b) The first bit (LSB) shall be used in the Destination Address field as an address type designation bit to identify the Destination Address either as an individual or as a group address. If this bit is 0, it shall indicate that the address field contains an individual address. If this bit is 1, it shall indicate that the address field contains a group address that identifies none, one or more, or all of the stations connected to the LAN. In the Source Address field, the first bit is reserved and set to 0.
c) The second bit shall be used to distinguish between locally or globally administered addresses. For globally administered (or U, universal) addresses, the bit is set to 0. If an address is to be assigned locally, this bit shall be set to 1. Note that for the broadcast address, this bit is also a 1.
d) Each octet of each address field shall be transmitted least significant bit first.

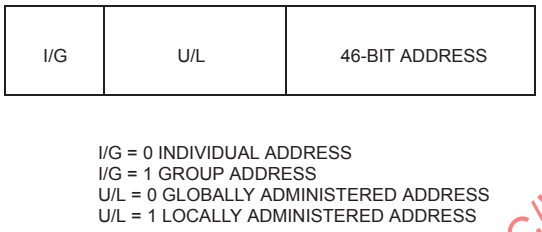

Figure 3–3—Address field format

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3.2.3.1 Address designation

A MAC sublayer address is one of two types:

a) *Individual Address*. The address associated with a particular station on the network.
b) *Group Address*. A multidestination address, associated with one or more stations on a given network. There are two kinds of multicast addresses:
   1) *Multicast-Group Address*. An address associated by higher-level convention with a group of logically related stations.
   2) *Broadcast Address*. A distinguished, predefined multicast address that always denotes the set of all stations on a given LAN.

All 1's in the Destination Address field shall be predefined to be the Broadcast Address. This group shall be predefined for each communication medium to consist of all stations actively connected to that medium; it shall be used to broadcast to all the active stations on that medium. All stations shall be able to recognize the Broadcast Address. It is not necessary that a station be capable of generating the Broadcast Address.

The address space shall also be partitioned into locally administered and globally administered addresses. The nature of a body and the procedures by which it administers these global (U) addresses is beyond the scope of this standard.[24]

3.2.4 Destination Address field

The Destination Address field specifies the station(s) for which the MAC frame is intended. It may be an individual or multicast (including broadcast) address.

[24]For information on how to use MAC addresses, see IEEE Std 802, Overview and Architecture. To apply for an Organizationally Unique Identifier for building a MAC address, contact the Registration Authority, IEEE Standards Department, P.O. Box 1331, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA; +1 732 562 3813; fax +1 732 562 1571. URL: http://standards.ieee.org/develop/regauth/

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3.2.5 Source Address field

The Source Address field specifies the station sending the MAC frame. The Source Address field is not interpreted by the MAC sublayer.

3.2.6 Length/Type field

This two-octet field takes one of two meanings, depending on its numeric value. For numerical evaluation, the first octet is the most significant octet of this field.

a) If the value of this field is less than or equal to 1500 decimal (05DC hexadecimal), then the Length/Type field indicates the number of MAC client data octets contained in the subsequent MAC Client Data field of the basic frame (Length interpretation).
b) If the value of this field is greater than or equal to 1536 decimal (0600 hexadecimal), then the Length/Type field indicates the Ethertype of the MAC client protocol (Type interpretation).[25]
The Length and Type interpretations of this field are mutually exclusive.

When used as a Type field, it is the responsibility of the MAC client to ensure that the MAC client operates properly when the MAC sublayer pads the supplied MAC Client data, as discussed in 3.2.7.

Regardless of the interpretation of the Length/Type field, if the length of the MAC Client Data field is less than the minimum required for proper operation of the protocol, a Pad field (a sequence of octets) will be added after the MAC Client Data field but prior to the FCS field, specified below. The procedure that determines the size of the Pad field is specified in 4.2.8. The Length/Type field is transmitted and received with the high order octet first.

NOTE—Clause 2 of IEEE Std 802 defines a set of Ethertype values and associated mechanisms for use in prototype and vendor-specific protocol development.

3.2.7 MAC Client Data field

The MAC Client Data field contains a sequence of octets. Full data transparency is provided in the sense that any arbitrary sequence of octet values may appear in the MAC Client Data field up to a maximum field length determined by the particular implementation.

Ethernet implementations shall support at least one of three maximum MAC Client Data field sizes defined as follows:

a) 1500 decimal—basic frames (see 1.4.109)
b) 1504 decimal—Q-tagged frames (see 1.4.347)
c) 1982 decimal—envelope frames (see 1.4.195)

If layer management is implemented, frames with a MAC Client Data field larger than the supported maximum MAC Client Data field size are counted. It is recommended that new implementations support the transmission and reception of envelope frames, item c) above.

NOTE 1—The envelope frame is intended to allow inclusion of additional prefixes and suffixes required by higher layer encapsulation protocols (see 1.4.190) such as those defined by the IEEE 802.1 working group (such as Provider Bridges and MAC Security), ITU-T or IETF (such as MPLS). The original MAC Client Data field maximum remains 1500 octets while the encapsulation protocols may add up to an additional 482 octets. Use of these extra octets for other purposes is not recommended, and may result in MAC frames being dropped or corrupted as they may violate maximum MAC frame size restrictions if encapsulation protocols are required to operate on them.

[25]Ethertype assignments are administered by the Registration Authority, IEEE Standards Department, P.O. Box 1331, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA; +1 732 562 3813; fax +1 732 562 1571. URL: http://standards.ieee.org/develop/regauth/.

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NOTE 2—All IEEE 802.3 MAC frames share a common format. The processing of the three types of MAC frames is not differentiated within the IEEE 802.3 MAC, except for management. However, they may be distinguished within the MAC client.

NOTE 3—All Q-tagged frames are envelope frames, but not all envelope frames are Q-tagged frames.

See 4.4 for a discussion of MAC parameters; see 4.2.3.3 for a discussion of the minimum frame size and minFrameSize.

3.2.8 Pad field

A minimum MAC frame size is required for correct CSMA/CD protocol operation (see 4.2.3.3 and 4.4). If necessary, a Pad field (in units of octets) is appended after the MAC Client Data field prior to calculating and appending the FCS field. The size of the Pad, if any, is determined by the size of the MAC Client Data field supplied by the MAC client and the minimum MAC frame size and address size MAC parameters (see 4.4).

The length of the Pad field required for MAC Client Data that is clientDatasize/8 octets long is max [0, minFrameSize – (clientDatasize + 2 × addressSize + 48)] bits.

3.2.9 Frame Check Sequence (FCS) field

A cyclic redundancy check (CRC) is used by the transmit and receive algorithms to generate a CRC value for the FCS field. The FCS field contains a 4-octet (32-bit) CRC value. This value is computed as a function of the contents of the protected fields of the MAC frame: the Destination Address, Source Address, Length/Type field, MAC Client Data, and Pad (that is, all fields except FCS). The encoding is defined by the following generating polynomial.

$$G(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$$

Mathematically, the CRC value corresponding to a given MAC frame is defined by the following procedure:

a) The first 32 bits of the frame are complemented.
b) The n bits of the protected fields are then considered to be the coefficients of a polynomial $M(x)$ of degree $n – 1$. (The first bit of the Destination Address field corresponds to the $x^{(n-1)}$ term and the last bit of the MAC Client Data field (or Pad field if present) corresponds to the x^0 term.)
c) $M(x)$ is multiplied by x^{32} and divided by $G(x)$, producing a remainder $R(x)$ of degree ≤ 31.
d) The coefficients of $R(x)$ are considered to be a 32-bit sequence.
e) The bit sequence is complemented and the result is the CRC.

The 32 bits of the CRC value are placed in the FCS field so that the x^{31} term is the left-most bit of the first octet, and the x^0 term is the right most bit of the last octet. (The bits of the CRC are thus transmitted in the order $x^{31}, x^{30}, \ldots, x^1, x^0$.) See Hammond, et al. [B36].

3.2.10 Extension field

The Extension field follows the FCS field, and is made up of a sequence of extension bits, which are readily distinguished from data bits. The length of the field is in the range of zero to (slotTime–minFrameSize) bits, inclusive. The contents of the Extension field are not included in the FCS computation.

The Extension field may have a length of greater than zero under the conditions that are described in 4.2.3.4. The length of the Extension field will be zero under all other conditions. Implementations defined in 4.4.2 may ignore this field altogether if the number of bit times in the slotTime parameter is equal to the number of bits in the minFrameSize parameter.

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3.3 Order of bit transmission

Each octet of the MAC frame, with the exception of the FCS, is transmitted least significant bit first.

3.4 Invalid MAC frame

An invalid MAC frame shall be defined as one that meets at least one of the following conditions:

a) The frame length is inconsistent with a length value specified in the length/type field. If the length/type field contains a type value as defined by 3.2.6, then the frame length is assumed to be consistent with this field and should not be considered an invalid frame on this basis.
b) It is not an integral number of octets in length.
c) The bits of the incoming frame (exclusive of the FCS field itself) do not generate a CRC value identical to the one received.

The contents of invalid MAC frames shall not be passed to the LLC or MAC Control sublayers.[26] The occurrence of invalid MAC frames may be communicated to network management.

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[26]Invalid MAC frames may be ignored, discarded, or used in a private manner by MAC clients other than LLC or MAC control. The use of such frames is beyond the scope of this standard.

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4. Media Access Control

4.1 Functional model of the MAC method

4.1.1 Overview

The architectural model described in Clause 1 is used in this clause to provide a functional description of the LAN CSMA/CD MAC sublayer.

The MAC sublayer defines a medium-independent facility, built on the medium-dependent physical facility provided by the Physical Layer, and under the access-layer-independent LAN LLC sublayer (or other MAC client). It is applicable to a general class of local area broadcast media suitable for use with the media access discipline known as Carrier Sense Multiple Access with Collision Detection (CSMA/CD).

The LLC sublayer and the MAC sublayer together are intended to have the same function as that described in the OSI model for the Data Link Layer alone. In a broadcast network, the notion of a data link between two network entities does not correspond directly to a distinct physical connection. Nevertheless, the partitioning of functions presented in this standard requires two main functions generally associated with a data link control procedure to be performed in the MAC sublayer. They are as follows:

a) Data encapsulation (transmit and receive)
   1) Framing (frame boundary delimitation, frame synchronization)
   2) Addressing (handling of source and destination addresses)
   3) Error detection (detection of physical medium transmission errors)
b) Media Access Management
   1) Medium allocation (collision avoidance)
   2) Contention resolution (collision handling)

An optional MAC control sublayer, architecturally positioned between LLC (or other MAC client) and the MAC, is specified in Clause 31. This MAC Control sublayer is transparent to both the underlying MAC and its client (typically LLC). The MAC sublayer operates independently of its client; i.e., it is unaware whether the client is LLC or the MAC Control sublayer. This allows the MAC to be specified and implemented in one manner, whether or not the MAC Control sublayer is implemented. References to LLC as the MAC client in text and figures apply equally to the MAC Control sublayer, if implemented.

This standard provides for two modes of operation of the MAC sublayer:

a) In *half duplex* mode, stations contend for the use of the physical medium, using the CSMA/CD algorithms specified. Bidirectional communication is accomplished by rapid exchange of frames, rather than full duplex operation. Half duplex operation is possible on all supported media; it is required on those media that are incapable of supporting simultaneous transmission and reception without interference, for example, 10BASE2 and 100BASE-T4.
b) The *full duplex* mode of operation can be used when all of the following are true:
   1) The physical medium is capable of supporting simultaneous transmission and reception without interference (e.g., 10BASE-T, 10BASE-FL, and 100BASE-TX/FX).
   2) There are exactly two stations on the LAN. This allows the physical medium to be treated as a full duplex point-to-point link between the stations. Since there is no contention for use of a shared medium, the multiple access (i.e., CSMA/CD) algorithms are unnecessary.
   3) Both stations on the LAN are capable of and have been configured to use full duplex operation.

The most common configuration envisioned for full duplex operation consists of a central bridge (also known as a switch) with a dedicated LAN connecting each bridge port to a single device.

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The formal specification of the MAC in 4.2 comprises both the half duplex and full duplex modes of operation. The remainder of this clause provides a functional model of the CSMA/CD MAC method.

4.1.2 CSMA/CD operation

This subclause provides an overview of frame transmission and reception in terms of the functional model of the architecture. This overview is descriptive, rather than definitional; the formal specifications of the operations described here are given in 4.2 and 4.3. Specific implementations for CSMA/CD mechanisms that meet this standard are given in 4.4. Figure 1–1 provides the architectural model described functionally in the subclauses that follow.

The Physical Layer Signaling (PLS) component of the Physical Layer provides an interface to the MAC sublayer for the serial transmission of bits onto the physical media. For completeness, in the operational description that follows some of these functions are included as descriptive material. The concise specification of these functions is given in 4.2 for the MAC functions and in Clause 7 for PLS.

Transmit frame operations are independent from the receive frame operations. A transmitted frame addressed to the originating station will be received and passed to the MAC client at that station. This characteristic of the MAC sublayer may be implemented by functionality within the MAC sublayer or full duplex characteristics of portions of the lower layers.

4.1.2.1 Normal operation

4.1.2.1.1 Transmission without contention

When a MAC client requests the transmission of a frame, the Transmit Data Encapsulation component of the CSMA/CD MAC sublayer constructs the frame from the client-supplied data. It prepends a preamble and a Start Frame Delimiter to the beginning of the frame. Using information provided by the client, the CSMA/CD MAC sublayer also appends a Pad at the end of the MAC information field of sufficient length to ensure that the transmitted frame length satisfies a minimum frame-size requirement (see 4.2.3.3). It also prepends destination and source addresses, the length/type field, and appends a frame check sequence to provide for error detection. If the MAC supports the use of client-supplied frame check sequence values, then it shall use the client-supplied value, when present. If the use of client-supplied frame check sequence values is not supported, or if the client-supplied frame check sequence value is not present, then the MAC shall compute this value. The frame is then handed to the Transmit Media Access Management component in the MAC sublayer for transmission.

In half duplex mode, Transmit Media Access Management attempts to avoid contention with other traffic on the medium by monitoring the carrier sense signal provided by the Physical Layer Signaling (PLS) component and deferring to passing traffic. When the medium is clear, frame transmission is initiated (after a brief interframe delay to provide recovery time for other CSMA/CD MAC sublayers and for the physical medium). The MAC sublayer then provides a serial stream of bits to the Physical Layer for transmission.

In half duplex mode, at an operating speed of 1000 Mb/s, the minimum frame size is insufficient to ensure the proper operation of the CSMA/CD protocol for the desired network topologies. To circumvent this problem, the MAC sublayer will append a sequence of extension bits to frames which are less than slotTime bits in length so that the duration of the resulting transmission is sufficient to ensure proper operation of the CSMA/CD protocol.

In half duplex mode, at an operating speed of 1000 Mb/s, the CSMA/CD MAC may optionally transmit additional frames without relinquishing control of the transmission medium, up to a specified limit.

In full duplex mode, there is no need for Transmit Media Access Management to avoid contention with other traffic on the medium. Frame transmission may be initiated after the interframe delay, regardless of the

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presence of receive activity. In full duplex mode, the MAC sublayer does not perform either carrier extension or frame bursting.

The Physical Layer performs the task of generating the signals on the medium that represent the bits of the frame. Simultaneously, it monitors the medium and generates the collision detect signal, which in the contention-free case under discussion, remains off for the duration of the frame. A functional description of the Physical Layer is given in Clause 7 and beyond.

When transmission has completed without contention, the CSMA/CD MAC sublayer so informs the MAC client and awaits the next request for frame transmission.

4.1.2.1.2 Reception without contention

At each receiving station, the arrival of a frame is first detected by the Physical Layer, which responds by synchronizing with the incoming preamble, and by turning on the receiveDataValid signal. As the encoded bits arrive from the medium, they are decoded and translated back into binary data. The Physical Layer passes subsequent bits up to the MAC sublayer, where the leading bits are discarded, up to and including the end of the preamble and Start Frame Delimiter.

Meanwhile, the Receive Media Access Management component of the MAC sublayer, having observed receiveDataValid, has been waiting for the incoming bits to be delivered. Receive Media Access Management collects bits from the Physical Layer entity as long as the receiveDataValid signal remains on. When the receiveDataValid signal is removed, the frame is truncated to an octet boundary, if necessary, and passed to Receive Data Decapsulation for processing.

Receive Data Decapsulation checks the frame's Destination Address field to decide whether the frame should be received by this station. If so, it passes the Destination Address (DA), the Source Address (SA), the Length/Type, the Data and (optionally) the Frame Check Sequence (FCS) fields to the MAC client, along with an appropriate status code, as defined in 4.3.2. It also checks for invalid MAC frames by inspecting the frame check sequence to detect any damage to the frame enroute, and by checking for proper octet-boundary alignment of the end of the frame. Frames with a valid FCS may also be checked for proper octet-boundary alignment.

In half duplex mode, at an operating speed of 1000 Mb/s, frames may be extended by the transmitting station under the conditions described in 4.2.3.4. The extension is discarded by the MAC sublayer of the receiving station, as defined in the procedural model in 4.2.9.

4.1.2.2 Access interference and recovery

In half duplex mode, if multiple stations attempt to transmit at the same time, it is possible for them to interfere with each other's transmissions, in spite of their attempts to avoid this by deferring. When transmissions from two stations overlap, the resulting contention is called a collision. Collisions occur only in half duplex mode, where a collision indicates that there is more than one station attempting to use the shared physical medium. In full duplex mode, two stations may transmit to each other simultaneously without causing interference. The Physical Layer may generate a collision indication, but this is ignored by the full duplex MAC.

A given station can experience a collision during the initial part of its transmission (the collision window) before its transmitted signal has had time to propagate to all stations on the CSMA/CD medium. Once the collision window has passed, a transmitting station is said to have acquired the medium; subsequent collisions are avoided since all other (properly functioning) stations can be assumed to have noticed the signal and to be deferring to it. The time to acquire the medium is thus based on the round-trip propagation time of the Physical Layer whose elements include the PLS, PMA, and physical medium.

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In the event of a collision, the transmitting station's Physical Layer initially notices the interference on the medium and then turns on the collision detect signal. In half duplex mode, this is noticed in turn by the Transmit Media Access Management component of the MAC sublayer, and collision handling begins. First, Transmit Media Access Management enforces the collision by transmitting a bit sequence called jam. In 4.4, implementations that use this enforcement procedure are provided. This ensures that the duration of the collision is sufficient to be noticed by the other transmitting station(s) involved in the collision. After the jam is sent, Transmit Media Access Management terminates the transmission and schedules another transmission attempt after a randomly selected time interval. Retransmission is attempted again in the face of repeated collisions. Since repeated collisions indicate a busy medium, however, Transmit Media Access Management attempts to adjust to the medium load by backing off (voluntarily delaying its own retransmissions to reduce its load on the medium). This is accomplished by expanding the interval from which the random retransmission time is selected on each successive transmit attempt. Eventually, either the transmission succeeds, or the attempt is abandoned on the assumption that the medium has failed or has become overloaded.

In full duplex mode, a station ignores any collision detect signal generated by the Physical Layer. Transmit Media Access Management in a full duplex station will always be able to transmit its frames without contention, so there is never any need to jam or reschedule transmissions.

At the receiving end, the bits resulting from a collision are received and decoded by the PLS just as are the bits of a valid frame. Fragmentary frames received during collisions are distinguished from valid transmissions by the MAC sublayer's Receive Media Access Management component.

4.1.3 Relationships to the MAC client and Physical Layers

The CSMA/CD MAC sublayer provides services to the MAC client required for the transmission and reception of frames. Access to these services is specified in 4.3. The CSMA/CD MAC sublayer makes a best effort to acquire the medium and transfer a serial stream of bits to the Physical Layer. Although certain errors are reported to the client, error recovery is not provided by MAC. Error recovery may be provided by the MAC client or higher (sub)layers.

4.2 CSMA/CD Media Access Control (MAC) method: Precise specification

4.2.1 Introduction

A precise algorithmic definition is given in this subclause, providing procedural model for the CSMA/CD MAC process with a program in the computer language Pascal. See references [B12] and [B23] for resource material. Note whenever there is any apparent ambiguity concerning the definition of some aspect of the CSMA/CD MAC method, it is the Pascal procedural specification in 4.2.7 through 4.2.10 which should be consulted for the definitive statement. Subclauses 4.2.2 through 4.2.6 provide, in prose, a description of the access mechanism with the formal terminology to be used in the remaining subclauses.

4.2.2 Overview of the procedural model

The functions of the CSMA/CD MAC method are presented below, modeled as a program written in the computer language Pascal. This procedural model is intended as the primary specification of the functions to be provided in any CSMA/CD MAC sublayer implementation. It is important to distinguish, however, between the model and a real implementation. The model is optimized for simplicity and clarity of presentation, while any realistic implementation shall place heavier emphasis on such constraints as efficiency and suitability to a particular implementation technology or computer architecture. In this context, several important properties of the procedural model shall be considered.

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4.2.2.1 Ground rules for the procedural model

a) First, it shall be emphasized that *the description of the MAC sublayer in a computer language is in no way intended to imply that procedures shall be implemented as a program executed by a computer.* The implementation may consist of any appropriate technology including hardware, firmware, software, or any combination.
b) Similarly, it shall be emphasized that it is the behavior of any MAC sublayer implementations that shall match the standard, not their internal structure. The internal details of the procedural model are useful only to the extent that they help specify that behavior clearly and precisely.
c) The handling of incoming and outgoing frames is rather stylized in the procedural model, in the sense that frames are handled as single entities by most of the MAC sublayer and are only serialized for presentation to the Physical Layer. In reality, many implementations will instead handle frames serially on a bit, octet or word basis. This approach has not been reflected in the procedural model, since this only complicates the description of the functions without changing them in any way.
d) The model consists of algorithms designed to be executed by a number of concurrent processes; these algorithms collectively implement the CSMA/CD procedure. The timing dependencies introduced by the need for concurrent activity are resolved in two ways:
    1) *Processes Versus External Events.* It is assumed that the algorithms are executed "very fast" relative to external events, in the sense that a process never falls behind in its work and fails to respond to an external event in a timely manner. For example, when a frame is to be received, it is assumed that the Media Access procedure ReceiveFrame is always called well before the frame in question has started to arrive.
    2) *Processes Versus Processes.* Among processes, no assumptions are made about relative speeds of execution. This means that each interaction between two processes shall be structured to work correctly independent of their respective speeds. Note, however, that the timing of interactions among processes is often, in part, an indirect reflection of the timing of external events, in which case appropriate timing assumptions may still be made.

It is intended that the concurrency in the model reflect the parallelism intrinsic to the task of implementing the MAC client and MAC procedures, although the actual parallel structure of the implementations is likely to vary.

4.2.2.2 Use of Pascal in the procedural model

Several observations need to be made regarding the method with which Pascal is used for the model. Some of these observations are as follows:

a) The following limitations of the language have been circumvented to simplify the specification:
    1) The elements of the program (variables and procedures, for example) are presented in logical groupings, in top-down order. Certain Pascal ordering restrictions have thus been circumvented to improve readability.
    2) The *process* and *cycle* constructs of Concurrent Pascal, a Pascal derivative, have been introduced to indicate the sites of autonomous concurrent activity. As used here, a process is simply a parameterless procedure that begins execution at "the beginning of time" rather than being invoked by a procedure call. A cycle statement represents the main body of a process and is executed repeatedly forever.
    3) The lack of variable array bounds in the language has been circumvented by treating frames as if they are always of a single fixed size (which is never actually specified). The size of a frame depends on the size of its data field, hence the value of the "pseudo-constant" frameSize should be thought of as varying in the long term, even though it is fixed for any given frame.
    4) The use of a variant record to represent a frame (as fields and as bits) follows the spirit but not the letter of the Pascal Report, since it allows the underlying representation to be viewed as two different data types.
b) The model makes no use of any explicit interprocess synchronization primitives. Instead, all interprocess interaction is done by way of carefully stylized manipulation of shared variables. For

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example, some variables are set by only one process and inspected by another process in such a manner that the net result is independent of their execution speeds. While such techniques are not generally suitable for the construction of large concurrent programs, they simplify the model and more nearly resemble the methods appropriate to the most likely implementation technologies (microcode, hardware state machines, etc.)

4.2.2.3 Organization of the procedural model

The procedural model used here is based on seven cooperating concurrent processes. The Frame Transmitter process and the Frame Receiver process are provided by the clients of the MAC sublayer (which may include the LLC sublayer) and make use of the interface operations provided by the MAC sublayer. The other five processes are defined to reside in the MAC sublayer. The seven processes are as follows:

a) Frame Transmitter process
b) Frame Receiver process
c) Bit Transmitter process
d) Bit Receiver process
e) Deference process
f) BurstTimer process
g) SetExtending process

This organization of the model is illustrated in Figure 4–1 and reflects the fact that the communication of entire frames is initiated by the client of the MAC sublayer, while the timing of collision backoff and of individual bit transfers is based on interactions between the MAC sublayer and the Physical-Layer-dependent bit time.

Figure 4–1 depicts the static structure of the procedural model, showing how the various processes and procedures interact by invoking each other. Figure 4–2a, 4–2b, 4–3a, and 4–3b summarize the dynamic behavior of the model during transmission and reception, focusing on the steps that shall be performed, rather than the procedural structure that performs them. The usage of the shared state variables is not depicted in the figures, but is described in the comments and prose in the following subclauses.

4.2.2.4 Layer management extensions to procedural model

In order to incorporate network management functions, this Procedural Model has been expanded. Network management functions have been incorporated in two ways. First, 4.2.7–4.2.10, 4.3.2, Figure 4–2a, and Figure 4–2b have been modified and expanded to provide management services. Second, Layer Management procedures have been added as 5.2.4. Note that Pascal variables are shared between Clause 4 and Clause 5. Within the Pascal descriptions provided in Clause 4, a "‡" in the left margin indicates a line that has been added to support management services. These lines are only required if Layer Management is being implemented. These changes do not affect any aspect of the MAC behavior as observed at the LLC-MAC and MAC-PLS interfaces.

The Pascal procedural specification shall be consulted for the definitive statement when there is any apparent ambiguity concerning the definition of some aspect of the CSMA/CD MAC access method.

The Layer Management facilities provided by the CSMA/CD MAC and Physical Layer management definitions provide the ability to manipulate management counters and initiate actions within the layers. The managed objects within this standard are defined as sets of attributes, actions, notifications, and behaviors in accordance with IEEE Std 802.1F-1993, and ISO/IEC International Standards for network management.

4.2.3 Packet transmission model

Packet transmission includes the following data encapsulation and Media Access management aspects:

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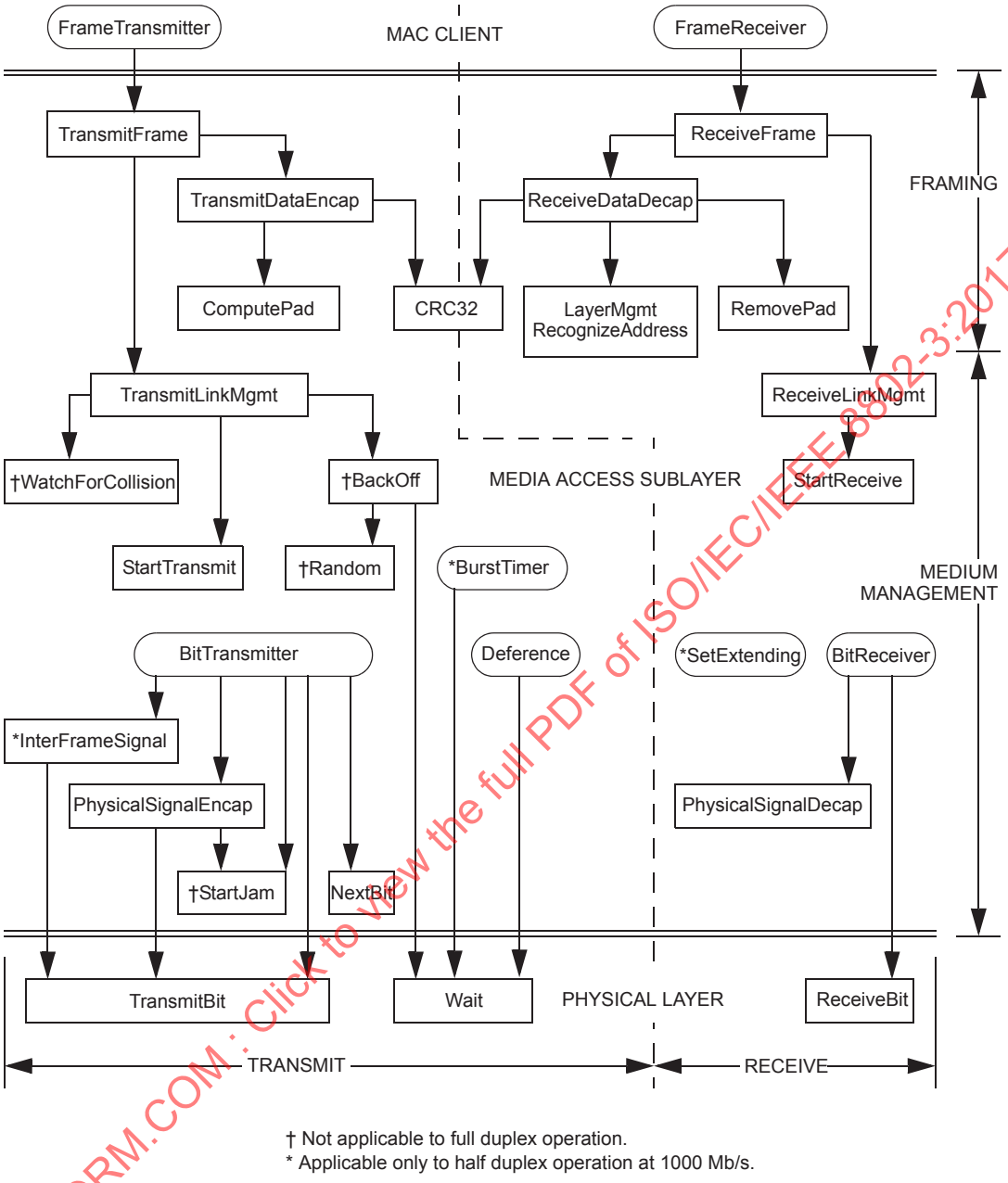

† Not applicable to full duplex operation.
* Applicable only to half duplex operation at 1000 Mb/s.

Figure 4–1—Relationship among CSMA/CD procedures

a) Transmit Data Encapsulation includes the assembly of the outgoing packet (from the values provided by the MAC client) and frame check sequence generation (if not provided by the MAC client).
b) Transmit Media Access Management includes carrier deference, interpacket gap, collision detection and enforcement, collision backoff and retransmission, carrier extension and packet bursting.

4.2.3.1 Transmit data encapsulation

The fields of the CSMA/CD MAC frame are set to the values provided by the MAC client as arguments to the TransmitFrame operation (see 4.3) with the following possible exceptions: the padding field, the extension field, and the frame check sequence. The padding field is necessary to enforce the minimum frame

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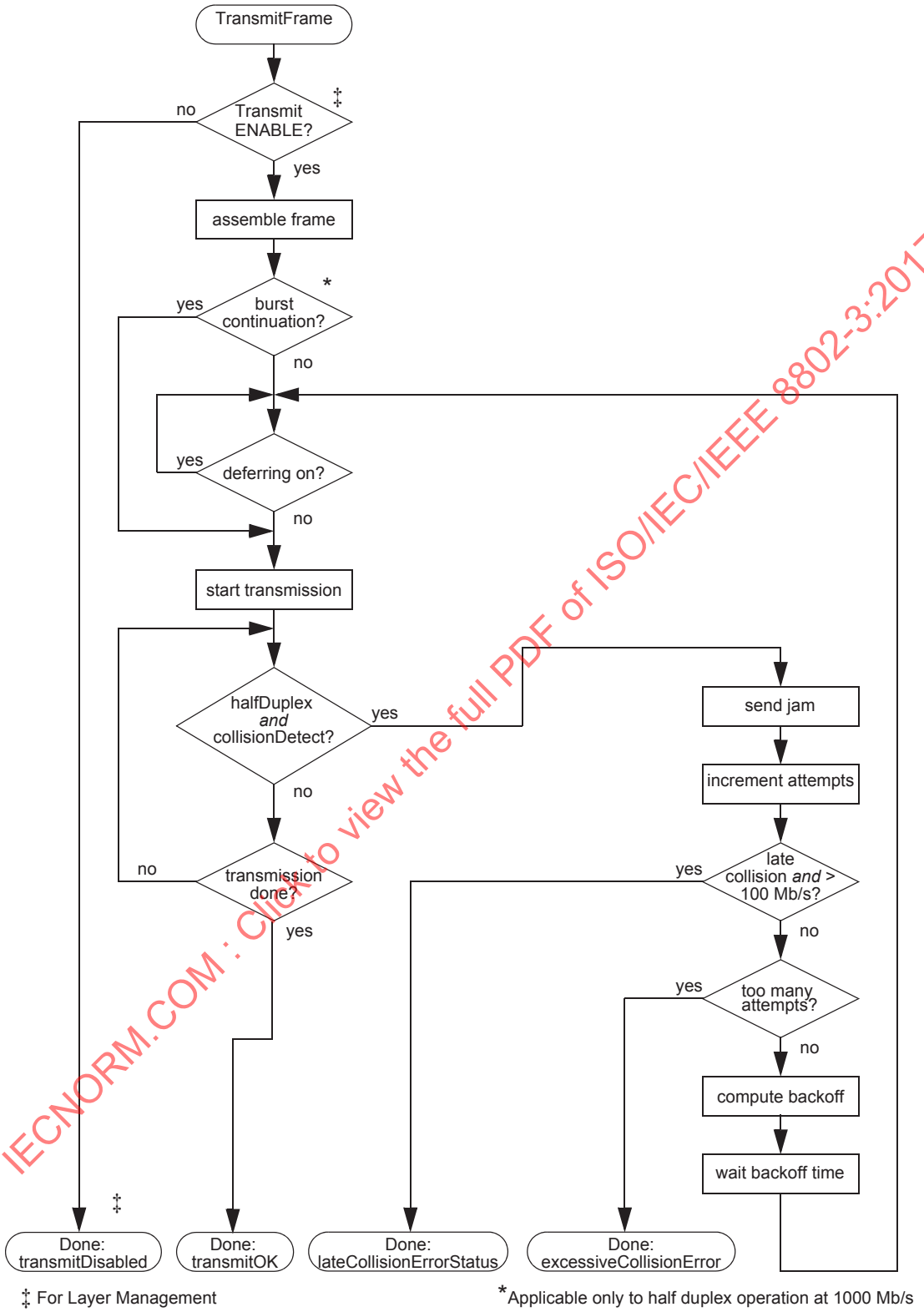

a) TransmitFrame

Figure 4–2a—Control flow summary

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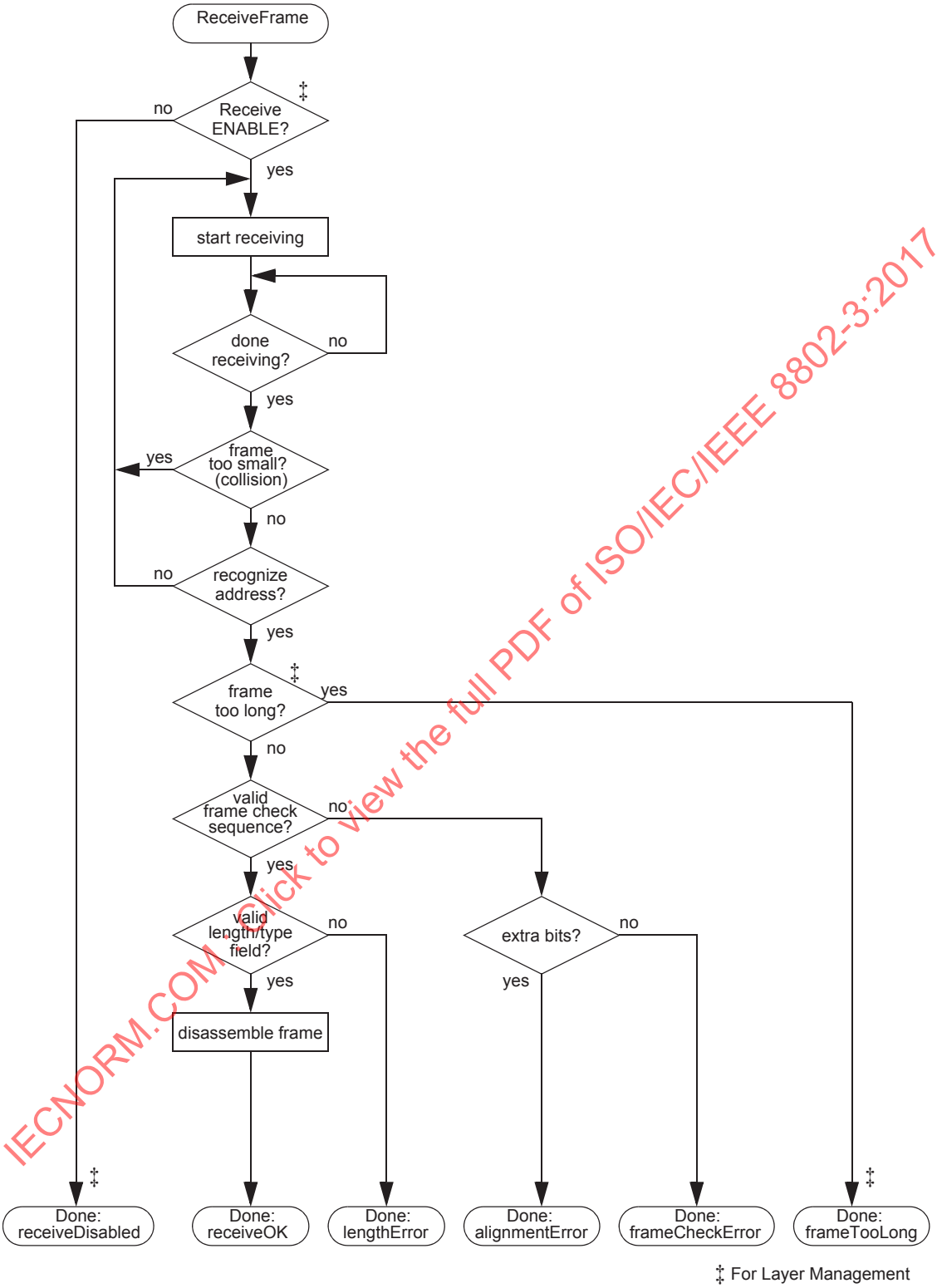

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b) ReceiveFrame

Figure 4–2b—Control flow summary

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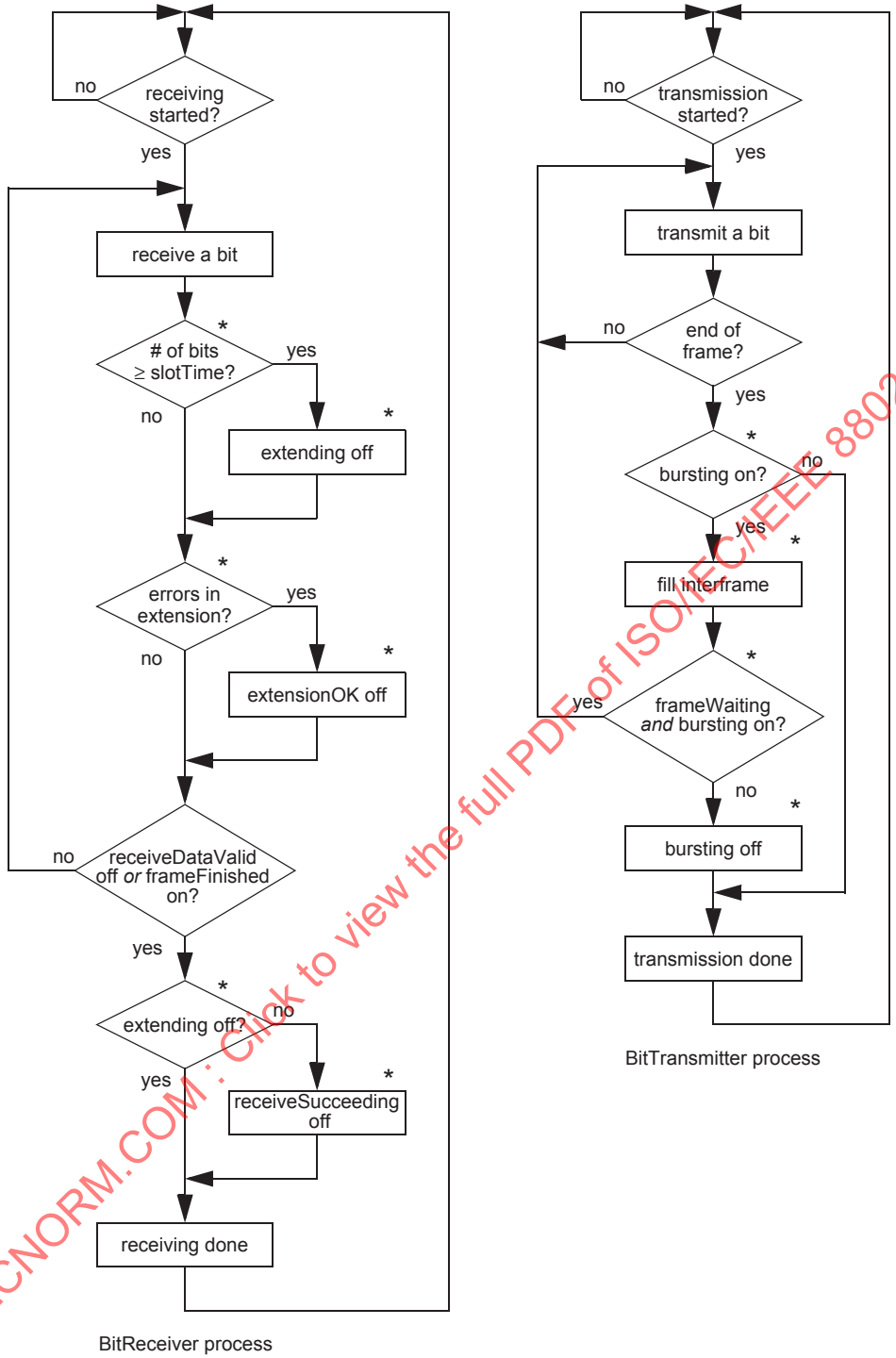

a) MAC sublayer

Figure 4–3a—Control flow

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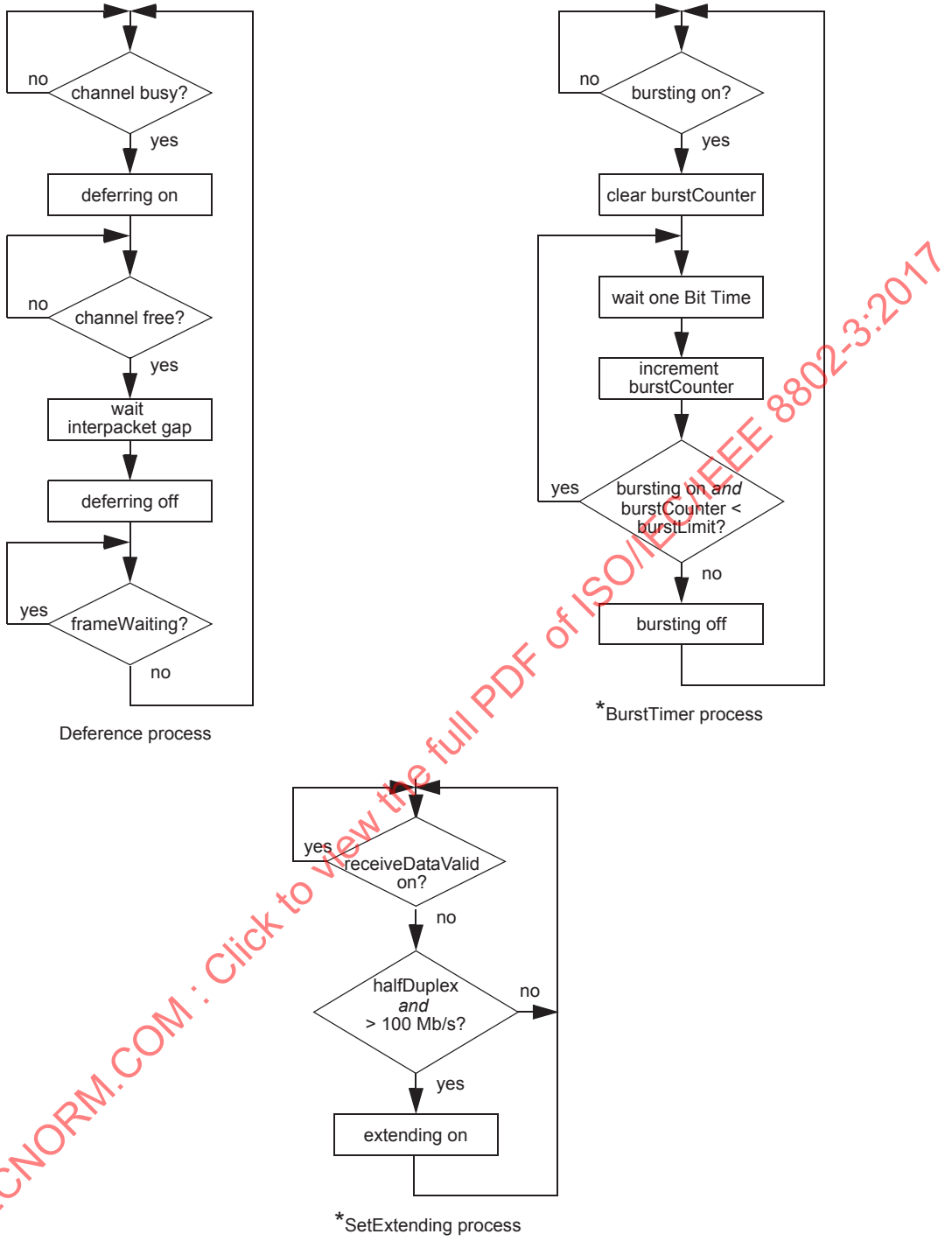

*Applicable only to half duplex operation at 1000 Mb/s

b) MAC sublayer

Figure 4–3b—Control flow

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size. The extension field is necessary to enforce the minimum carrier event duration on the medium in half duplex mode at an operating speed of 1000 Mb/s. The frame check sequence field may be (optionally) provided as an argument to the MAC sublayer. It is optional for a MAC to support the provision of the frame check sequence in such an argument. If this field is provided by the MAC client, the padding field shall also be provided by the MAC client, if necessary. If this field is not provided by the MAC client, or if the MAC does not support the provision of the frame check sequence as an external argument, it is set to the CRC value generated by the MAC sublayer, after appending the padding field, if necessary.

4.2.3.2 Transmit media access management

4.2.3.2.1 Deference

When a packet is submitted by the MAC client for transmission, the transmission is initiated as soon as possible, but in conformance with the rules of deference stated below. The rules of deference differ between half duplex and full duplex modes.

a) *Half duplex mode*

Even when it has nothing to transmit, the CSMA/CD MAC sublayer monitors the physical medium for traffic by watching the carrierSense signal provided by the PLS. Whenever the medium is busy, the CSMA/CD MAC defers to the passing packet by delaying any pending transmission of its own. After the last bit of the passing packet (that is, when *carrierSense* changes from true to false), the CSMA/CD MAC continues to defer for a proper interPacketGap (see 4.2.3.2.2).

If, at the end of the interPacketGap, a packet is waiting to be transmitted, transmission is initiated independent of the value of carrierSense. When transmission has completed (or immediately, if there was nothing to transmit) the CSMA/CD MAC sublayer resumes its original monitoring of carrierSense.

NOTE—It is possible for the PLS carrier sense indication to fail to be asserted briefly during a collision on the media. If the Deference process simply times the interpacket gap based on this indication it is possible for a short interpacket gap to be generated, leading to a potential reception failure of a subsequent frame. To enhance system robustness the following optional measures, as specified in 4.2.8, are recommended when interPacketGapPart1 is other than zero.

Start the timing of the interPacketGap as soon as transmitting and carrierSense are both false. Reset the interPacketGap timer if carrierSense becomes true during the first 2/3 of the interPacketGap timing interval. During the final 1/3 of the interval, the timer shall not be reset to ensure fair access to the medium. An initial period shorter than 2/3 of the interval is permissible including zero.

b) *Full duplex mode*

In full duplex mode, the CSMA/CD MAC does not defer pending transmissions based on the carrierSense signal from the PLS. Instead, it uses the internal variable *transmitting* to maintain proper MAC state while the transmission is in progress. After the last bit of a transmitted frame, (that is, when *transmitting* changes from true to false), the MAC continues to defer for a proper interPacketGap (see 4.2.3.2.2).

4.2.3.2.2 Interpacket gap

As defined in 4.2.3.2.1, the rules for deferring to passing packets ensure a minimum interpacket spacing of interPacketGap bit times. This is intended to provide interpacket recovery time for other CSMA/CD sublayers and for the physical medium.

Note that interPacketGap is the minimum value of the interpacket gap. If necessary for implementation reasons, a transmitting sublayer may use a larger value with a resulting decrease in its throughput. The larger value is determined by the parameters of the implementation, see 4.4.

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A larger value for interpacket gap is used for dynamically adapting the nominal data rate of the MAC sublayer to SONET/SDH data rates (with packet granularity) for WAN-compatible applications of this standard. While in this optional mode of operation, the MAC sublayer counts the number of bits sent during a frame's transmission. After the packet's transmission has been completed, the MAC sublayer extends the minimum interpacket gap by a number of bits that is proportional to the length of the previously transmitted packet. For more details, see 4.2.7 and 4.2.8.

4.2.3.2.3 Collision handling (half duplex mode only)

Once a CSMA/CD sublayer has finished deferring and has started transmission, it is still possible for it to experience contention for the medium. Collisions can occur until acquisition of the network has been accomplished through the deference of all other stations' CSMA/CD sublayers.

The dynamics of collision handling are largely determined by a single parameter called the slot time. This single parameter describes three important aspects of collision handling:

a) It is an upper bound on the acquisition time of the medium.
b) It is an upper bound on the length of a packet fragment generated by a collision.
c) It is the scheduling quantum for retransmission.

To fulfill all three functions, the slot time shall be larger than the sum of the Physical Layer round-trip propagation time and the Media Access Layer maximum jam time. The slot time is determined by the parameters of the implementation, see 4.4.

4.2.3.2.4 Collision detection and enforcement (half duplex mode only)

Collisions are detected by monitoring the collisionDetect signal provided by the Physical Layer. When a collision is detected during a packet transmission, the transmission is not terminated immediately. Instead, the transmission continues until additional bits specified by jamSize have been transmitted (counting from the time collisionDetect went on). This collision enforcement or jam guarantees that the duration of the collision is sufficient to ensure its detection by all transmitting stations on the network. The content of the jam is unspecified; it may be any fixed or variable pattern convenient to the Media Access implementation; however, the implementation shall not be intentionally designed to be the 32-bit CRC value corresponding to the (partial) packet transmitted prior to the jam.

4.2.3.2.5 Collision backoff and retransmission (half duplex mode only)

When a transmission attempt has terminated due to a collision, it is retried by the transmitting CSMA/CD sublayer until either it is successful or a maximum number of attempts (attemptLimit) have been made and all have terminated due to collisions. Note that all attempts to transmit a given packet are completed before any subsequent outgoing packets are transmitted. The scheduling of the retransmissions is determined by a controlled randomization process called "truncated binary exponential backoff." At the end of enforcing a collision (jamming), the CSMA/CD sublayer delays before attempting to retransmit the packet. The delay is an integer multiple of slotTime. The number of slot times to delay before the *n*th retransmission attempt is chosen as a uniformly distributed random integer *r* in the range:

$$0 \le r < 2^k$$

where

$$k = \min(n, 10)$$

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If all attemptLimit attempts fail, this event is reported as an error. Algorithms used to generate the integer *r* should be designed to minimize the correlation between the numbers generated by any two stations at any given time.

Note that the values given above define the most aggressive behavior that a station may exhibit in attempting to retransmit after a collision. In the course of implementing the retransmission scheduling procedure, a station may introduce extra delays that will degrade its own throughput, but in no case may a station's retransmission scheduling result in a lower average delay between retransmission attempts than the procedure defined above.

4.2.3.2.6 Full duplex transmission

In full duplex mode, there is never contention for a shared physical medium. The Physical Layer may indicate to the MAC that there are simultaneous transmissions by both stations, but since these transmissions do not interfere with each other, a MAC operating in full duplex mode must not react to such Physical Layer indications. Full duplex stations do not defer to received traffic, nor abort transmission, jam, backoff, and reschedule transmissions as part of Transmit Media Access Management. Transmissions may be initiated whenever the station has a packet queued, subject only to the interpacket gap required to allow recovery for other sublayers and for the physical medium.

4.2.3.2.7 Packet bursting (half duplex mode only)

At an operating speed of 1000 Mb/s, an implementation may optionally transmit a series of packets without relinquishing control of the transmission medium. This mode of operation is referred to as *burst mode*. Once a packet has been successfully transmitted, the transmitting station can begin transmission of another packet without contending for the medium because all of the other stations on the network will continue to defer to its transmission, provided that it does not allow the medium to assume an idle condition between packets. The transmitting station fills the interpacket gap interval with extension bits, which are readily distinguished from data bits at the receiving stations, and which maintain the detection of carrier in the receiving stations. The transmitting station is allowed to initiate packet transmission until a specified limit, referred to as burstLimit, is reached. The value of burstLimit is specified in 4.4.2. Figure 4–4 shows an example of transmission with packet bursting.

The first packet of a burst will be extended, if necessary, as described in 4.2.3.4. Subsequent packets within a burst do not require extension. In a properly configured network, and in the absence of errors, collisions cannot occur during a burst at any time after the first packet of a burst (including any extension) has been transmitted. Therefore, the MAC will treat any collision that occurs after the first packet of a burst, or that occurs after the slotTime has been reached in the first packet of a burst, as a late collision.

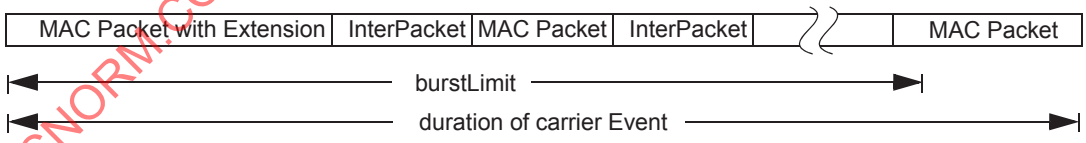

Figure 4–4—Packet bursting

4.2.3.3 Minimum frame size

The CSMA/CD Media Access mechanism requires that a minimum frame length of minFrameSize bits be transmitted. If frameSize is less than minFrameSize, then the CSMA/CD MAC sublayer shall append extra bits in units of octets (Pad), after the end of the MAC Client Data field but prior to calculating and appending the FCS (if not provided by the MAC client). The number of extra bits shall be sufficient to ensure that the frame, from the DA field through the FCS field inclusive, is at least minFrameSize bits. If the

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FCS is (optionally) provided by the MAC client, the Pad shall also be provided by the MAC client. The content of the Pad is unspecified.

4.2.3.4 Carrier extension (half duplex mode only)

At an operating speed of 1000 Mb/s, the slotTime employed at slower speeds is inadequate to accommodate network topologies of the desired physical extent. Carrier Extension provides a means by which the slotTime can be increased to a sufficient value for the desired topologies, without increasing the minFrameSize parameter, as this would have deleterious effects. Non-data bits, referred to as extension bits, are appended to frames that are less than slotTime bits in length so that the resulting transmission is at least one slotTime in duration. Carrier Extension can be performed only if the underlying Physical Layer is capable of sending and receiving symbols that are readily distinguished from data symbols, as is the case in most Physical Layers that use a block encoding/decoding scheme. The maximum length of the extension is equal to the quantity (slotTime − minFrameSize). Figure 4–5 depicts a frame with carrier extension.

The MAC continues to monitor the medium for collisions while it is transmitting extension bits, and it will treat any collision that occurs after the threshold (slotTime) as a late collision.

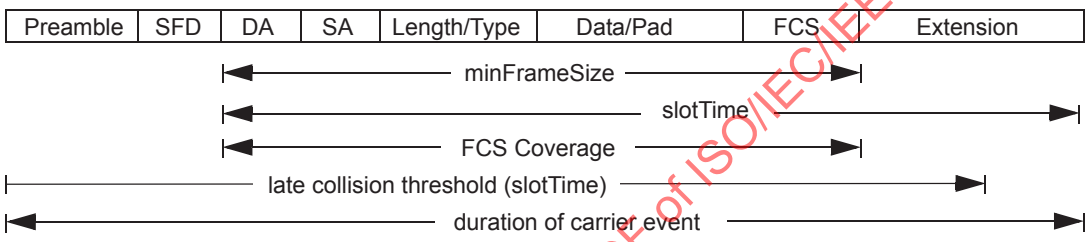

Figure 4–5—Frame with carrier extension

4.2.4 Frame reception model

CSMA/CD MAC sublayer frame reception includes both data decapsulation and Media Access management aspects:

a) Receive Data Decapsulation comprises address recognition, frame check sequence validation, and frame disassembly to pass the fields of the received frame to the MAC client.

b) Receive Media Access Management comprises recognition of collision fragments from incoming frames and truncation of frames to octet boundaries.

4.2.4.1 Receive data decapsulation

4.2.4.1.1 Address recognition

The CSMA/CD MAC sublayer is capable of recognizing individual and group addresses.

a) *Individual Addresses.* The CSMA/CD MAC sublayer recognizes and accepts any frame whose DA field contains the individual address of the station.

b) *Group Addresses.* The CSMA/CD MAC sublayer recognizes and accepts any frame whose DA field contains the Broadcast address.

The CSMA/CD MAC sublayer is capable of activating some number of group addresses as specified by higher layers. The CSMA/CD MAC sublayer recognizes and accepts any frame whose Destination Address field contains an active group address. An active group address may be deactivated.

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The MAC sublayer may also provide the capability of operating in the promiscuous receive mode. In this mode of operation, the MAC sublayer recognizes and accepts all valid frames, regardless of their Destination Address field values.

4.2.4.1.2 Frame check sequence validation

FCS validation is essentially identical to FCS generation. If the bits of the incoming frame (exclusive of the FCS field itself) do not generate a CRC value identical to the one received, an error has occurred and the frame is identified as invalid.

4.2.4.1.3 Frame disassembly

Upon recognition of the Start Frame Delimiter at the end of the preamble sequence, the CSMA/CD MAC sublayer accepts the frame. If there are no errors, the frame is disassembled and the fields are passed to the MAC client by way of the output parameters of the ReceiveFrame operation.

4.2.4.2 Receive media access management

4.2.4.2.1 Framing

The CSMA/CD sublayer recognizes the boundaries of an incoming MAC frame by monitoring the receiveDataValid signal provided by the Physical Layer. Two possible length errors can occur that indicate ill-framed data: the MAC frame may be too long, or its length may not be an integer number of octets.

a) *Maximum Frame Size.* The receiving CSMA/CD sublayer is not required to enforce the MAC frame size limit, but it is allowed to truncate MAC frames longer than maxFrameSizeLimit octets (see 4.2.7.1). If optional layer management is implemented, such frames may be counted whether or not they are truncated. They may also be reported as an implementation-dependent error.

> **CAUTION**
> It is recommended that any implementation that truncates MAC frames should invalidate those frames as they may have severely weakened error protection and may cause serious problems if forwarded to the MAC client.

b) *Integer Number of Octets in Frame.* Since the format of a valid MAC frame specifies an integer number of octets, only a collision or an error can produce a MAC frame with a length that is not an integer multiple of 8 bits. Complete MAC frames (that is, not rejected as collision fragments; see 4.2.4.2.2) that do not contain an integer number of octets are truncated to the nearest octet boundary. If frame check sequence validation detects an error in such a MAC frame, the status code alignmentError is reported.

When a burst of MAC frames is received while operating in half duplex mode at an operating speed of 1000 Mb/s, the individual MAC frames within the burst are delimited by sequences of interpacket fill symbols, which are conveyed to the receiving MAC sublayer as extension bits. Once the collision filtering requirements for a given MAC frame, as described in 4.2.4.2.2, have been satisfied, the receipt of an extension bit can be used as an indication that all of the data bits of the MAC frame have been received.

4.2.4.2.2 Collision filtering

In the absence of a collision, the shortest valid transmission in half duplex mode must be at least one slotTime in length. Within a burst of frames, the first frame of a burst must be at least slotTime bits in length in order to be accepted by the receiver, while subsequent frames within a burst must be at least minFrameSize in length. Anything less is presumed to be a fragment resulting from a collision, and is discarded by the receiver. In half duplex mode, occasional collisions are a normal part of the Media Access management procedure. The discarding of such a fragment by a MAC is not reported as an error.

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The shortest valid transmission in full duplex mode must be at least minFrameSize in length. While collisions do not occur in full duplex mode MACs, a full duplex MAC nevertheless discards received frames containing less than minFrameSize bits. The discarding of such a frame by a MAC is not reported as an error.

4.2.5 Preamble generation

In a LAN implementation, most of the Physical Layer components are allowed to provide valid output some number of bit times after being presented valid input signals. Thus it is necessary for a preamble to be sent before the start of data, to allow the PLS circuitry to reach its steady state. Upon request by TransmitLinkMgmt to transmit the first bit of a new frame, PhysicalSignalEncap shall first transmit the preamble, a bit sequence used for physical medium stabilization and synchronization, followed by the Start Frame Delimiter. If, while transmitting the preamble or Start Frame Delimiter, the collision detect variable becomes true, any remaining preamble and Start Frame Delimiter bits shall be sent. The preamble pattern is:

10101010 10101010 10101010 10101010 10101010 10101010 10101010

The bits are transmitted in order, from left to right. The nature of the pattern is such that, for Manchester encoding, it appears as a periodic waveform on the medium that enables bit synchronization. It should be noted that the preamble ends with a "0."

4.2.6 Start frame sequence

The receiveDataValid signal is the indication to the MAC that the frame reception process should begin. Upon reception of the sequence 10101011 following the assertion of receiveDataValid, PhysicalSignalDecap shall begin passing successive bits to ReceiveLinkMgmt for passing to the MAC client.

4.2.7 Global declarations

This subclause provides detailed formal specifications for the CSMA/CD MAC sublayer. It is a specification of generic features and parameters to be used in systems implementing this media access method. Subclause 4.4 provides values for these sets of parameters for recommended implementations of this media access mechanism.

4.2.7.1 Common constants, types, and variables

The following declarations of constants, types and variables are used by the MAC frame transmission and reception sections of each CSMA/CD sublayer:

```
const
    addressSize = 48; {In bits, in compliance with 3.2.3}
    lengthOrTypeSize = 16; {In bits}
    clientDataSize = ...; {In bits, size of MAC Client Data; see 4.2.2.2, a) 3)}
    padSize = ...; {In bits, = max (0, minFrameSize — (2 x addressSize + lengthOrTypeSize +
                                        clientDataSize + crcSize))}
    dataSize = ...; {In bits, = clientDataSize + padSize}
    crcSize = 32; {In bits, 32-bit CRC}
    frameSize = ...; {In bits, = 2 x addressSize + lengthOrTypeSize + dataSize + crcSize; see 4.2.2.2, a)}
    minFrameSize = ..; {In bits, see 4.4}
    maxBasicFrameSize = 1518; {In octets, see 3.2.7, 4.4}
    maxEnvelopeFrameSize = 2000; {In octets, see 3.2.7, 4.4}
    qTagPrefixSize = 4; {In octets, length of Q-tag prefix, see 3.2.7, 4.4}
    maxFrameSizeLimit = maxBasicFrameSize or (maxBasicFrameSize + qTagPrefixSize) or
```

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```
                maxEnvelopeFrameSize ; {in octets}
    extend = ...; {Boolean, true if (slotTime − minFrameSize) > 0, false otherwise}
    extensionBit = ...; {A non-data value which is used for carrier extension and interpacket
                during bursts}
    extensionErrorBit = ...; {A non-data value which is used to jam during carrier extension}
    minTypeValue = 1536; {Minimum value of the Length/Type field for Type interpretation}
    maxBasicDataSize = 1500;
                {In octets, the maximum length of the MAC Client Data field of the basic frame.}
    slotTime = ...; {In bit times, unit of time for collision handling, implementation-dependent, see 4.4}
    preambleSize = 56; {In bits, see 4.2.5}
    sfdSize = 8; {In bits, Start Frame Delimiter}
    headerSize = 64; {In bits, sum of preambleSize and sfdSize}
type
    Bit = (0, 1);
    PhysicalBit = (0, 1, extensionBit, extensionErrorBit);
                {Bits transmitted to the Physical Layer can be either 0, 1, extensionBit or
                extensionErrorBit. Bits received from the Physical Layer can be either 0, 1
                or extensionBit}
    AddressValue = array [1..addressSize] of Bit;
    LengthOrTypeValue = array [1..lengthOrTypeSize] of Bit;
    DataValue = array [1..dataSize] of Bit; {Contains the portion of the MAC frame that starts with the first
                bit following the Length/Type field and ends with the last bit
                prior to the FCS field}
    CRCValue = array [1..crcSize] of Bit;
    PreambleValue = array [1..preambleSize] of Bit;
    SfdValue = array [1..sfdSize] of Bit;
    ViewPoint = (fields, bits); {Two ways to view the contents of a frame}
    HeaderViewPoint = (headerFields, headerBits);
    Frame = record {Format of MAC frame}
        case view: ViewPoint of
            fields: (
                destinationField: AddressValue;
                sourceField: AddressValue;
                lengthOrTypeField: LengthOrTypeValue;
                dataField: DataValue;
                fcsField: CRCValue);
            bits: (contents: array [1..frameSize] of Bit)
        end; {MAC frame}
    Header = record {Format of Preamble and Start Frame Delimiter}
        case headerView: HeaderViewPoint of
            headerFields: (
                preamble: PreambleValue;
                sfd: SfdValue);
            headerBits: (headerContents: array [1..headerSize] of Bit)
        end; {Defines header for MAC frame}
    TransmitStatus = (transmitOK, excessiveCollisionError, lateCollisionErrorStatus);
‡   TransmitStatus = (transmitDisabled, transmitOK, excessiveCollisionError,
                lateCollisionErrorStatus);
    ReceiveStatus = (receiveOK, lengthError, frameCheckError, alignmentError);
‡   ReceiveStatus = (receiveDisabled, receiveOK, frameTooLong, frameCheckError,
                lengthError, alignmentError);
var
    halfDuplex: Boolean; {Indicates the desired mode of operation. halfDuplex is a static variable; its value
```

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shall only be changed by the invocation of the Initialize procedure}

4.2.7.2 Transmit state variables

The following items are specific to packet transmission. (See also 4.4.)

```
const
    interPacketGap = ...; {In bit times, minimum gap between packets, see 4.4}
    interPacketGapPart1 = ...; {In bit times, duration of the first portion of
                                interPacketGap. In the
                                range of 0 to 2/3 of interPacketGap}
    interPacketGapPart2 = ...; {In bit times, duration of the remainder of
                                interPacketGap. Equal to
                                interPacketGap –
                                interPacketGapPart1}
    ipgStretchRatio = ...; {In bits, determines the number of bits in a packet that
                            require one octet of interPacketGap extension,
                            when ipgStretchMode is enabled;
                            see 4.4 and 4.2.8}
    attemptLimit = ...; {Max number of times to attempt transmission}
    backOffLimit = ...; {Limit on number of times to back off}
    burstLimit= ...; {In bits, limit for initiation of packet transmission in Burst Mode,
                      see 4.4 and 4.2.8}
    jamSize = ...; {In bits, the value depends upon port type and duplex/half-duplex mode.
                    See 4.1.2.2 and 4.4.}
var
    outgoingFrame: Frame; {The frame to be transmitted}
    outgoingHeader: Header;
    currentTransmitBit, lastTransmitBit: 1..frameSize; {Positions of current and last outgoing bits in
                                                        outgoingFrame}
    lastHeaderBit: 1..headerSize;
    deferring: Boolean; {Implies any pending transmission must wait for the medium to clear}
    frameWaiting: Boolean; {Indicates that outgoingFrame is deferring}
    attempts: 0..attemptLimit; {Number of transmission attempts on outgoingFrame}
    newCollision: Boolean; {Indicates that a collision has occurred but has not yet been jammed}
    transmitSucceeding: Boolean; {Running indicator of whether transmission is succeeding}
    burstMode: Boolean; {Indicates the desired mode of operation, and enables the transmission of
                         multiple frames in a single carrier event. burstMode is a static variable; its
                         value shall only be changed by the invocation of the Initialize procedure}
    bursting: Boolean; {In burstMode, the given station has acquired the medium and the burst timer has
                        not yet expired}
    burstStart: Boolean; {In burstMode, indicates that the first frame transmission is in progress}
    extendError: Boolean; {Indicates a collision occurred while sending extension bits}
    ipgStretchMode: Boolean; {Indicates the desired mode of operation, and enables
                              the lowering of the average data rate
                              of the MAC sublayer (with packet granularity), using
                              extension of the minimum interPacketGap.
                              ipgStretchMode is a static
                              variable; its value shall only be changed by the invocation of the Initialize
                              procedure}
    ipgStretchCount: 0..ipgStretchRatio; {In bits, a running
                                          counter that counts the number of bits during a
                                          packet's transmission that are to be considered for the
                                          minimum interPacketGap extension,
```

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while operating in ipgStretchMode}
ipgStretchSize: 0..(((maxFrameSizeLimit) x 8 + headerSize + interPacketGap
+ ipgStretchRatio – 1) *div* ipgStretchRatio);
{In octets, a running counter that counts the integer number of octets that are to be added to the minimum interPacketGap, while operating in ipgStretchMode}

4.2.7.3 Receive state variables

The following items are specific to frame reception. (See also 4.4.)

var
incomingFrame: Frame; {The frame being received}
receiving: Boolean; {Indicates that a frame reception is in progress}
excessBits: 0..7; {Count of excess trailing bits beyond octet boundary}
receiveSucceeding: Boolean; {Running indicator of whether reception is succeeding}
validLength: Boolean; {Indicator of whether received frame has a length error}
exceedsMaxLength: Boolean; {Indicator of whether received frame has a length longer than the maximum permitted length}
extending: Boolean; {Indicates whether the current frame is subject to carrier extension}
extensionOK: Boolean; {Indicates whether any bit errors were found in the extension part of a packet, which is not checked by the CRC}
passReceiveFCSMode: Boolean; {Indicates the desired mode of operation, and enables passing of the frame check sequence field of all received frames from the MAC sublayer to the MAC client. passReceiveFCSMode is a static variable}

4.2.7.4 State variable initialization

The procedure Initialize must be run when the MAC sublayer begins operation, before any of the processes begin execution. Initialize sets certain crucial shared state variables to their initial values. (All other global variables are appropriately reinitialized before each use.) Initialize then waits for the medium to be idle, and starts operation of the various processes.

NOTE—Care should be taken to ensure that the time from the completion of the Initialize process to when the first packet transmission begins is at least an interPacketGap.

If Layer Management is implemented, the Initialize procedure shall only be called as the result of the initializeMAC action (30.3.1.2.1).

procedure Initialize;
begin
frameWaiting := false;
deferring := false;
newCollision := false;
transmitting := false; {An interface to Physical Layer; see below}
receiving := false;
halfDuplex := ...; {True for half duplex operation, false for full duplex operation. For operation at speeds above 1000 Mb/s, halfDuplex shall always be false}
bursting := false;
burstMode := ...; { True for half duplex operation at an operating speed of 1000 Mb/s, when multiple frames' transmission in a single carrier event is desired and supported, false otherwise}
extending := extend *and* halfDuplex;

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```
    ipgStretchMode := ...; {True for operating speeds above 1000 Mb/s when lowering the average data rate
                            of the MAC sublayer (with frame granularity) is desired and supported, false
                            otherwise}
    ipgStretchCount := 0;
    ipgStretchSize := 0;
    passReceiveFCSMode := ...; {True when enabling the passing of the frame check sequence of all
                                received frames from the MAC sublayer to the MAC client is desired and
                                supported, false otherwise}
    if halfDuplex then while carrierSense or receiveDataValid do nothing
    else while receiveDataValid do nothing
    {Start execution of all processes}
end; {Initialize}
```

4.2.8 Frame transmission

The algorithms in this subclause define MAC sublayer frame transmission. The function TransmitFrame implements the frame transmission operation provided to the MAC client.

The TransmitFrame operation is synchronous. Its duration is the entire attempt to transmit the frame; when the operation completes, transmission has either succeeded or failed, as indicated by the TransmitStatus status code.

The transmitDisabled status code (if layer management is implemented) indicates that the transmitter is not enabled. Successful transmission is indicated by the status code transmitOK. The code excessiveCollisionError indicates that the transmission attempt was aborted due to excessive collisions, because of heavy traffic or a network failure. MACs operating in the half duplex mode at the speed of 1000 Mb/s are required to report lateCollisionErrorStatus in response to a late collision; MACs operating in the half duplex mode at speeds of 100 Mb/s and below are not required to do so. TransmitStatus is not used by the service interface defined in 2.3.1. TransmitStatus may be used in an implementation dependent manner.

```
function TransmitFrame (
    destinationParam: AddressValue;
    sourceParam: AddressValue;
    lengthOrTypeParam: LengthOrTypeValue;
    dataParam: DataValue;
    fcsParamValue: CRCValue;
    fcsParamPresent: Bit): TransmitStatus;
procedure TransmitDataEncap; {Nested procedure; see body below}
begin
    if transmitEnabled then
        begin
            TransmitDataEncap;
            TransmitFrame := TransmitLinkMgmt
        end
    else TransmitFrame := transmitDisabled
end; {TransmitFrame}
```

If transmission is enabled, TransmitFrame calls the internal procedure TransmitDataEncap to construct the frame. Next, TransmitLinkMgmt is called to perform the actual transmission. The TransmitStatus returned indicates the success or failure of the transmission attempt.

TransmitDataEncap builds the frame and places the 32-bit CRC in the frame check sequence field:

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```
procedure TransmitDataEncap;
begin
   with outgoingFrame do
      begin {Assemble frame}
         view := fields;
         destinationField := destinationParam;
         sourceField := sourceParam;
         lengthOrTypeField := lengthOrTypeParam;
         if fcsParamPresent then
            begin
               dataField := dataParam; {No need to generate pad if the FCS is passed from MAC client}
               fcsField := fcsParamValue {Use the FCS passed from MAC client}
            end
         else
            begin
               dataField := ComputePad(dataParam);
               fcsField := CRC32(outgoingFrame)
            end;
         view := bits
      end {Assemble frame}
   with outgoingHeader do
      begin
         headerView := headerFields;
         preamble := ...; {* '1010...10,' LSB to MSB*}
         sfd := ...; {* '10101011,' LSB to MSB*}
         headerView := headerBits
      end
end; {TransmitDataEncap}
```

If the MAC client chooses to generate the frame check sequence field for the frame, it passes this field to the MAC sublayer via the fcsParamValue parameter. If the fcsParamPresent parameter is true, TransmitDataEncap uses the fcsParamValue parameter as the frame check sequence field for the frame. Such a frame shall not require any padding, since it is the responsibility of the MAC client to ensure that the frame meets the minFrameSize constraint. If the fcsParamPresent parameter is false, the fcsParamValue parameter is unspecified.TransmitDataEncap first calls the ComputePad function, followed by a call to the CRC32 function to generate the padding (if necessary) and the frame check sequence field for the frame internally to the MAC sublayer.

ComputePad appends an array of arbitrary bits to the MAC client data to pad the frame to the minimum frame size:

```
function ComputePad(var dataParam: DataValue): DataValue;
begin
   ComputePad := {Append an array of size padSize of arbitrary bits to the MAC client dataField}
end; {ComputePad}
```

TransmitLinkMgmt attempts to transmit the frame. In half duplex mode, it first defers to any passing traffic. In half duplex mode, if a collision occurs, transmission is terminated properly and retransmission is scheduled following a suitable backoff interval:

```
function TransmitLinkMgmt: TransmitStatus;
begin
   attempts := 0;
```

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```
    transmitSucceeding := false;
    lateCollisionCount := 0;
    deferred := false; {Initialize}
    excessDefer := false;
    while  (attempts < attemptLimit) and (not transmitSucceeding)
                                          and (not extend or lateCollisionCount = 0) do
                                  {No retransmission after late collision if operating at 1000 Mb/s}
      begin {Loop}
        if bursting then {This is a burst continuation}
          frameWaiting := true {Start transmission without checking deference}
        else {Non bursting case, or first frame of a burst}
          begin
            if attempts>0 then BackOff;
            frameWaiting := true;
            while deferring do {Defer to passing frame, if any[27]}
              if halfDuplex then deferred := true;
            burstStart := true;
            if burstMode then bursting := true
          end;
        lateCollisionError := false;
        StartTransmit;
        frameWaiting := false;
        if halfDuplex then
        begin
          while transmitting do WatchForCollision;
          if lateCollisionError then lateCollisionCount := lateCollisionCount + 1;
          attempts := attempts + 1
        end {Half duplex mode}
        else while transmitting do nothing {Full duplex mode}
      end; {Loop}
    LayerMgmtTransmitCounters; {Update transmit and transmit error counters in 5.2.4.2}
    if transmitSucceeding then
      begin
        if burstMode then burstStart := false; {Can't be the first frame anymore}
        TransmitLinkMgmt := transmitOK
      end
    else if (extend and lateCollisionCount > 0) then TransmitLinkMgmt := lateCollisionErrorStatus;
    else  TransmitLinkMgmt := excessiveCollisionError
  end;{TransmitLinkMgmt}
```

Each time a frame transmission attempt is initiated, StartTransmit is called to alert the BitTransmitter process that bit transmission should begin:

```
  procedure StartTransmit;
  begin
    currentTransmitBit := 1;
    lastTransmitBit := frameSize;
    lastHeaderBit := headerSize;
    transmitSucceeding := true;
    transmitting := true
  end; {StartTransmit}
```

[27] The Deference process ensures that the reception of traffic does not cause deferring to be true when in full duplex mode. Deferring is used in full duplex mode to enforce the minimum interpacket gap spacing.

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In half duplex mode, TransmitLinkMgmt monitors the medium for contention by repeatedly calling WatchForCollision, once frame transmission has been initiated:

```
procedure WatchForCollision;
begin
   if transmitSucceeding and collisionDetect then
      begin
         if currentTransmitBit > (slotTime – headerSize) then lateCollisionError := true;
         newCollision := true;
         transmitSucceeding := false;
         if burstMode then
         begin
            bursting := false;
            if not burstStart then
               lateCollisionError := true {Every collision is late, unless it hits the first frame in a burst}
         end
      end
end; {WatchForCollision}
```

WatchForCollision, upon detecting a collision, updates newCollision to ensure proper jamming by the BitTransmitter process. The current transmit bit number is checked to see if this is a late collision. If the collision occurs later than a collision window of slotTime bits into the packet, it is considered as evidence of a late collision. The point at which the collision is received is determined by the network media propagation time and the delay time through a station and, as such, is implementation-dependent (see 4.1.2.2). While operating at speeds of 100 Mb/s or lower, an implementation may optionally elect to end retransmission attempts after a late collision is detected. While operating at the speed of 1000 Mb/s, an implementation shall end retransmission attempts after a late collision is detected.

After transmission of the jam has been completed, if TransmitLinkMgmt determines that another attempt should be made, BackOff is called to schedule the next attempt to retransmit the frame.

```
function Random (low, high: integer): integer;
begin
   Random := ...{Uniformly distributed random integer r, such that low ≤ r < high}
end; {Random}
```

BackOff performs the truncated binary exponential backoff computation and then waits for the selected multiple of the slot time.

```
var maxBackOff: 2..1024; {Working variable of BackOff}
procedure BackOff;
begin
   if attempts = 1 then maxBackOff := 2
   else if attempts ≤ backOffLimit then maxBackOff := maxBackOff x 2;
   Wait(slotTime x Random(0, maxBackOff))
end; {BackOff}
```

BurstTimer is a process that does nothing unless the bursting variable is true. When bursting is true, BurstTimer increments burstCounter until the burstLimit limit is reached, whereupon BurstTimer assigns the value false to bursting:

```
process BurstTimer;
begin
```

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```
    cycle
        while not bursting do nothing; {Wait for a burst}
        Wait(burstLimit);
        bursting := false
    end {burstMode cycle}
end; {BurstTimer}
```

The Deference process runs asynchronously to continuously compute the proper value for the variable deferring. In the case of half duplex burst mode, deferring remains true throughout the entire burst. Interpacket gap spacing may be used to lower the average data rate of a MAC at operating speeds above 1000 Mb/s in the full duplex mode, when it is necessary to adapt it to the data rate of a WAN-based Physical Layer. When interpacket stretching is enabled, deferring remains true throughout the entire extended interpacket gap, which includes the sum of interPacketGap and the interpacket extension as determined by the BitTransmitter:

```
process Deference;
    var realTimeCounter: integer; wasTransmitting: Boolean;
begin
    if halfDuplex then cycle{Half duplex loop}
        while not carrierSense do nothing; {Watch for carrier to appear}
        deferring := true;  {Delay start of new transmissions}
        wasTransmitting := transmitting;
        while carrierSense or transmitting do wasTransmitting := wasTransmitting or transmitting;
        if wasTransmitting then Wait(interPacketGapPart1) {Time out first part of
            interpacket gap}
        else
            begin
                realTimeCounter := interPacketGapPart1;
                repeat
                    while carrierSense do realTimeCounter := interPacketGapPart1;
                    Wait(1);
                    realTimeCounter := realTimeCounter – 1
                until (realTimeCounter = 0)
            end;
        Wait(interPacketGapPart2); {Time out second part of
            interpacket gap}
        deferring := false; {Allow new transmissions to proceed}
        while frameWaiting do nothing {Allow waiting transmission, if any}
    end {Half duplex loop}
    else cycle {Full duplex loop}
        while not transmitting do nothing; {Wait for the start of a transmission}
        deferring := true; {Inhibit future transmissions}
        while transmitting do nothing; {Wait for the end of the current transmission}
        Wait(interPacketGap + ipgStretchSize × 8); {Time out entire interpacket
            gap and IPG extension}
        if not frameWaiting then {Don't roll over the remainder into the next frame}
            begin
                Wait(8);
                ipgStretchCount := 0
            end
        deferring := false {Don't inhibit transmission}
    end {Full duplex loop}
end; {Deference}
```

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If the ipgStretchMode is enabled, the Deference process continues to enforce interpacket gap for an additional number of bit times, after the completion of timing the interPacketGap. The additional number of bit times is reflected by the variable ipgStretchSize. If the variable ipgStretchCount is less than ipgStretchRatio and the next frame is ready for transmission (variable frameWaiting is true), the Deference process enforces interpacket gap only for the integer number of octets, as indicated by ipgStretchSize, and saves ipgStretchCount for the next frame's transmission. If the next frame is not ready for transmission (variable frameWaiting is false), then the Deference process initializes the ipgStretchCount variable to zero.

The BitTransmitter process runs asynchronously, transmitting bits at a rate determined by the Physical Layer's TransmitBit operation:

```
process BitTransmitter;
begin
   cycle {Outer loop}
      if transmitting then
         begin {Inner loop}
            extendError := false;
            if ifsStretchMode then {Calculate the counter values}
               begin
                  ipgStretchSize := (ipgStretchCount + headerSize +
                     frameSize + interPacketGap) div
                                          ipgStretchRatio; {Extension of the
                                          interpacket gap}
                  ipgStretchCount := (ipgStretchCount + headerSize +
                     frameSize + interPacketGap)
                        mod ipgStretchRatio {Remainder to carry over into
                           the next frame's transmission}
               end;
            PhysicalSignalEncap;  {Send preamble and start of frame delimiter}
            while transmitting do
               begin
                  if (currentTransmitBit > lastTransmitBit) then TransmitBit(extensionBit)
                  else if extendError then TransmitBit(extensionErrorBit) {Jam in extension}
                  else TransmitBit(outgoingFrame[currentTransmitBit]);
                  if newCollision then StartJam else NextBit
               end;
            if bursting then
               begin
                  interPacketSignal;
                  if extendError then
                     if transmitting then transmitting := false
                                       {TransmitFrame may have been called during
                                          interPacketSignal}
                     else IncLargeCounter(lateCollision);
                                       {Count late collisions which were missed by TransmitLinkMgmt}
                  bursting := bursting and (frameWaiting or transmitting)
               end
         end {Inner loop}
   end {Outer loop}
end; {BitTransmitter}
```

The bits transmitted to the Physical Layer can take one of four values: data zero (0), data one (1), extensionBit (EXTEND), or extensionErrorBit (EXTEND_ERROR). The values extensionBit and extensionErrorBit are not transmitted between the first preamble bit of a frame and the last data bit of a

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frame under any circumstances. The BitTransmitter calls the procedure TransmitBit with bitParam = extensionBit only when it is necessary to perform carrier extension on a frame after all of the data bits of a frame have been transmitted. The BitTransmitter calls the procedure TransmitBit with bitParam = extensionErrorBit only when it is necessary to jam during carrier extension.

```
procedure PhysicalSignalEncap;
begin
    while currentTransmitBit ≤ lastHeaderBit do
        begin
            TransmitBit(outgoingHeader[currentTransmitBit]); {Transmit header one bit at a time}
            currentTransmitBit := currentTransmitBit + 1
        end;
    if newCollision then StartJam else currentTransmitBit := 1
end; {PhysicalSignalEncap}
```

The procedure interPacketSignal fills the interpacket interval between the frames of a burst with extensionBits. InterPacketSignal also monitors the variable collisionDetect during the interpacket interval between the frames of a burst, and will end a burst if a collision occurs during the interpacket interval. The procedural model is defined such that a MAC operating in the burstMode will emit an extraneous sequence of interPacketSize extensionBits in the event that there are no additional frames ready for transmission after interPacketSignal returns. Implementations may be able to avoid sending this extraneous sequence of extensionBits if they have access to information (such as the occupancy of a transmit queue) that is not assumed to be available to the procedural model.

```
procedure interPacketSignal;
    var interPacketCount, interPacketTotal: integer;
begin
    interPacketCount := 0;
    interPacketTotal := interPacketSpacing;
    while interPacketCount < interPacketTotal do
        begin
            if not extendError then TransmitBit(extensionBit)
            else TransmitBit(extensionErrorBit);
            interPacketCount := interPacketCount + 1;
            if collisionDetect and not extendError then
            begin
                bursting := false;
                extendError := true;
                interPacketCount := 0;
                interPacketTotal := jamSize
            end
        end
end; {interPacketSignal}

procedure NextBit;
begin
    currentTransmitBit := currentTransmitBit + 1;
    if halfDuplex and burstStart and transmitSucceeding then {Carrier extension may be required}
        transmitting := (currentTransmitBit ≤ max(lastTransmitBit, slotTime))
    else transmitting := (currentTransmitBit ≤ lastTransmitBit)
end; {NextBit}

procedure StartJam;
begin
```

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```
    extendError := currentTransmitBit > lastTransmitBit;
    currentTransmitBit := 1;
    lastTransmitBit := jamSize;
    newCollision := false
end; {StartJam}
```

BitTransmitter, upon detecting a new collision, immediately enforces it by calling StartJam to initiate the transmission of the jam. The jam should contain a sufficient number of bits of arbitrary data so that it is assured that both communicating stations detect the collision. (StartJam uses the first set of bits of the frame up to jamSize, merely to simplify this program.)

4.2.9 Frame reception

The algorithms in this subclause define CSMA/CD Media Access sublayer frame reception.

The function ReceiveFrame implements the frame reception operation provided to the MAC client.

The ReceiveFrame operation is synchronous. The operation does not complete until a frame has been received. The fields of the frame are delivered via the output parameters with a status code.

The receiveDisabled status code (if layer management is implemented) indicates that the receiver is not enabled. Successful reception is indicated by the status code receiveOK. The frameTooLong error code (if layer management is implemented) indicates that the last frame received had a frameSize beyond the maximum allowable frame size. The code frameCheckError indicates that the frame received was damaged by a transmission error. The lengthError indicates that the lengthOrTypeParam value was both consistent with a length interpretation of this field (i.e., its value was less than or equal to maxValidFrame), and inconsistent with the frameSize of the received frame. The code alignmentError indicates that the frame received was damaged, and that in addition, its length was not an integer number of octets. ReceiveStatus is not mapped to any MAC client parameter by the service interface defined in 2.3.2. ReceiveStatus may be used in an implementation dependent manner.

```
function ReceiveFrame (
    var destinationParam: AddressValue;
    var sourceParam: AddressValue;
    var lengthOrTypeParam: LengthOrTypeValue;
    var dataParam: DataValue;
    var fcsParamValue: CRCValue;
    var fcsParamPresent: Bit): ReceiveStatus;
function ReceiveDataDecap: ReceiveStatus; {Nested function; see body below}
begin
    if receiveEnabled then
        repeat
            ReceiveLinkMgmt;
            ReceiveFrame := ReceiveDataDecap;
        until receiveSucceeding
    else ReceiveFrame := receiveDisabled
end; {ReceiveFrame}
```

If enabled, ReceiveFrame calls ReceiveLinkMgmt to receive the next valid frame, and then calls the internal function ReceiveDataDecap to return the frame's fields to the MAC client if the frame's address indicates that it should do so. The returned ReceiveStatus indicates the presence or absence of detected transmission errors in the frame.

```
function ReceiveDataDecap: ReceiveStatus;
```

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```
‡     var status: ReceiveStatus; {Holds receive status information}
   begin
‡     with incomingFrame do
‡        begin
‡           view := fields;
‡           receiveSucceeding := LayerMgmtRecognizeAddress(destinationField);
            if receiveSucceeding then
               begin {Disassemble MAC frame}
                  destinationParam := destinationField;
                  sourceParam := sourceField;
                  lengthOrTypeParam := lengthOrTypeField;
                  dataParam := RemovePad(lengthOrTypeField, dataField);
                  fcsParamValue := fcsField;
                  fcsParamPresent := passReceiveFCSMode;
                  exceedsMaxLength := ...; {Check to determine if received MAC frame size exceeds
                                            maxFrameSizeLimit.
                                            MAC implementations use maxFrameSizeLimit to
                                            determine if management counts the frame as too long.
                                            It is recommended that new implementations support
                                            maxFrameSizeLimit = maxEnvelopeFrameSize )
                  if exceedsMaxLength then status := frameTooLong
                  else if fcsField = CRC32(incomingFrame) and extensionOK then
‡                        if validLength then status := receiveOK else status := lengthError
‡                 else if excessBits = 0 or not extensionOK then status := frameCheckError
‡                 else status := alignmentError;
‡                 LayerMgmtReceiveCounters(status); {Update receive counters in 5.2.4.3}
                  view := bits
               end {Disassemble MAC frame}
‡        end; {With incomingFrame}
‡     ReceiveDataDecap := status
   end; {ReceiveDataDecap}

   function LayerMgmtRecognizeAddress(address: AddressValue): Boolean;
   begin
      if {promiscuous receive enabled} then LayerMgmtRecognizeAddress := true;
      if address = ... {MAC station address} then LayerMgmtRecognizeAddress := true;
      if address = ... {Broadcast address} then LayerMgmtRecognizeAddress := true;
      if address = ... {One of the addresses on the multicast list and multicast reception is enabled} then
                                                LayerMgmtRecognizeAddress := true;
      LayerMgmtRecognizeAddress := false
   end; {LayerMgmtRecognizeAddress}
```

The function RemovePad strips any padding that was generated to meet the minFrameSize constraint, if possible. When the MAC sublayer operates in the mode that enables passing of the frame check sequence field of all received MAC frames to the MAC client (passReceiveFCSMode variable is true), it shall not strip the padding and it shall leave the data field of the MAC frame intact. Length checking is provided for Length interpretations of the Length/Type field. For Length/Type field values in the range between maxBasicDataSize and minTypeValue, the behavior of the RemovePad function is unspecified:

```
   function RemovePad(var lengthOrTypeParam: LengthOrTypeValue; dataParam: DataValue): DataValue;
   begin
      if lengthOrTypeParam ≥ minTypeValue then
         begin
            validLength := true; {Don't perform length checking for Type interpretation}
```

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```
            RemovePad := dataParam
        end
    else if lengthOrTypeParam ≤ maxBasicDataSize then
        begin
            validLength := {For length interpretations of the Length/Type field, check to determine if value
                            represented by Length/Type field matches the received clientDataSize};
            if validLength and not passReceiveFCSMode then
                RemovePad := {Truncate the dataParam (when present) to the value represented by the
                              lengthOrTypeParam (in octets) and return the result}
            else RemovePad := dataParam
        end
end; {RemovePad}
```

ReceiveLinkMgmt attempts repeatedly to receive the bits of a frame, discarding any fragments from collisions by comparing them to the minimum valid frame size:

```
procedure ReceiveLinkMgmt;
begin
    repeat
        StartReceive;
        while receiving do nothing; {Wait for frame to finish arriving}
        excessBits := frameSize mod 8;
        frameSize := frameSize – excessBits; {Truncate to octet boundary}
        receiveSucceeding := receiveSucceeding and (frameSize ≥ minFrameSize)
                                                {Reject collision fragments}
    until receiveSucceeding
end; {ReceiveLinkMgmt}

procedure StartReceive;
begin
    receiveSucceeding := true;
    receiving := true
end; {StartReceive}
```

The BitReceiver process runs asynchronously, receiving bits from the medium at the rate determined by the Physical Layer's ReceiveBit operation, partitioning them into frames, and optionally receiving them:

```
process BitReceiver;
    var   b: PhysicalBit;
          incomingFrameSize: integer; {Count of all bits received in frame including extension}
          frameFinished: Boolean;
          enableBitReceiver: Boolean;
          currentReceiveBit: 1..frameSize; {Position of current bit in incomingFrame}
begin
    cycle {Outer loop}
        if receiveEnabled then
            begin {Receive next frame from Physical Layer}
                currentReceiveBit := 1;
                incomingFrameSize := 0;
                frameFinished := false;
                enableBitReceiver := receiving;
                PhysicalSignalDecap; {Skip idle and extension, strip off preamble and sfd}
                if enableBitReceiver then extensionOK := true;
                while receiveDataValid and not frameFinished do
```

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```
            begin {Inner loop to receive the rest of an incoming frame}
               b := ReceiveBit; {Next bit from physical medium}
               incomingFrameSize := incomingFrameSize + 1;
               if b = 0 or b = 1 then {Normal case}
                  if enableBitReceiver then {Append to frame}
                  begin
                     if incomingFrameSize > currentReceiveBit then extensionOK := false;
                                          {Errors in the extension get mapped to data bits on input}
                     incomingFrame[currentReceiveBit] := b;
                     currentReceiveBit := currentReceiveBit + 1
                  end
               else if not extending then frameFinished := true; {b must be an extensionBit}
               if incomingFrameSize ≥ slotTime then extending := false
            end; {Inner loop}
         if enableBitReceiver then
            begin
               frameSize := currentReceiveBit – 1;
               receiveSucceeding := not extending;
               receiving := false
            end
      end {Enabled}
   end {Outer loop}
end; {BitReceiver}
```

The bits received from the Physical Layer can take one of three values: data zero (0), data one (1), or extensionBit (EXTEND). The value extensionBit will not occur between the first preamble bit of a frame and the last data bit of a frame in normal circumstances. Extension bits are counted by the BitReceiver but are not appended to the incoming frame. The BitReceiver checks whether the bit received from the Physical Layer is a data bit or an extensionBit before appending it to the incoming frame. Thus, the array of bits in incomingFrame will only contain data bits. The underlying Reconciliation Sublayer (RS) maps incoming EXTEND_ERROR bits to normal data bits. Thus, the reception of additional data bits after the frame extension has started is an indication that the frame should be discarded.

```
procedure PhysicalSignalDecap;
begin
   {Receive one bit at a time from physical medium until a valid sfd is detected, discard bits and return}
end; {PhysicalSignalDecap}
```

The process SetExtending controls the extending variable, which determines whether a received frame must be at least slotTime bits in length or merely minFrameSize bits in length to be considered valid by the BitReceiver. SetExtending sets the extending variable to true whenever receiveDataValid is de-asserted, while in half duplex mode at an operating speed of 1000 Mb/s:

```
process SetExtending;
begin
   cycle {Loop forever}
      while receiveDataValid do nothing;
      extending := extend and halfDuplex
   end {Loop}
end; {SetExtending}
```

4.2.10 Common procedures

The function CRC32 is used by both the transmit and receive algorithms to generate a 32-bit CRC value:

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```
function CRC32(f: Frame): CRCValue;
begin
    CRC32 := {The 32-bit CRC for the entire frame as defined in 3.2.9, excluding the FCS field (if pres-
             ent)}
end; {CRC32}
```

Purely to enhance readability, the following procedure is also defined:

procedure nothing; *begin end*;

The idle state of a process (that is, while waiting for some event) is cast as repeated calls on this procedure.

4.3 Interfaces to/from adjacent layers

4.3.1 Overview

The purpose of this clause is to provide precise definitions of the interfaces between the architectural layers defined in Clause 1 in compliance with the Media Access Service Specification given in Clause 2. In addition, the services required from the physical medium are defined.

The notation used here is the Pascal language, in keeping with the procedural nature of the precise MAC sublayer specification (see 4.2). Each interface is described as a set of procedures or shared variables, or both, that collectively provide the only valid interactions between layers. The accompanying text describes the meaning of each procedure or variable and points out any implicit interactions among them.

Note that the description of the interfaces in Pascal is a notational technique, and in no way implies that they can or should be implemented in software. This point is discussed more fully in 4.2, that provides complete Pascal declarations for the data types used in the remainder of this clause. Note also that the synchronous (one frame at a time) nature of the frame transmission and reception operations is a property of the architectural interface between the MAC client and MAC sublayers, and need not be reflected in the implementation interface between a station and its sublayer.

4.3.2 MAC service

The services provided to the MAC client by the MAC sublayer are transmission and reception of MAC frames using service primitives MA_DATA.request and MA_DATA.indication, as defined in Clause 2. For historical reasons the MAC sublayer definitions use two functions, TransmitFrame and ReceiveFrame, defined in 4.2.8 and 4.2.9. The relationship between these two functions and the service primitives is defined by the MAC client state diagrams in 4.3.2.1 and 4.3.2.2.

The state machines in 4.3.2 follow the conventions in 21.5.

4.3.2.1 MAC client transmit interface state diagram

4.3.2.1.1 Variables

data
: The value of mac_service_data_unit excluding the first two octets (Length/Type field).

destination_address
: The Destination Address field parsed from the client request.

fcsPresent
: Indicates whether the MA_DATA.request service primitive contained the frame_check_sequence field.

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frame_check_sequence
: The fcs field parsed from the client request.

lengthOrType
: The value of the first two octets at the start of the mac_service_data_unit.

mac_service_data_unit
: The concatenation of the lengthOrType field and the data field parsed from the client request.

source_address
: The Source Address field parsed from the client request.

TransmitStatus
: Indicates the status of the transmitted MAC frame. See 4.2.8.

4.3.2.1.2 Functions

TransmitFrame
: The MAC sublayer function invoked to transmit a MAC frame with the specified parameters. See 4.2.8.

4.3.2.1.3 Messages

MA_DATA.request
: The service primitive used to convey a MAC frame to be transmitted from the MAC client. See 2.3.1. The action invoked is not considered to end until the transmission of the frame by the MAC has concluded.

4.3.2.1.4 MAC client transmit interface state diagram

Figure 4–6 specifies the behavior of the transmit interface from the MAC client.

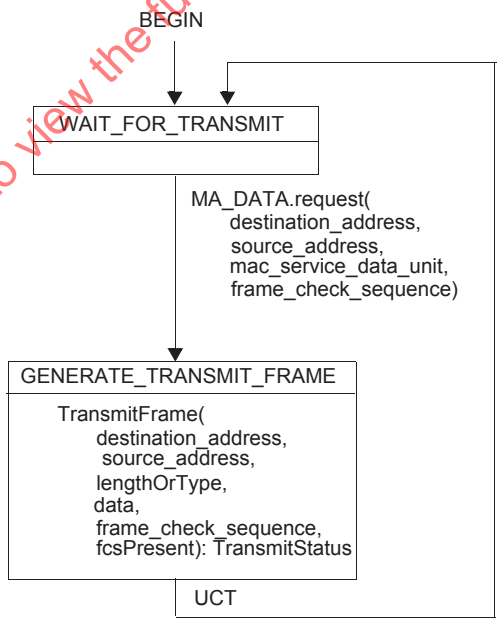

Figure 4–6— MAC client transmit interface state diagram

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4.3.2.2 MAC client receive interface state diagram

4.3.2.2.1 Variables

destination_address
: The Destination Address field parsed from the received MAC frame.

source_address
: The Source Address field parsed from the received MAC frame.

lengthOrType
: The lengthOrType field parsed from the received MAC frame.

data
: The data payload field parsed from the received MAC frame.

fcsPresent
: A Boolean set by the MAC sublayer.

ReceiveStatus
: Indicates the status of the received MAC frame.

mac_service_data_unit
: The concatenation of the lengthOrType field and the data field parsed from the received MAC frame.

frame_check_sequence
: The fcs field parsed from the received MAC frame.

4.3.2.2.2 Functions

ReceiveFrame
: The MAC sublayer function invoked to accept an incoming MAC frame with the specified parameters. See 4.2.9.

4.3.2.2.3 Messages

MA_DATA.indication
: The service primitive used to transfer an incoming MAC frame to the MAC client with the specified parameters. See 2.3.2.

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4.3.2.2.4 MAC client receive interface state diagram

Figure 4–7 specifies the behavior of the receive interface to the MAC client.

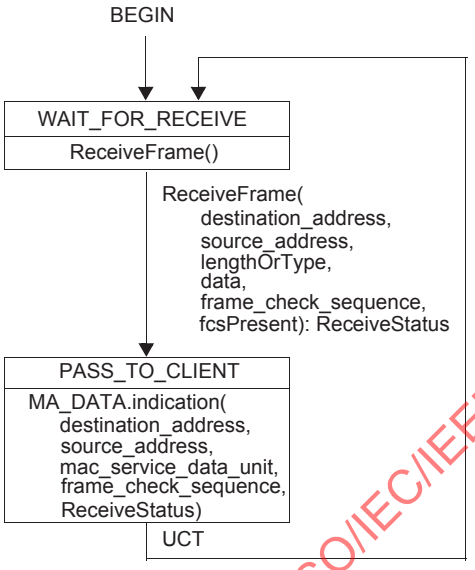

Figure 4–7—MAC client receive interface state diagram

4.3.3 Services required from the Physical Layer

The interface through which the CSMA/CD MAC sublayer uses the facilities of the Physical Layer consists of a function, a pair of procedures and four Boolean variables:

Table 4–1—Physical Layer interface

Function	Procedures	Variables
ReceiveBit	TransmitBit Wait	collisionDetect carrierSense receiveDataValid transmitting

During transmission, the contents of an outgoing frame are passed from the MAC sublayer to the Physical Layer by way of repeated use of the TransmitBit operation:

procedure TransmitBit (bitParam: PhysicalBit);

Each invocation of TransmitBit passes one new bit of the outgoing frame to the Physical Layer. The TransmitBit operation is synchronous. The duration of the operation is the entire transmission of the bit. The operation completes, when the Physical Layer is ready to accept the next bit and it transfers control to the MAC sublayer.

The overall event of data being transmitted is signaled to the Physical Layer by way of the variable transmitting:

var transmitting: Boolean;

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Before sending the first bit of a frame, the MAC sublayer sets transmitting to true, to inform the Physical Media Access that a stream of bits will be presented via the TransmitBit operation. After the last bit of the frame has been presented, the MAC sublayer sets transmitting to false to indicate the end of the frame.

The presence of a collision in the physical medium is signaled to the MAC sublayer by the variable collisionDetect:

var collisionDetect: Boolean*;*

The collisionDetect signal remains true during the duration of the collision.

NOTE—In full duplex mode, collision indications may still be generated by the Physical Layer; however, they are ignored by the full duplex MAC.

The collisionDetect signal is generated only during transmission and is never true at any other time; in particular, it cannot be used during frame reception to detect collisions between overlapping transmissions from two or more other stations.

During reception, the contents of an incoming frame are retrieved from the Physical Layer by the MAC sublayer via repeated use of the ReceiveBit operation:

function ReceiveBit: PhysicalBit;

Each invocation of ReceiveBit retrieves one new bit of the incoming frame from the Physical Layer. The ReceiveBit operation is synchronous. Its duration is the entire reception of a single bit. Upon receiving a bit, the MAC sublayer shall immediately request the next bit until all bits of the frame have been received. (See 4.2 for details.)

The overall event of data being received is signaled to the MAC sublayer by the variable receiveDataValid:

var receiveDataValid: Boolean*;*

When the Physical Layer sets receiveDataValid to true, the MAC sublayer shall immediately begin retrieving the incoming bits by the ReceiveBit operation. When receiveDataValid subsequently becomes false, the MAC sublayer can begin processing the received bits as a completed frame. If an invocation of ReceiveBit is pending when receiveDataValid becomes false, ReceiveBit returns an undefined value, which should be discarded by the MAC sublayer. (See 4.2 for details.)

NOTE—When a burst of frames is received in half duplex mode at an operating speed of 1000 Mb/s, the variable receiveDataValid will remain true throughout the burst. Furthermore, the variable receiveDataValid remains true throughout the extension field. In these respects, the behavior of the variable receiveDataValid is different from the underlying GMII signal RX_DV, from which it may be derived. See 35.2.1.7.

The overall event of activity on the physical medium is signaled to the MAC sublayer by the variable carrierSense:

var carrierSense: Boolean*;*

In half duplex mode, the MAC sublayer shall monitor the value of carrierSense to defer its own transmissions when the medium is busy. The Physical Layer sets carrierSense to true immediately upon detection of activity on the physical medium. After the activity on the physical medium ceases, carrierSense is set to false. Note that the true/false transitions of carrierSense are not defined to be precisely synchronized with the beginning and the end of the frame, but may precede the beginning and lag the end, respectively. (See 4.2 for details.) In full duplex mode, carrierSense is undefined.

The Physical Layer also provides the procedure Wait:

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procedure Wait (bitTimes: integer)*;*

This procedure waits for the specified number of bit times. This allows the MAC sublayer to measure time intervals in units of the (physical-medium-dependent) bit time.

Another important property of the Physical Layer, which is an implicit part of the interface presented to the MAC sublayer, is the round-trip propagation time of the physical medium. Its value represents the maximum time required for a signal to propagate from one end of the network to the other, and for a collision to propagate back. The round-trip propagation time is primarily (but not entirely) a function of the physical size of the network. The round-trip propagation time of the Physical Layer is defined in 4.4 for a selection of physical media.

4.4 Specific implementations

4.4.1 Compatibility overview

To provide total compatibility at all levels of the standard, it is required that each network component implementing the CSMA/CD MAC sublayer procedure adheres rigidly to these specifications. The information provided in 4.4.2 provides design parameters for specific implementations of this access method. Variations from these values result in a system implementation that violates the standard.

A DTE shall be capable of operating in half duplex mode, full duplex mode, or both. In any given instantiation of a network conforming to this standard, all stations shall be configured to use the same mode of operation, either half duplex or full duplex.

All DTEs connected to a repeater or a mixing segment shall be configured to use the half duplex mode of operation. When a pair of DTEs are connected to each other with a link segment, both devices shall be configured to use the same mode of operation, either half duplex or full duplex.

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4.4.2 MAC parameters

The parameter values shown in Table 4–2 shall be used for their corresponding MAC data rate.

Table 4–2—MAC parameters

Parameters	MAC data rate			
	Up to and including 100 Mb/s	**1 Gb/s**	**10 Gb/s**	**40 Gb/s and 100 Gb/s**
slotTime	512 bit times	4096 bit times	not applicable	not applicable
interPacketGap[a]	96 bits	96 bits	96 bits	96 bits
attemptLimit	16	16	not applicable	not applicable
backoffLimit	10	10	not applicable	not applicable
jamSize	32 bits	32 bits	not applicable	not applicable
maxBasicFrameSize	1518 octets	1518 octets	1518 octets	1518 octets
maxEnvelopeFrameSize	2000 octets	2000 octets	2000 octets	2000 octets
minFrameSize	512 bits (64 octets)	512 bits (64 octets)	512 bits (64 octets)	512 bits (64 octets)
burstLimit	not applicable	65 536 bits	not applicable	not applicable
ipgStretchRatio	not applicable	not applicable	104 bits	not applicable

[a]References to interFrameGap or interFrameSpacing in other clauses (e.g., 13, 35, and 42) shall be interpreted as interPacketGap.

NOTE 1—For 10 Mb/s operation, the spacing between two successive non-colliding packets, from start of idle at the end of the first packet to start of Preamble of the subsequent packet, can have a minimum value of 47 BT (bit times), at the AUI receive line of the DTE. This interpacket gap shrinkage is caused by variable network delays, added preamble bits, and clock skew.

NOTE 2—For 1BASE-5operation, see also DTE Deference Delay in 12.9.2.

NOTE 3—For 1 Gb/s operation, the spacing between two non-colliding packets, from the last bit of the FCS field of the first packet to the first bit of the Preamble of the second packet, can have a minimum value of 64 BT (bit times), as measured at the GMII receive signals at the DTE. This interpacket gap shrinkage may be caused by variable network delays, added preamble bits, and clock tolerances.

NOTE 4—For 10 Gb/s operation, the spacing between two packets, from the last bit of the FCS field of the first packet to the first bit of the Preamble of the second packet, can have a minimum value of 40 BT (bit times), as measured at the XGMII receive signals at the DTE. This interpacket gap shrinkage may be caused by variable network delays and clock tolerances.

NOTE 5—For 10 Gb/s operation, the value of ipgStretchRatio of 104 bits adapts the average data rate of the MAC sublayer to SONET/SDH STS-192 data rate (with frame granularity), for WAN-compatible applications of this standard.

NOTE 6—For 10 Mb/s half-duplex operation, the use of envelope frames is not recommended for use with repeaters, as described in Clause 9, as a result of possible frame corruption due to clock skew.

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NOTE 7—For 40 Gb/s and 100 Gb/s operation, the received interpacket gap (the spacing between two packets, from the last bit of the FCS field of the first packet to the first bit of the Preamble of the second packet) can have a minimum value of 8 BT (bit times), as measured at the XLGMII or CGMII receive signals at the DTE due to clock tolerance and lane alignment requirements.

WARNING

Any deviation from the above specified values may affect proper operation of the network.

4.4.3 Configuration guidelines

The operational mode of the MAC may be determined either by the Auto-Negotiation functions specified in Clause 28 and Clause 37, or through manual configuration. When manual configuration is used, the devices on both ends of a link segment must be configured to matching modes to ensure proper operation. When Auto-Negotiation is used, the MAC must be configured to the mode determined by Auto-Negotiation before assuming normal operation.

NOTE—Improper configuration of duplex modes may result in improper network behavior.

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5. Layer Management

All parts of Clause 5, except for 5.2.4 and its subclauses, are deprecated by Clause 30.

5.1 Introduction

This clause provides the Layer Management specification for DTEs based on the CSMA/CD access method. It defines facilities comprised of a set of statistics and actions needed to provide Layer Management services. The information in this clause should be used in conjunction with the Procedural Model defined in 4.2.7–4.2.10. The Procedural Model provides a formal description of the relationship between the CSMA/CD Layer Entities and the Layer Management facilities.

This Layer Management specification has been developed in accordance with the OSI management architecture as specified in the ISO Management Framework document, ISO/IEC 7498-4:1989. It is independent of any particular management application or management protocol.

The management facilities defined in this standard may be accessed both locally and remotely. Thus, the Layer Management specification provides facilities that can be accessed from within a station or can be accessed remotely by means of a peer management protocol operating between application entities.

In CSMA/CD no peer management facilities are necessary for initiating or terminating normal protocol operations or for handling abnormal protocol conditions. The monitoring of these activities is done by the carrier sense and collision detection mechanisms. Since these activities are necessary for normal operation of the protocol, they are not considered to be a function of Layer Management and are therefore not discussed in this clause.

Implementation of DTE Management is not a requirement for conformance to Clause 4 and Clause 7.

5.1.1 Systems Management overview

Within the ISO/IEC Open Systems Interconnection (OSI) architecture, the need to handle the special problems of initializing, terminating, and monitoring ongoing activities and assisting in their harmonious operations, as well as handling abnormal conditions, is recognized. These needs are collectively addressed by the systems management component of the OSI architecture.

A Management Protocol is required for the exchange of information between systems on a network. This Layer Management clause is independent of any particular Management Protocol.

This Layer Management clause, in conjunction with the Layer Management standards of other layers, provides the means to perform various management functions. Layer Management collects information needed from the MAC and Physical Layers. It also provides a means to exercise control over those layers.

The relationship between the various management entities and the layer entities according to the ISO model is shown in Figure 19–1.

5.1.2 Layer Management model

The Layer Management facilities provided by the CSMA/CD MAC and Physical Layer management definitions provide the ability to manipulate management counters and initiate actions within the layers.

The managed objects within this standard are defined as sets of attributes, actions, notifications, and behaviors in accordance with IEEE Std 802-2001 and ISO/IEC International Standards for network management.

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The precise semantics of the relationship between the CSMA/CD Layer Entities and the Layer Management facilities are defined in 4.2.7–4.2.10 and in 5.2.4.

5.1.3 Packages

This standard and ISO/IEC guidelines make provision for grouping attributes, operations and notifications in implementation groups or "packages" within each managed object class. DTE Management has two packages that are required for management at the minimum conformance configuration. The basic package is also useful for system configurations that wish to implement MAU Management without DTE Management. The packages for DTE Management are specified in Table 1.

5.1.4 Conformance requirements

Implementation of both the basic and the mandatory package of the MAC entity are the minimum requirements for claiming conformance to DTE Management.

5.2 Management facilities

5.2.1 Introduction

This subclause of the standard defines the Layer Management facilities for the Ethernet MAC and Physical Layers. The intent of this subclause is to furnish a management specification that can be used by the wide variety of different DTE devices that may be attached to a network specified by this standard. Thus, a comprehensive list of management facilities is provided.

The improper use of some of the facilities described in this subclause may cause serious disruption of the network. In accordance with ISO management architecture, any necessary security provisions should be provided by the Agent in the Local System Environment. This can be in the form of specific security features or in the form of security features provided by the peer communication facilities.

All counters defined in this specification are assumed to be wraparound counters. Wraparound counters are those that automatically go from their maximum value (or final value) to zero and continue to operate. These unsigned counters do not provide for any explicit means to return them to their minimum (zero), i.e., reset. Because of their nature, wraparound counters should be read frequently enough to avoid loss of information.

5.2.2 DTE MAC Sublayer Management facilities

This subclause defines the Layer Management facilities specific to the MAC sublayer Managed Object Class. Note that with regard to reception-related error statistics, a hierarchical order has been established such that when multiple error statuses can be associated with one frame, only one status is returned to the LLC. This hierarchy in descending order is as follows:

frameTooLong

alignmentError

frameCheckError

lengthError

The counters are primarily incremented based on the status returned to the LLC, and therefore the hierarchical order of the counters is determined by the order of the status. Frame fragments are not included in any of

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the statistics unless otherwise stated. In implementing any of the specified actions, receptions and transmissions that are in progress are completed before the action takes effect.

Table 5-1—Packages

			Basic Package (Mandatory)	Mandatory Package (Mandatory)	Recommended Package (Optional)	Optional Package (Optional)	Array Package (Optional)	Excessive Deferral Package (Optional)
oMAC-entity managed object class								
aMACID	ATTRIBUTE	GET	X					
aFramesTransmittedOK	ATTRIBUTE	GET			X			
aSingleCollisionFrames	ATTRIBUTE	GET			X			
aMultipleCollisionFrames	ATTRIBUTE	GET			X			
aFramesReceivedOK	ATTRIBUTE	GET			X			
aFrameCheckSequenceErrors	ATTRIBUTE	GET			X			
aAlignmentErrors	ATTRIBUTE	GET			X			
acInitializeMAC	ACTION		X					
aOctetsTransmittedOK	ATTRIBUTE	GET				X		
aFramesWithDeferredXmissions	ATTRIBUTE	GET				X		
aLateCollisions	ATTRIBUTE	GET				X		
aFramesAbortedDueToXSColls	ATTRIBUTE	GET				X		
aFramesLostDueToIntMACXmitError	ATTRIBUTE	GET				X		
aCarrierSenseErrors	ATTRIBUTE	GET				X		
aOctetsReceivedOK	ATTRIBUTE	GET				X		
aFramesLostDueToIntMACRcvError	ATTRIBUTE	GET				X		
aPromiscuousStatus	ATTRIBUTE	GET-SET				X		
aReadMulticastAddressList	ATTRIBUTE	GET				X		
acAddGroupAddress	ACTION					X		
acDeleteGroupAddress	ACTION					X		
aMulticastFramesXmittedOK	ATTRIBUTE	GET					X	
aBroadcastFramesXmittedOK	ATTRIBUTE	GET					X	
aFramesWithExcessiveDeferral	ATTRIBUTE	GET						X
aMulticastFramesReceivedOK	ATTRIBUTE	GET					X	
aBroadcastFramesReceivedOK	ATTRIBUTE	GET					X	
aInRangeLengthErrors	ATTRIBUTE	GET					X	
aOutOfRangeLengthField	ATTRIBUTE	GET					X	
aFrameTooLongErrors	ATTRIBUTE	GET					X	
aMACEnableStatus	ATTRIBUTE	GET-SET					X	
aTransmitEnableStatus	ATTRIBUTE	GET-SET					X	
aMulticastReceiveStatus	ATTRIBUTE	GET-SET					X	
aReadWriteMACAddress	ATTRIBUTE	GET-SET					X	
acExecuteSelfTest	ACTION						X	
aCollisionFrames	ATTRIBUTE	GET						X
oResourceTypeID managed object class								
aResourceTypeIDName	ATTRIBUTE	GET	X					
aResourceInfo	ATTRIBUTE	GET	X					
oPHY-entity managed object class								
aPHYID	ATTRIBUTE	GET				X		
aSQETestErrors	ATTRIBUTE	GET				X		

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5.2.2.1 DTE MAC sublayer attributes

5.2.2.1.1 aMACID

ATTRIBUTE
APPROPRIATE SYNTAX:
INTEGER
BEHAVIOUR DEFINED AS:
The value of aMACID is assigned so as to uniquely identify a MAC among the subordinate managed objects of the containing object.

5.2.2.1.2 aFramesTransmittedOK

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 16 000 counts per second.
BEHAVIOUR DEFINED AS:
A count of frames that are successfully transmitted. This counter is incremented when the TransmitStatus is reported as transmitOK. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2).

5.2.2.1.3 aSingleCollisionFrames

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 13 000 counts per second.
BEHAVIOUR DEFINED AS:
A count of frames that are involved in a single collision and are subsequently transmitted successfully. This counter is incremented when the result of a transmission is reported as transmitOK and the attempt value is 2. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2).

5.2.2.1.4 aMultipleCollisionFrames

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 11 000 counts per second.
BEHAVIOUR DEFINED AS:
A count of frames that are involved in more than one collision and are subsequently transmitted successfully. This counter is incremented when the TransmitStatus is reported as transmitOK and the value of the attempts variable is greater than 2 and less or equal to attemptLimit. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2).

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5.2.2.1.5 aFramesReceivedOK

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 16 000 counts per second.
BEHAVIOUR DEFINED AS:
A count of frames that are successfully received (receiveOK). This does not include frames received with frame-too-long, FCS, length or alignment errors, or frames lost due to internal MAC sublayer error. This counter is incremented when the ReceiveStatus is reported as receiveOK. The actual update occurs in the LayerMgmtReceiveCounters procedure (5.2.4.3).

5.2.2.1.6 aFrameCheckSequenceErrors

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 16 000 counts per second.
BEHAVIOUR DEFINED AS:
A count of frames that are an integral number of octets in length and do not pass the FCS check. This counter is incremented when the ReceiveStatus is reported as frameCheckError. The actual update occurs in the LayerMgmtReceiveCounters procedure (5.2.4.3).

5.2.2.1.7 aAlignmentErrors

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 16 000 counts per second.
BEHAVIOUR DEFINED AS:
A count of frames that are not an integral number of octets in length and do not pass the FCS check. This counter is incremented when the ReceiveStatus is reported as alignmentError. The actual update occurs in the LayerMgmtReceiveCounters procedure (5.2.4.3).

5.2.2.1.8 aOctetsTransmittedOK

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 1 230 000 counts per second.
BEHAVIOUR DEFINED AS:
A count of data and padding octets of frames that are successfully transmitted. This counter is incremented when the TransmitStatus is reported as transmitOK. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2).

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5.2.2.1.9 aFramesWithDeferredXmissions

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 13 000 counts per second.
BEHAVIOUR DEFINED AS:
A count of frames whose transmission was delayed on its first attempt because the medium was busy. This counter is incremented when the boolean variable deferred has been asserted by the TransmitLinkMgmt function (4.2.8). Frames involved in any collisions are not counted. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2).

5.2.2.1.10 aLateCollisions

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 16 000 counts per second.
BEHAVIOUR DEFINED AS:
A count of the times that a collision has been detected later than 512 bit times into the transmitted packet. A late collision is counted twice, i.e., both as a collision and as a lateCollision. This counter is incremented when the lateCollisionCount variable is nonzero. The actual update is incremented in the LayerMgmtTransmitCounters procedure (5.2.4.2).

5.2.2.1.11 aFramesAbortedDueToXSColls

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 3255 counts per second.
BEHAVIOUR DEFINED AS:
A count of the frames that due to excessive collisions are not transmitted successfully. This counter is incremented when the value of the attempts variable equals attemptLimit during a transmission. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2).

5.2.2.1.12 aFramesLostDueToIntMACXmitError

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 75 000 counts per second.
BEHAVIOUR DEFINED AS:
A count of frames that would otherwise be transmitted by the station, but could not be sent due to an internal MAC sublayer transmit error. If this counter is incremented, then none of the other counters in this subclause are incremented. The exact meaning and mechanism for incrementing this counter is implementation dependent.

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5.2.2.1.13 aCarrierSenseErrors

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 16 000 counts per second.
BEHAVIOUR DEFINED AS:
A count of times that the carrierSense variable was not asserted or was deasserted during the transmission of a frame without collision (see 7.2.4.6). This counter is incremented when the carrierSenseFailure flag is true at the end of transmission. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2).

5.2.2.1.14 aOctetsReceivedOK

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 1 230 000 counts per second.
BEHAVIOUR DEFINED AS:
A count of data and padding octets in frames that are successfully received. This does not include octets in frames received with frame-too-long, FCS, length or alignment errors, or frames lost due to internal MAC sublayer error. This counter is incremented when the result of a reception is reported as a receiveOK status. The actual update occurs in the LayerMgmtReceiveCounters procedure (5.2.4.3).

5.2.2.1.15 aFramesLostDueToIntMACRcvError

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 16 000 counts per second.
BEHAVIOUR DEFINED AS:
A count of frames that would otherwise be received by the station, but could not be accepted due to an internal MAC sublayer receive error. If this counter is incremented, then none of the other counters in this subclause are incremented. The exact meaning and mechanism for incrementing this counter is implementation dependent.

5.2.2.1.16 aPromiscuousStatus

ATTRIBUTE
APPROPRIATE SYNTAX:
BOOLEAN
BEHAVIOUR DEFINED AS:
A GET operation returns the value true for promiscuous mode enabled, and false otherwise.
Frames without errors received solely because this attribute has the value true are counted as frames received correctly; frames received in this mode that do contain errors update the appropriate error counters.
A SET operation to the value true provides a means to cause the LayerMgmtRecognizeAddress function to accept frames regardless of their destination address.

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A SET operation to the value false causes the MAC sublayer to return to the normal operation of carrying out address recognition procedures for station, broadcast, and multicast group addresses (LayerMgmtRecognizeAddress function).;

5.2.2.1.17 aReadMulticastAddressList

ATTRIBUTE
APPROPRIATE SYNTAX:
Sequence of MAC addresses.
BEHAVIOUR DEFINED AS:
Return the current multicast address list.;

5.2.2.1.18 aMulticastFramesXmittedOK

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 16 000 counts per second.
BEHAVIOUR DEFINED AS:
A count of frames that are successfully transmitted, as indicated by the status value transmitOK, to a group destination address other than broadcast. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2).

5.2.2.1.19 aBroadcastFramesXmittedOK

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 16 000 counts per second.
BEHAVIOUR DEFINED AS:
A count of the frames that were successfully transmitted, as indicated by the TransmitStatus transmitOK, to the broadcast address. Frames transmitted to multicast addresses are not broadcast frames and are excluded. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2).

5.2.2.1.20 aFramesWithExcessiveDeferral

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 412 counts per second.
BEHAVIOUR DEFINED AS:
A count of frames that deferred for an excessive period of time. This counter may only be incremented once per LLC transmission. This counter is incremented when the excessDefer flag is set. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2).

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5.2.2.1.21 aMulticastFramesReceivedOK

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 16 000 counts per second.
BEHAVIOUR DEFINED AS:
A count of frames that are successfully received and are directed to an active nonbroadcast group address. This does not include frames received with frame-too-long, FCS, length, or alignment errors, or frames lost due to internal MAC sublayer error. This counter is incremented as indicated by the receiveOK status, and the value in the destinationField. The actual update occurs in the LayerMgmtReceiveCounters procedure (5.2.4.3).

5.2.2.1.22 aBroadcastFramesReceivedOK

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 16 000 counts per second.
BEHAVIOUR DEFINED AS:
A count of frames that are successfully received and are directed to the broadcast group address. This does not include frames received with frame-too-long, FCS, length, or alignment errors, or frames lost due to internal MAC sublayer error. This counter is incremented as indicated by the receiveOK status, and the value in the destinationField. The actual update occurs in the LayerMgmtReceiveCounters procedure (5.2.4.3).

5.2.2.1.23 aInRangeLengthErrors

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 16 000 counts per second.
BEHAVIOUR DEFINED AS:
A count of frames with a length field value between the minimum unpadded LLC data size and the maximum allowed LLC data size, inclusive, that does not match the number of LLC data octets received. The counter also contains frames with a length field value less than the minimum unpadded LLC data size. The actual update occurs in the LayerMgmtReceiveCounters procedure (5.2.4.3).

5.2.2.1.24 aOutOfRangeLengthField

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 16 000 counts per second.
BEHAVIOUR DEFINED AS:
A count of frames with a length field value greater than the maximum allowed LLC data size. The actual update occurs in the LayerMgmtReceiveCounters procedure (5.2.4.3).

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5.2.2.1.25 aFrameTooLongErrors

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 815 counts per second.
BEHAVIOUR DEFINED AS:
A count of frames that are received and exceed the maximum permitted frame size. This counter is incremented when the status of a frame reception is frameTooLong. The actual update occurs in the LayerMgmtReceiveCounters procedure (5.2.4.3).

5.2.2.1.26 aMACEnableStatus

ATTRIBUTE
APPROPRIATE SYNTAX:
BOOLEAN
BEHAVIOUR DEFINED AS:
True if MAC sublayer is enabled, and false if disabled. This is accomplished by setting or checking the values of the receiveEnabled and transmitEnabled variables.;
Setting to true provides a means to cause the MAC sublayer to enter the normal operational state at idle. The PLS is reset by this operation (see 7.2.2.2.1). This is accomplished by setting receiveEnabled and transmitEnabled to true.
Setting to false causes the MAC sublayer to end all transmit and receive operations, leaving it in a disabled state. This is accomplished by setting receiveEnabled and transmitEnabled to false.

5.2.2.1.27 aTransmitEnableStatus

ATTRIBUTE
APPROPRIATE SYNTAX:
BOOLEAN
BEHAVIOUR DEFINED AS:
True if transmission is enabled, and false otherwise. This is accomplished by setting or checking the value of the transmitEnabled variable.
Setting this to true provides a means to enable MAC sublayer frame transmission (TransmitFrame function). This is accomplished by setting transmitEnabled to true.
Setting this to false will inhibit the transmission of further frames by the MAC sublayer (TransmitFrame function). This is accomplished by setting transmitEnabled to false.

5.2.2.1.28 aMulticastReceiveStatus

ATTRIBUTE
APPROPRIATE SYNTAX:
BOOLEAN
BEHAVIOUR DEFINED AS:
True if multicast receive is enabled, and false otherwise.;
Setting this to true provides a means to cause the MAC sublayer to return to the normal operation of multicast frame reception.

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Setting this to false will inhibit the reception of further multicast frames by the MAC sublayer.

5.2.2.1.29 aReadWriteMACAddress

ATTRIBUTE
APPROPRIATE SYNTAX:
MACAddress
BEHAVIOUR DEFINED AS:
Read the MAC station address or change the MAC station address to the one supplied (RecognizeAddress function). Note that the supplied station address shall not have the group bit set and shall not be the null address.

5.2.2.1.30 aCollisionFrames

ATTRIBUTE
APPROPRIATE SYNTAX:
A SEQUENCE of 32 generalized nonresetable counters. Each counter has a maximum increment rate of 13 000 counts per second.
BEHAVIOUR DEFINED AS:
A histogram of collision activity. The indices of this array (1 to attemptLimit–1) denote the number of collisions experienced in transmitting a frame. Each element of this array contains a counter that denotes the number of frames that have experienced a specific number of collisions. When the TransmitStatus is reported as transmitOK and the value of the attempts variable equals n, then collisionFrames[n–1] counter is incremented. The elements of this array are incremented in the LayerMgmtTransmitCounters procedure (5.2.4.2).

5.2.2.2 DTE MAC Sublayer actions

5.2.2.2.1 acInitializeMAC

ACTION
APPROPRIATE SYNTAX:
None required
BEHAVIOUR DEFINED AS:
This action provides a means to call the Initialize procedure (4.2.7.4). This action also results in the initialization of the PLS.

5.2.2.2.2 acAddGroupAddress

ACTION
APPROPRIATE SYNTAX:
MACAddress
BEHAVIOUR DEFINED AS:
Add the supplied multicast group address to the address recognition filter (RecognizeAddress function).

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5.2.2.2.3 acDeleteGroupAddress

ACTION
APPROPRIATE SYNTAX:
MACAddress
BEHAVIOUR DEFINED AS:
Delete the supplied multicast group address from the address recognition filter (RecognizeAddress function).

5.2.2.2.4 acExecuteSelfTest

ACTION
APPROPRIATE SYNTAX:
None required
BEHAVIOUR DEFINED AS:
Execute a self-test and report the results (success or failure). The actual mechanism employed to carry out the self-test is not defined in this standard.

5.2.2.3 ResourceTypeID Managed Object Class

5.2.2.3.1 ResourceTypeID

Implementation of this managed object in accordance with the definition contained in IEEE Std 802.1F-1993 is a conformance requirement of this standard. A single instance of the Resource Type ID managed object exists within the DTE–MAC managed object class. The managed object itself is contained in IEEE Std 802.1F-1993; therefore, only the name binding appears in this standard.

5.2.3 DTE Physical Sublayer Management facilities

This subclause defines the Layer Management facilities specific to the Physical Layer Signaling (PLS) sublayer Managed Object Class. The PLS is required to be within a managed CSMA/CD port of a DTE. Management of that portion of the physical sublayer whose physical containment within the DTE is optional is outside the scope of this subclause.

5.2.3.1 DTE Physical Sublayer attributes

5.2.3.1.1 aPHYID

ATTRIBUTE
APPROPRIATE SYNTAX:
INTEGER
BEHAVIOUR DEFINED AS:
The value of aPHYID is assigned so as to uniquely identify a PHY, i.e., Physical Layer among the subordinate managed objects of system (systemID and system are defined in ISO/IEC 10165-2:1992).;

5.2.3.1.2 aSQETestErrors

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized nonresetable counter. This counter has a maximum increment rate of 16 000 counts per second.

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BEHAVIOUR DEFINED AS:

A count of times that the SQE_TEST_ERROR was received. The SQE_TEST_ERROR is set in accordance with the rules for verification of the SQE detection mechanism in the PLS Carrier Sense Function (see 7.2.4.6).

5.2.4 DTE Management procedural model

The following model provides the descriptions for Layer Management facilities.

5.2.4.1 Common constants and types

The following are the common constants and types required for the Layer Management procedures.

const

maxDeferTime = …; {2 × (maxBasicFrameSize × 8), for operating speeds of 100 Mb/s and below, and 2 × (burstLimit + maxBasicFrameSize × 8 + headerSize) for operating speeds greater than 100 Mb/s, in bits, error timer limit for maxDeferTime}

type

CounterLarge = 0..maxLarge; {see footnote[28]}.

5.2.4.2 Transmit variables and procedures

The following items are specific to frame transmission:

var

excessDefer: Boolean; {set in process DeferTest}
carrierSenseFailure: Boolean; {set in process CarrierSenseTest}
transmitEnabled: Boolean; {set by MAC action}
lateCollisionError: Boolean; {set in Section 4 procedure WatchForCollision}
deferred: Boolean; {set in Section 4 function TransmitLinkMgmt}
carrierSenseTestDone: Boolean; {set in process CarrierSenseTest}
lateCollisionCount: 0..attemptLimit – 1; {count of late collision that is used in Clause 4 TransmitLinkMgmt and BitTransmitter}
{MAC transmit counters}
framesTransmittedOK: CounterLarge; {mandatory}
singleCollisionFrames: CounterLarge; {mandatory}
multipleCollisionFrames: CounterLarge; {mandatory}
collisionFrames: array [1..attemptLimit – 1] of CounterLarge; {recommended}
octetsTransmittedOK: CounterLarge; {recommended}
deferredTransmissions: CounterLarge; {recommended}
multicastFramesTransmittedOK: CounterLarge; {optional}
broadcastFramesTransmittedOK: CounterLarge; {optional}
{MAC transmit error counters}
lateCollision: CounterLarge; {recommended}
excessiveCollision: CounterLarge; {recommended}
carrierSenseErrors: CounterLarge; {optional}
excessiveDeferral: CounterLarge; {optional}
halfDuplex: Boolean; {Indicates the desired mode. halfDuplex is a static variable; its value does not change between invocations of the Initialize procedure}

[28]The CounterLarge declaration is an example of how to declare a counter. This particular example produces a 32 bit counter.

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Procedure LayerMgmtTransmitCounters is invoked from the TransmitLinkMgmt function and from the BitTransmitter process in 4.2.8 to update the transmit and transmit error counters.

```
procedure LayerMgmtTransmitCounters;
begin
   if halfDuplex then
      while not carrierSenseTestDone do nothing;
   if transmitSucceeding then
   begin
      IncLargeCounter(framesTransmittedOK);
      SumLarge(octetsTransmittedOK, dataSize/8); {dataSize (in bits) is defined in 4.2.7.1}
      if destinationField = … {check to see if to a multicast destination}
         then IncLargeCounter(multicastFramesTransmittedOK);
      if destinationField = … {check to see if to a broadcast destination}
         then IncLargeCounter(broadcastFramesTransmittedOK);

      if attempts > 1 then
      begin {transmission delayed by collision}
         if attempts = 2 then
            IncLargeCounter(singleCollisionFrames) {delay by 1 collision}
         else {attempts > 2, delayed by multiple collisions}
            IncLargeCounter(multipleCollisionFrames)
         IncLargeCounter(collisionFrames[attempts – 1])
      end {delay by collision}
   end; {transmitSucceeding}

   if deferred and (attempts = 1) then
      IncLargeCounter(deferredTransmissions);
   if lateCollisionCount > 0 then {test if late collision detected}
      SumLarge(lateCollision, lateCollisionCount);
   if attempts = attemptLimit and not transmitSucceeding then
      IncLargeCounter(excessiveCollision);
   if carrierSenseFailure then
      IncLargeCounter(carrierSenseErrors);
   if excessDefer then
      IncrementLargeCounter(excessiveDeferral)
end; {LayerMgmtTransmitCounters}
```

The DeferTest process sets the excessDefer flag if a transmission attempt has been deferred for a period of time longer than maxDeferTime.

```
process DeferTest;
   var deferBitTimer: 0..maxDeferTime;
   begin
      cycle
      begin
         deferBitTimer := 0;
         while frameWaiting and not excessDefer do
         begin
            Wait(oneBitTime); {see 4.3.3}
            if deferBitTimer = maxDeferTime then
               excessDefer := true
            else
               deferBitTimer := deferBitTimer + 1
```

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```
        end; {while}
        while transmitting do nothing
    end {cycle}
end; {DeferTest}
```

The CarrierSenseTest process sets the carrierSenseFailure flag if carrier sense disappears while transmitting or if it never appears during an entire transmission.

```
process CarrierSenseTest;
    var
        carrierSeen: Boolean; {Running indicator of whether or not carrierSense has been true at any
                               time during the current transmission}
        collisionSeen: Boolean; {Running indicator of whether or not the collisionDetect asserted any
                                 time during the entire transmission}
begin
    cycle {main loop}
        while not transmitting do nothing; {wait for start of transmission}
        carrierSenseFailure := false;
        carrierSeen := false;
        collisionSeen := false;
        carrierSenseTestDone := false;
        while transmitting do
        begin {inner loop}
            if carrierSense then
                carrierSeen := true;
            else
                if carrierSeen then {carrierSense disappeared before end of transmission}
                    carrierSenseFailure := true;
            if collisionDetect then
                collisionSeen := true
        end; {inner loop}
        if not carrierSeen then
            carrierSenseFailure := true {carrier sense never appeared}
        else
            if collisionSeen then
                carrierSenseFailure := false;
        carrierSenseTestDone := true
    end {main loop}
end; {CarrierSenseTest}
```

5.2.4.3 Receive variables and procedures

The following items are specific to frame reception:

```
    var
        receiveEnabled: Boolean; {set by MAC action}
        {MAC receive counters}
        framesReceivedOK: CounterLarge; {mandatory}
        octetsReceivedOK: CounterLarge; {recommended}

        {MAC receive error counters}
        frameCheckSequenceErrors: CounterLarge; {mandatory}
        alignmentErrors: CounterLarge; {mandatory}
        inRangeLengthErrors: CounterLarge; {optional}
```

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```
outOfRangeLengthField: CounterLarge; {optional}
frameTooLongErrors: CounterLarge; {optional}

{MAC receive address counters}
multicastFramesReceivedOK: CounterLarge; {optional}
broadcastFramesReceivedOK: CounterLarge; {optional}
```

Procedure LayerMgmtReceiveCounters is called by the ReceiveDataDecap function in 4.2.9 and increments the appropriate receive counters.

```
procedure LayerMgmtReceiveCounters (status: ReceiveStatus);
begin
  case status of
    receiveDisabled:
    begin
      nothing
    end; {receiveDisabled}
    receiveOK:
    begin
      IncLargeCounter(framesReceivedOK);
      SumLarge(octetsReceivedOK, dataSize/8); {dataSize (in bits) is defined in 4.2.7.1}
      if destinationField = … {check to see if to a multicast destination}
        then IncLargeCounter(multicastFramesReceivedOK);
      if destinationField = … {check to see if to a broadcast destination}
        then IncLargeCounter(broadcastFramesReceivedOK)
    end; {receiveOK}
    frameTooLong:
    begin
      IncLargeCounter(frameTooLongErrors)
    end; {frameTooLong}
    frameCheckError:
    begin
      IncLargeCounter(frameCheckSequenceErrors)
    end; {frameCheckError}
    alignmentError:
    begin
      IncLargeCounter(alignmentErrors)
    end; {alignmentError}
    lengthError: {Note that ReceiveStatus is never lengthError for a type interpretation of the
                  Length/Type field. See 4.2.9}
    begin
      if {Length/Type field value is between the minimum MAC client data size that does not
          require padding and maxBasicDataSize inclusive, and does not match the number of data
          octets received} or {Length/Type field value is less than the minimum allowed MAC
          client data size that does not require padding and the number of MAC client data octets
          received is greater than the minimum MAC client data size that does not
          require padding}
          then
          IncLargeCounter(inRangeLengthError);
        if {Length/Type field value is greater than maxBasicDataSize} then
          IncLargeCounter(outOfRangeLengthField)
    end {lengthError}
  end {case status}
end; {LayerMgmtReceiveCounters}
```

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Function LayerMgmtRecognizeAddress checks if reception of certain addressing types has been enabled. Note that in Pascal, assignment to a function causes the function to return immediately.

```
function LayerMgmtRecognizeAddress(address: AddressValue): Boolean;
begin
   if {promiscuous receive enabled} then
      LayerMgmtRecognizeAddress := true;
   if address = … {MAC station address} then
      LayerMgmtRecognizeAddress := true;
   if address = … {broadcast address} then
      LayerMgmtRecognizeAddress := true;
   if address = … {one of the addresses on the multicast list and multicast reception is enabled} then
      LayerMgmtRecognizeAddress := true;
   LayerMgmtRecognizeAddress := false
end; {LayerMgmtRecognizeAddress}
```

5.2.4.4 Common procedures

Procedure LayerMgmtInitialize initializes all the variables and constants required to implement Layer Management.

```
procedure LayerMgmtInitialize;
begin
   {initialize flags for enabling/disabling transmission and reception}
   receiveEnabled := true;
   transmitEnabled := true;
   {initialize transmit flags for DeferTest and CarrierSenseTest}
   deferred := false;
   lateCollisionError := false;
   excessDefer := false;
   carrierSenseFailure := false;
   carrierSenseTestDone := false

   {Initialize all MAC sublayer management counters to zero}

end; {LayerMgmtInitialize}
```

Procedure IncLargeCounter increments a 32-bit wraparound counter.

```
procedure IncLargeCounter (var counter: CounterLarge);
begin
   {increment the 32-bit counter}
end; {IncLargeCounter}
```

Procedure SumLarge adds a value to a 32-bit wraparound counter.

```
procedure SumLarge (
   var counter: CounterLarge;
   var offset: Integer);
begin
   {add offset to the 32-bit counter}
end; {SumLarge}
```

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6. Physical Signaling (PLS) service specifications

6.1 Scope and field of application

This clause specifies the services provided by the PLS sublayer to the MAC sublayer for 1 Mb/s and 10 Mb/s implementations of this standard (see Figure 6–1). The services are described in an abstract way and do not imply any particular implementation.

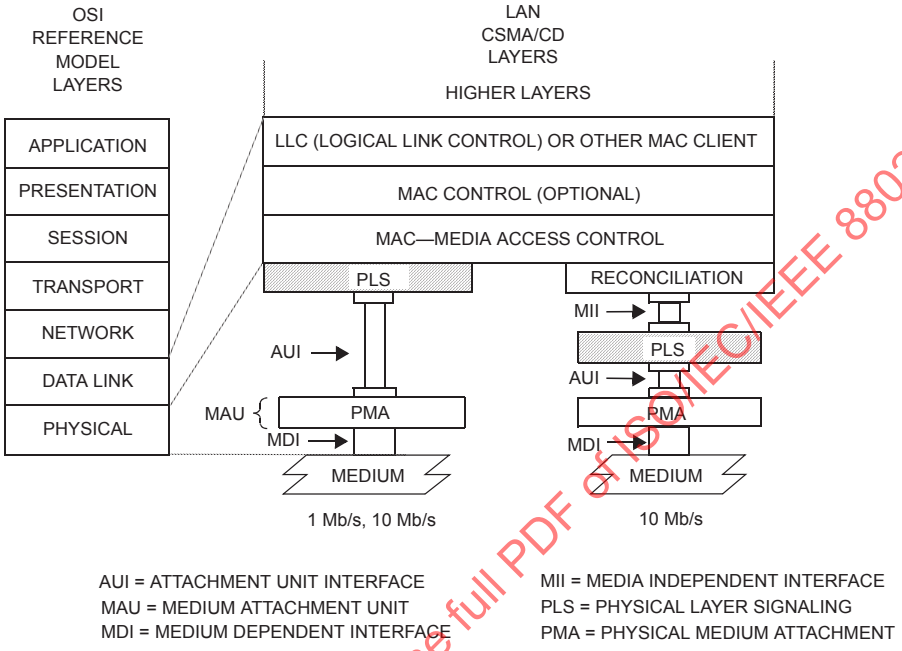

Figure 6–1—PLS service specification relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

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6.2 Overview of the service

6.2.1 General description of services provided by the layer

The services provided by the PLS sublayer allow the local MAC sublayer entity to exchange data bits (PLS data_units) with peer MAC sublayer entities.

6.2.2 Model used for the service specification

The model used in this service specification is identical to that used in 1.2.2.1.

6.2.3 Overview of interactions

The primitives associated with the MAC sublayer to PLS sublayer interface fall into two basic categories:

a) Service primitives that support MAC peer-to-peer interactions.
b) Service primitives that have local significance and support sublayer-to-sublayer interactions.

The following primitives are grouped into these two categories:

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a) Peer-to-Peer
   PLS_DATA.request
   PLS_DATA.indication
b) Sublayer-to-Sublayer
   PLS_CARRIER.indication
   PLS_SIGNAL.indication
   PLS_DATA_VALID.indication

The PLS_DATA primitives support the transfer of data from a single MAC sublayer entity to all other peer MAC sublayer entities contained within the same LAN defined by the broadcast medium.

NOTE—In half duplex mode, all bits transferred from a MAC sublayer entity will in turn be received by the entity itself.

The PLS_CARRIER, PLS_DATA_VALID, and the PLS_SIGNAL primitives provide information needed by the local MAC sublayer entity to perform the media access functions.

6.2.4 Basic services and options

All of the service primitives described in this subclause are considered mandatory.

6.3 Detailed service specification

6.3.1 Peer-to-peer service primitives

6.3.1.1 PLS_DATA.request

6.3.1.1.1 Function

This primitive defines the transfer of data from the MAC sublayer to the local PLS entity.

6.3.1.1.2 Semantics of the service primitive

The primitive shall provide the following parameters:

PLS_DATA.request (OUTPUT_UNIT)

The OUTPUT_UNIT parameter can take on one of three values: ONE, ZERO, or DATA_COMPLETE and represent a single data bit. The DATA_COMPLETE value signifies that the Media Access Control sublayer has no more data to output.

6.3.1.1.3 When generated

This primitive is generated by the MAC sublayer to request the transmission of a single data bit on the physical medium or to stop transmission.

6.3.1.1.4 Effect of receipt

The receipt of this primitive will cause the PLS entity to encode and transmit either a single data bit or to cease transmission.

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6.3.1.2 PLS_DATA.indication

6.3.1.2.1 Function

This primitive defines the transfer of data from the PLS sublayer to the MAC sublayer.

6.3.1.2.2 Semantics of the service primitive

The semantics of the service primitive are as follows:

PLS_DATA. indicate (INPUT_UNIT)

The INPUT_UNIT parameter can take one of two values each representing a single bit: ONE or ZERO.

6.3.1.2.3 When generated

The PLS_DATA.indication is generated to all MAC sublayer entities in the network after a PLS_DATA.request is issued.

NOTE—In half duplex mode, an indication is also presented to the MAC entity that issued the request.

6.3.1.2.4 Effect of receipt

The effect of receipt of this primitive by the MAC sublayer is not specified in this Clause.

6.3.2 Sublayer-to-sublayer service primitives

6.3.2.1 PLS_CARRIER.indication

6.3.2.1.1 Function

This primitive transfers the status of the activity on the physical medium from the PLS sublayer to the MAC sublayer.

6.3.2.1.2 Semantics of the service primitive

The semantics of the primitive are as follows:

PLS_CARRIER.indication (CARRIER_STATUS)

The CARRIER_STATUS parameter can take one of two values: CARRIER_ON or CARRIER_OFF. The CARRIER_ON value indicates that the DTE Physical Layer had received an *input* message or a *signal_quality_error* message from the MAU. The CARRIER_OFF value indicates that the DTE Physical Layer had received an *input_idle* message and is not receiving an SQE *signal_quality_error* message from the MAU.

6.3.2.1.3 When generated

The PLS_CARRIER.indication service primitive is generated whenever CARRIER_STATUS makes a transition from CARRIER_ON to CARRIER_OFF or vice versa.

6.3.2.1.4 Effect of receipt

The effect of receipt of this primitive by the MAC sublayer is not specified in this Clause.

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6.3.2.2 PLS_SIGNAL.indication

6.3.2.2.1 Function

This primitive transfers the status of the Physical Layer signal quality from the PLS sublayer to the MAC sublayer.

6.3.2.2.2 Semantics of the service primitive

The semantics of the service primitive are as follows:

PLS_SIGNAL.indication (SIGNAL_STATUS)

The SIGNAL_STATUS parameter can take one of two values: SIGNAL_ERROR or NO_SIGNAL_ERROR. The SIGNAL_ERROR value indicates to the MAC sublayer that the PLS has received a *signal_quality_error* message from the MAU. The NO_SIGNAL_ERROR value indicates that the PLS has ceased to receive *signal_quality_error* messages from the MAU.

6.3.2.2.3 When generated

The PLS_SIGNAL.indication service primitive is generated whenever SIGNAL_ STATUS makes a transition from SIGNAL_ERROR to NO_SIGNAL_ERROR or vice versa.

6.3.2.2.4 Effect of receipt

The effect of receipt of this primitive by the MAC sublayer is not specified in this Clause.

6.3.2.3 PLS_DATA_VALID.indication

6.3.2.3.1 Function

This primitive provides a facility for transferring framing information to the MAC sublayer.

6.3.2.3.2 Semantics of the service primitive

The semantics of the service primitive are as follows:

PLS_DATA_VALID.indication (DATA_VALID_STATUS)

The DATA_VALID_STATUS parameter can take one of two values: DATA_VALID or DATA_NOT_VALID. The DATA_VALID value indicates that the INPUT_UNIT parameter of the PLS_DATA.indication primitive contains valid data of an incoming frame. The DATA_NOT_VALID value indicates that the INPUT_UNIT parameter of the PLS_DATA.indication primitive does not contain valid data of an incoming frame.

6.3.2.3.3 When generated

The PLS_DATA_VALID.indication service primitive is generated whenever the DATA_VALID_STATUS parameter makes a transition from DATA_VALID to DATA_NOT_VALID or vice versa.

6.3.2.3.4 Effect of receipt

The effect of receipt of this primitive by the MAC sublayer is not specified in this Clause.

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7. Physical Signaling (PLS) and Attachment Unit Interface (AUI) specifications

7.1 Scope

This clause defines the logical, electrical, and mechanical characteristics for the PLS and AUI between Data Terminal Equipment and Medium Attachment Units used in CSMA/CD local area networks. The relationship of this specification to the entire IEEE LAN standard is shown in Figure 7–1. The purpose of this interface is to provide an interconnection that is simple and inexpensive and that permits the development of simple and inexpensive MAUs.

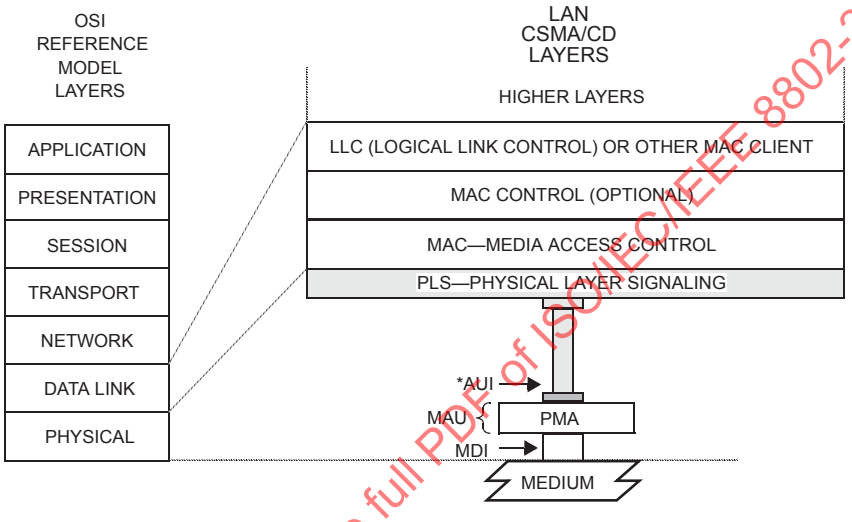

Figure 7–1—Physical Layer partitioning, relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model

This interface has the following characteristics:

a) Capable of supporting one or more of the specified data rates.
b) Capable of driving up to 50 m of cable.
c) Permits the DTE to test the AUI, AUI cable, MAU, and the medium itself.
d) Supports MAUs for baseband coax, baseband twisted-pair, broadband coax, and baseband fiber.

7.1.1 Definitions

See 1.4.

7.1.2 Summary of major concepts

a) Each direction of data transfer is serviced with two (making a total of four) balanced circuits: “Data” and “Control.”

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b) The Data and Control circuits are independently self-clocked, thereby, eliminating the need for separate timing circuits. This is accomplished with encoding of all signals. The Control circuit signaling rate is nominally (but not of necessity exactly) equal to the Data circuit signaling rate.
c) The Data circuits are used only for data transfer. No control signals associated with the interface are passed on these circuits. Likewise, the Control circuits are used only for control message transfer. No data signals associated with the interface are passed on these circuits.

7.1.3 Application

This standard applies to the interface used to interconnect Data Terminal Equipment (DTE) to a MAU that is not integrated as a physical part of the DTE. This interface is used to

a) Provide the DTE with media independence for baseband coax, baseband twisted pair, broadband coax, and baseband fiber media so that identical PLS, MAC, and MAC clients may be used with any of these media.
b) Provide for the separation, by cable of up to 50 m, of the DTE and the MAU.

7.1.4 Modes of operation

The AUI can operate in two different modes. All interfaces shall support the normal mode. The monitor mode is optional.

When the interface is being operated in the *normal* mode, the AUI is logically connected to the MDI. The DTE is required to follow the media access algorithms, which provide a single access procedure compatible with all LAN media, to send data over the AUI. The MAU always sends back to the DTE whatever data the MAU receives on the MDI.

When the interface is in the optional *monitor* mode, the MAUs transmitter is logically isolated from the medium. The MAU, in this mode, functions as an observer on the medium. Both the input function and the signal quality error function are operational (see the MAU state diagrams for specific details).

The PLS and AUI as specified here are able to support DTEs and MAUs operating in either half duplex or full duplex modes without change to the PLS or AUI. Full duplex MAUs do not support the monitor mode.

7.1.5 Allocation of function

The allocation of functions in the AUI is such that the majority of the functionality required by the interface can be provided by the DTE, leaving the MAU as simple as possible. This division of functions is based upon the recognition of the fact that since, in many cases, the MAU may be located in an inaccessible location adjacent to the physical medium, service of the MAU may often be difficult and expensive.

7.2 Functional specification

The AUI is designed to make the differences among the various media as transparent as possible to the DTE. The selection of logical control signals and the functional procedures are all designed to this end. Figure 7–2 is a reference model, a generalized MAU as seen by the DTE through the AUI.

Many of the terms used in this subclause are specific to the interface between this sublayer and the MAC sublayer. These terms are defined in the Service Specification for the PLS sublayer.

7.2.1 PLS–PMA (DTE–MAU) Interface protocol

The DTE and MAU communicate by means of a simple protocol across the AUI.

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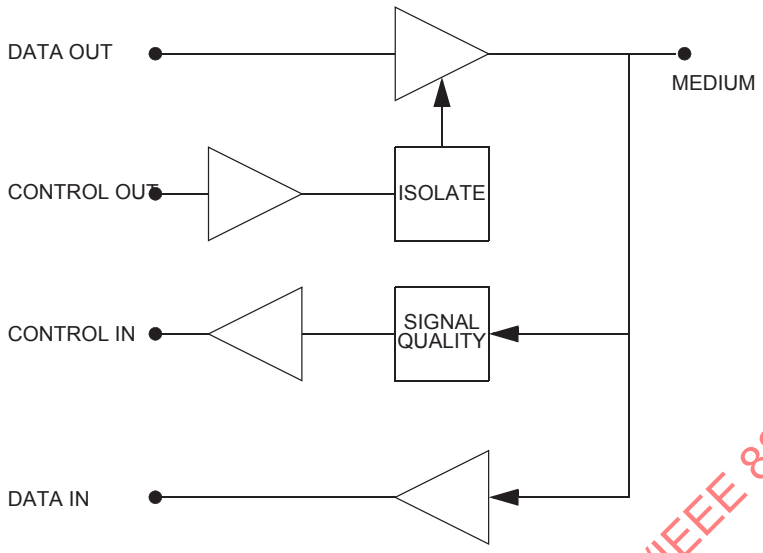

NOTE—The AUI (comprised of DO, DI, CO, CI circuits) is not exposed when the MAU is, optionally, part of the DTE.

Figure 7–2—Generalized MAU model

7.2.1.1 PLS to PMA messages

The following messages can be sent by PLS sublayer entities in the DTE to PMA sublayer entities in the MAU:

Message	Meaning
output	Output information
output_idle	No data to be output
normal	Cease to isolate the MAU
(Optional)	
isolate	Isolate MAU
mau_request	Request that the MAU be made available

7.2.1.1.1 *output* message

The PLS sublayer sends an *output* message to the PMA sublayer when the PLS sublayer receives an OUTPUT_UNIT from the MAC sublayer.

The physical realization of the *output* message is a CD0 or a CD1 sent by the DTE to the MAU on the Data Out circuit. The DTE sends a CD0 if the OUTPUT_UNIT is a ZERO or a CD1 if the OUTPUT_UNIT is a ONE. This message is time coded—that is, once this message has been sent, the function is not completed over the AUI until one bit time later. The *output* message cannot be sent again until the bit cell being sent as a result of sending the previous *output* message is complete.

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7.2.1.1.2 *output_idle* message

The PLS sublayer sends an *output_idle* message to the PMA sublayer at all times when the MAC sublayer is not in the process of transferring output data across the MAC to PLS interface. The *output_idle* message is no longer sent (and the first OUTPUT_UNIT is sent using the *output* message) as soon after the arrival of the first OUTPUT_UNIT as the MAU can be made available for data output. The *output_idle* message is again sent to the MAU when the DATA_COMPLETE is received from the MAC sublayer. The detailed usage of the *output_idle* message is shown in Figure 7–5.

The physical realization of the *output_idle* message is IDL sent by the DTE to the MAU on the Data Out circuit.

7.2.1.1.3 *normal* message

The PLS sublayer sends a *normal* message to the PMA sublayer after it receives the PLS *start* message from the PLS Reset and Identify function. The *normal* message is also sent after receipt of RESET_MONITOR_MODE from the management entity. The *normal* message is sent continuously by the PLS sublayer to the MAU, unless the PLS Output function requires that the *mau_request* message be sent to permit data output. If *mau_request* is sent during data output, the sending of *normal* will be resumed when the PLS Output function returns to the IDLE state. The *normal* signal is reset by the SET_MONITOR_MODE (this reset function is described more fully by Figure 7–4).

7.2.1.1.4 *isolate* message (optional)

The PLS sublayer sends an *isolate* message to the PMA (in the MAU) whenever the PLS sublayer receives SET_MONITOR_MODE from the management entity. In response to the *isolate* message, the MAU causes the means employed to impress data on the physical medium to be positively prevented from affecting the medium. Since signaling and isolation techniques differ from medium to medium, the manner in which this positive isolation of the transmitting means is accomplished is specified in the appropriate MAU subclause. However, the intent of this positive isolation of the transmitter is to ensure that the MAU will not interfere with the physical medium in such a way as to affect transmissions of other stations even in the event that the means normally employed to prevent the transmitter from affecting the medium have failed to do so. The specification of positive isolation is not to be construed to preclude use of either active or passive devices to accomplish this function.

The physical realization of the *isolate* message is a CS0 signal sent by the DTE to the MAU over the Control Out circuit.

7.2.1.1.5 *mau_request* message (optional)

The PLS sublayer sends the *mau_request* message to the PMA sublayer if the PMA sublayer is sending the *mau_not_available* message and the MAC sublayer has sent the first OUTPUT_UNIT of a new transmission. The PLS sublayer continues to send the *mau_request* message to the MAU until the MAC sublayer sends the DATA_COMPLETE request to the PLS sublayer across the MAC to PLS interface. See Figure 7–3, Figure 7–5, and Figure 7–9 for details.

In addition, the *mau_request* message is used by the Reset and Identify function in the IDENTIFY 3 state to determine whether the MAU has the Isolate function.

The physical realization of *mau_request* is a CS1 sent by the DTE to the MAU on the Control Out circuit.

The physical realization of the *normal* message is the IDL signal sent by the DTE to the MAU on the Control Out circuit. In the absence of the CO circuit, MAUs implementing the Isolate function shall act as if the *normal* message is present. The CO circuit components may be absent from the DTE, AUI, or MAU.

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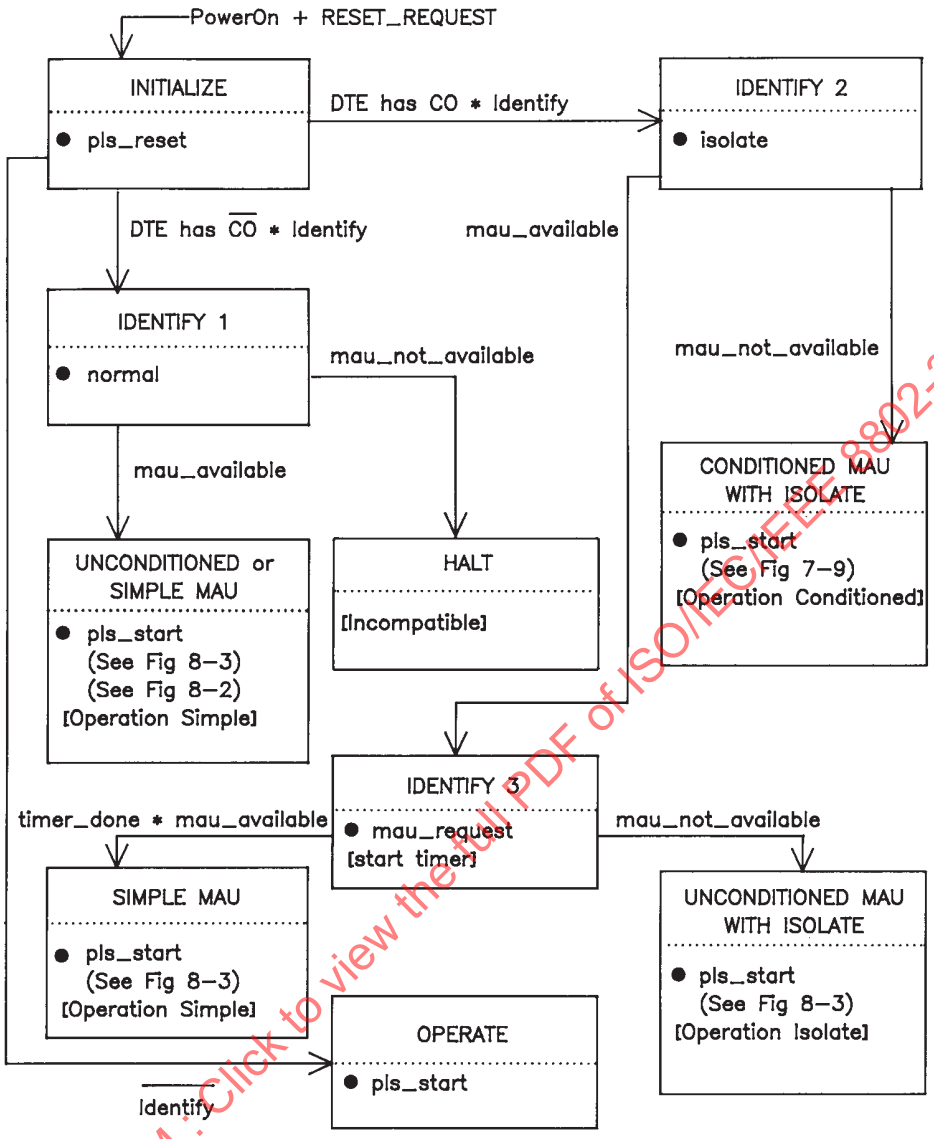

NOTES: (1) All states may be omitted except INITIALIZE and OPERATE
(2) "Identify" means DTE can recognize uniquely all CI messages and the entire function has been implemented
(3) "Identify" with bar means DTE fails to recognize *mau_not_available* or has a partial implementation of the function

Figure 7–3—PLS Reset and Identify function

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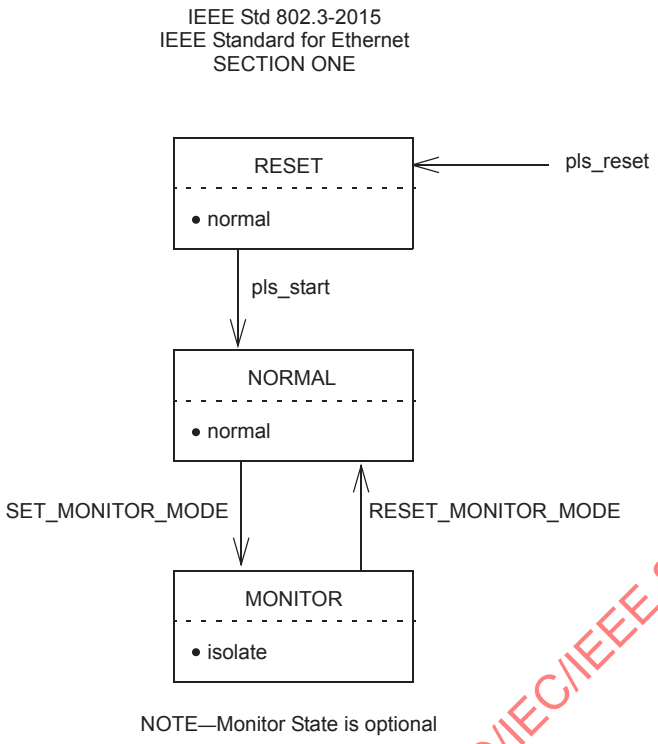

Figure 7–4—PLS Mode function

7.2.1.2 PMA to PLS interface

The following messages can be sent by the Physical Medium Attachment sublayer entities in the MAU to the PLS sublayer entities in the DTE:

Message	Meaning
input	Input information
input_idle	No input information
signal_quality_error	Error detected by MAU
mau_available	MAU is available for output
(Optional)	
mau_not_available	MAU is not available for output

In systems operating in full duplex mode, it is permitted, but not required, to implement the *signal_quality_error* message.

7.2.1.2.1 *input* message

The PMA sublayer sends an *input* message to the PLS sublayer when the MAU has received a bit from the medium and is prepared to transfer this bit to the DTE. The actual mapping of the signals on the medium to the type of *input* message to be sent to the DTE is contained in the specifications for each specific MAU type. In general, when the *signal_quality_error* message is being sent by the MAU, the symmetry specifications for circuit DI are not guaranteed to be met.

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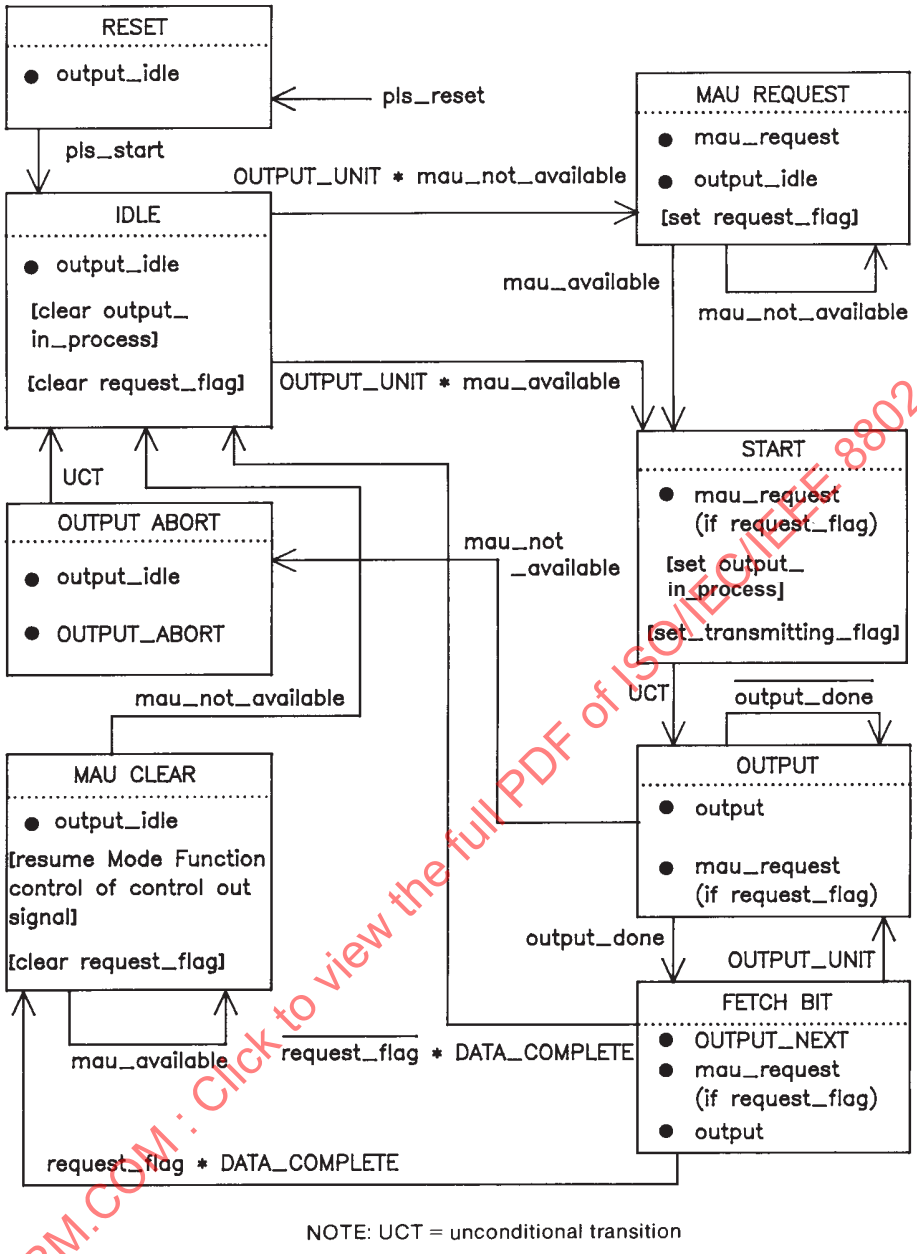

NOTE: UCT = unconditional transition

Figure 7–5—PLS Output function

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The physical realization of the *input* message consists of CD0 or CD1 waveforms. If the *signal_quality_error* message is being sent from the MAU, the input waveform is unpredictable.

NOTE—This signal is not necessarily retimed by the MAU. Consult the appropriate MAU specification for timing and jitter.

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7.2.1.2.2 *input_idle* message

The PMA sublayer sends an *input_idle* message to the PLS sublayer when the MAU does not have data to send to the DTE.

The physical realization of the *input_idle* message is an IDL sent by the MAU to the DTE on the Data In circuit.

7.2.1.2.3 *signal_quality_error* message

The PMA sublayer sends a *signal_quality_error* message to the PLS sublayer in response to any of three possible conditions. These conditions are improper signals on the medium, collision on the medium, and reception of the *output_idle* message. They are described in the lettered paragraphs that follow. The physical realization of the *signal_quality_error* message is a CS0 sent by the MAU to the DTE on the Control In circuit.

In systems operating in half duplex mode, the MAU is required to assert the *signal_quality_error* message at the appropriate times whenever the MAU is powered, and not just when the DTE is requesting data output. In systems operating in full duplex mode, it is permitted, but not required, to implement the *signal_quality_error* message. See Figure 7–9, Figure 8–2, and Figure 8–3 for details.

a) Improper Signals on the Medium. The MAU may send the *signal_quality_error* message at any time due to improper signals on the medium. The exact nature of these improper signals are medium-dependent. Typically, this condition might be caused by a malfunctioning MAU (for example, repeater or head-end) connected to the medium or by a break or short in the medium. See the appropriate MAU specification for specific conditions that may cause improper signals on a given medium.
b) Collision. Collision occurs when more than one MAU is transmitting on the medium. The local MAU shall send the *signal_quality_error* message in every instance when it is possible for it to ascertain that more than one MAU is transmitting on the medium. The MAU shall make the best determination possible. The MAU shall not send the *signal_quality_error* message when it is unable to determine conclusively that more than one MAU is transmitting.
c) *signal_quality_error* Message Test. The MAU sends the *signal_quality_error* message at the completion of the Output function. See Figure 7–9 and Clause 8 for a more complete description of this test.

7.2.1.2.4 *mau_available* message

The PMA sublayer sends the *mau_available* message to the PLS sublayer when the MAU is available for output. The *mau_available* message is always sent by a MAU that is always prepared to output data except when it is required to signal the *signal_quality_error* message. Such a MAU does not require *mau_request* to prepare itself for data output. See Figure 7–3, Figure 7–5, and Figure 7–9 for details.

The physical realization of the *mau_available* message is an IDL sent by the MAU to the DTE on the Control In circuit.

7.2.1.2.5 *mau_not_available* message (optional)

The PMA sublayer sends a *mau_not_available* message to the PLS sublayer when the MAU is not available for output. Figure 7–5 shows the relationship of *mau_not_available* to the Output function.

The *mau_not_available* message is also used by a MAU that contains the Isolate function and does not need to be conditioned for output to signal the presence of the Isolate function during the PLS Reset function (see Figure 7–3 and Figure 8–3).

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The physical realization of the *mau_not_available* message is a CS1 sent by the MAU to the DTE on the Control In circuit.

7.2.2 PLS interface to MAC and management entities

The PLS sublayer interfaces described here are for reference only. This clause specifies the services sent between the MAC sublayer and the PLS sublayer.

7.2.2.1 PLS–MAC interface

The following messages can be sent between PLS sublayer entities and MAC sublayer entities:

Message	Meaning
OUTPUT_UNIT	Data sent to the MAU
OUTPUT_STATUS	Response to OUTPUT_UNIT
INPUT_UNIT	Data received from the MAU
CARRIER_STATUS	Indication of channel activity
SIGNAL_STATUS	Indication of error/no error condition
DATA_VALID_STATUS	Indication of input activity

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7.2.2.1.1 OUTPUT_UNIT

The MAC sublayer sends the PLS sublayer an OUTPUT_UNIT every time the MAC sublayer has a bit to send. Once the MAC sublayer has sent an OUTPUT_UNIT to the PLS sublayer, it may not send another OUTPUT_UNIT until it has received an OUTPUT_STATUS message from the PLS sublayer. The OUTPUT_UNIT is a ONE if the MAC sublayer wants the PLS sublayer to send a CD1 to the PMA sublayer, a ZERO if a CD0 is desired, or a DATA_COMPLETE if an IDL is desired.

7.2.2.1.2 OUTPUT_STATUS

The PLS sublayer sends the MAC sublayer OUTPUT_STATUS in response to every OUTPUT_UNIT received by the PLS sublayer. OUTPUT_STATUS sent is an OUTPUT_NEXT if the PLS sublayer is ready to accept the next OUTPUT_UNIT from the MAC sublayer, or an OUTPUT_ABORT if the PLS sublayer was not able to process the previous OUTPUT_UNIT. (The purpose of OUTPUT_STATUS is to synchronize the MAC sublayer data output with the data rate of the physical medium.)

7.2.2.1.3 INPUT_UNIT

The PLS sublayer sends the MAC sublayer an INPUT_UNIT every time the PLS receives an *input* message from the PMA sublayer. The INPUT_UNIT is a ONE if the PLS sublayer receives a CD1 from the PMA sublayer, a ZERO if the PLS sublayer receives a CD0 from the PMA sublayer.

7.2.2.1.4 CARRIER_STATUS

The PLS sublayer sends the MAC sublayer CARRIER_STATUS whenever the PLS sublayer detects a change in carrier status. The PLS sublayer sends CARRIER_ON when it receives an *input* or *signal_quality_error* message from the PMA and the previous CARRIER_STATUS that the PLS sublayer sent to the MAC sublayer was CARRIER_OFF. The PLS sublayer sends CARRIER_OFF when it receives an *input_idle* from the PMA sublayer, no *signal_quality_error* (either *mau_available* or *mau_not_available*)

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message and the previous CARRIER_STATUS that the PLS sublayer sent to the MAC sublayer was CARRIER_ON.[29]

7.2.2.1.5 SIGNAL_STATUS

The PLS sublayer sends the MAC sublayer SIGNAL_STATUS whenever the PLS sublayer detects a change in the signal quality (as reported by the PMA). The PLS sublayer sends SIGNAL_ERROR when it receives a *signal_quality_error* message from the PMA sublayer and the previous SIGNAL_STATUS the PLS sublayer sent was NO_SIGNAL_ERROR. The PLS sublayer sends NO_SIGNAL_ERROR when it receives no *signal_quality_error* (either *mau_available* or *mau_not_available)* message from the PMA sublayer and the previous CARRIER_STATUS that the PLS sent to the MAC sublayer was SIGNAL_ERROR.[30]

7.2.2.1.6 DATA_VALID_STATUS

The PLS sublayer sends the MAC sublayer DATA_VALID_STATUS whenever the PLS sublayer detects a change in receive data status. The PLS sublayer sends DATA_VALID when it receives an *input* message from the PMA and the previous DATA_VALID_STATUS that the PLS sublayer sent to the MAC sublayer was DATA_NOT_VALID. The PLS sublayer sends DATA_NOT_VALID when it is not receiving an input message from the PMA and the previous DATA_VALID_STATUS that the PLS sublayer sent to the MAC sublayer was DATA_VALID.

7.2.2.2 PLS–management entity interface

The following messages may be sent between the PLS sublayer entities and intralayer or higher layer management entities:

Message	Meaning
RESET_REQUEST	Reset PLS to initial “Power On” state
RESET_RESPONSE	Provides operational information
MODE_CONTROL	Control operation
SQE_TEST	Signal Quality Error test results

7.2.2.2.1 RESET_REQUEST

The management entity sends the PLS sublayer RESET_REQUEST when the PLS sublayer needs to be reset to a known state. Upon receipt of RESET_REQUEST, the PLS sublayer resets all internal logic and restarts all functions. See Figure 7–3 for details.

[29] Formerly, the Carrier Sense function described in Figure 7–8 generated the CARRIER_STATUS message described above. For the sake of consistency with common implementation practice, the variable carrierSense (see 4.3.3) is generated directly by the Carrier Sense function in recent editions of the standard.

The mapping between the CARRIER_STATUS message and the carrierSense variable is as follows. When the carrierSense variable changes from False to True, the CARRIER_STATUS message is sent with the parameter CARRIER_ON. When the value of the carrierSense variable changes from True to False, the CARRIER_STATUS message is sent with the parameter CARRIER_OFF.

[30] Formerly, the PLS Error Sense function described in Figure 7–7 generated the SIGNAL_STATUS message described above. For the sake of consistency with common implementation practice, the variable collisionDetect (see 4.3.3) is generated directly by the PLS Error Sense function in recent editions of the standard.

The mapping between the SIGNAL_STATUS message and the collisionDetect variable is as follows. When the collisionDetect variable changes from False to True, the SIGNAL_STATUS message is sent with the parameter SIGNAL_ERROR. When the value of the collisionDetect variable changes from True to False, the SIGNAL_STATUS message is sent with the parameter NO_SIGNAL_ERROR.

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7.2.2.2.2 RESET_RESPONSE

The PLS sublayer sends the management entity RESET_RESPONSE upon completion of the Reset and Identify function (see Figure 7–3 and 7.2.4.1) whether invoked due to power on or due to a RESET_REQUEST. Which RESET_RESPONSE was sent is determined by the Reset and Identify function. A RESET_RESPONSE of OPERATION SIMPLE, OPERATION ISOLATE, or OPERATION CONDITIONED is sent if the MAU is compatible with the DTE and the MAU is simple (no isolate) or if the DTE does not support Isolate even if Isolate is supported by the MAU, supports Isolate but does not require conditioning, or supports Isolate and does require conditioning to output. A RESET_RESPONSE of INCOMPATIBLE is sent if the MAU is not compatible with the DTE (that is, the MAU requires conditioning but the DTE does not support conditioning).

7.2.2.2.3 MODE_CONTROL

The management entity sends MODE_CONTROL to the PLS sublayer to control PLS functions. MODE_CONTROL capabilities are as follows:

Message	Meaning
ACTIVATE PHYSICAL	Supply power on circuit VP
DEACTIVATE PHYSICAL	Remove power from circuit VP
SET_MONITOR_MODE	Send Isolate to MAU
RESET_MONITOR_MODE	Send Normal to MAU

7.2.2.2.4 SQE_TEST

The PLS sublayer sends SQE_TEST to the management entity at the conclusion of each *signal_quality_error* test (see Output Function, 7.2.4.3). The PLS sublayer sends SQE_TEST_ERROR if the *signal_quality_error* test fails or SQE_TEST_OK if the *signal_quality_error* test passes.

In systems operating in full duplex mode, it is permitted, but not required, to implement the SQE_TEST message.[31]

7.2.3 Frame structure

Frames transmitted on the AUI shall have the following structure:

<silence><preamble><sfd><data><etd><silence>

[31]Formerly, the PLS Carrier Sense function described in Figure 7–8 generated the SQE_TEST message described above. For the sake of consistency with common implementation practice, the variable SQETestError is generated directly by the PLS Carrier Sense function in recent editions of the standard.

The mapping between the SQE_TEST message and the PLS Carrier Sense function described in Figure 7–8 is as follows. When the transition from the state WAIT 1 to the state FAILURE occurs, the SQE_TEST message is sent with the parameter SQE_TEST_ERROR. When the transition from either the state WAIT 1 or the state ABORT_TEST to the state WAIT 2 occurs, the SIGNAL_STATUS message is sent with the parameter NO_SIGNAL_ERROR.

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The frame elements shall have the following characteristics:

Element	Characteristics
<silence>	= no transitions
<preamble>	= alternating (CD1) and (CD0) | 56 bit times (ending in CD0)
<sfd>	= (CD1)(CD0)(CD1)(CD0)(CD1)(CD0)(CD1)(CD1)
<data>	= 8 × N instances of CD0 or CD1
<etd>	= IDL

7.2.3.1 Silence

The <silence> delimiter provides an observation window for an unspecified period of time during which no transitions occur on the AUI. The minimum length of this period is specified by the access procedure.

7.2.3.2 Preamble

The <preamble> delimiter begins a frame transmission and provides a signal for receiver synchronization. The signal shall be an alternating pattern of (CD1) and (CD0). This pattern shall be transmitted on the Data Out circuit by the DTE to the MAU for a minimum of 56 bit times at the beginning of each frame. The last bit of the preamble (that is, the final bit of preamble before the start of frame delimiter) shall be a CD0.

The DTE is required to supply at least 56 bits of preamble in order to satisfy system requirements. System components consume preamble bits in order to perform their functions. The number of preamble bits sourced ensures an adequate number of bits are provided to each system component to correctly implement its function.

7.2.3.3 Start of Frame Delimiter (SFD)

The <sfd> indicates the start of a frame, and follows the preamble. The <sfd> element of a frame shall be

(CD1)(CD0)(CD1)(CD0)(CD1)(CD0)(CD1)(CD1)

7.2.3.4 Data

The <data> in a transmission shall be in multiples of eight (8) encoded data bits (CD0s and CD1s).

7.2.3.5 End of transmission delimiter

The <etd> delimiter indicates the end of a transmission and serves to turn off the transmitter. The signal shall be start of IDL.

7.2.4 PLS functions

The PLS sublayer functions consist of a Reset and Identify function and five simultaneous and asynchronous functions. These functions are Output, Input, Mode, Error Sense, and Carrier Sense. All of the five functions are started immediately following the completion of the Reset and Identify function. These functions are depicted in the state diagrams shown in Figure 7–3 through Figure 7–8, using notation described in 1.2.1.

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7.2.4.1 Reset and Identify function

The Reset and Identify function is executed any time either of two conditions occur. These two conditions are "power on" and the receipt of RESET_REQUEST from the management entity. The Reset and Identify function initializes all PLS functions, and (optionally) determines the capability of the MAU attached to the AUI. Figure 7–3 is the state diagram of the Reset and Identify function. The Identify portion of the function is optional.

7.2.4.2 Mode function

The MAU functions in two modes: normal and monitor. The monitor mode is optional. The state diagram of Figure 7–4 depicts the operation of the Mode function. When the MAU is operating in the normal mode, it functions as a direct connection between the DTE and the medium. Data sent from the DTE are impressed onto the medium by the MAU and all data appearing on the medium are sent to the DTE by the MAU. When the MAU is operating in the monitor mode, data appearing on the medium is sent to the DTE by the MAU as during the normal mode. *signal_quality_error* is also asserted on the AUI as during operation in the normal mode. However, in the monitor mode, the means employed to impress data on the physical medium is positively prevented from affecting the medium. Since signaling and isolation techniques differ from medium to medium, the manner in which this positive isolation of the transmitting means is accomplished is specified in the appropriate MAU document. However, the intent of this positive isolation of the transmitter is to ensure that the MAU will not interfere with the physical medium in such a way as to affect transmission of other stations even in the event of failure of the normal transmitter disabling control paths within the transmitting mechanism of the MAU.

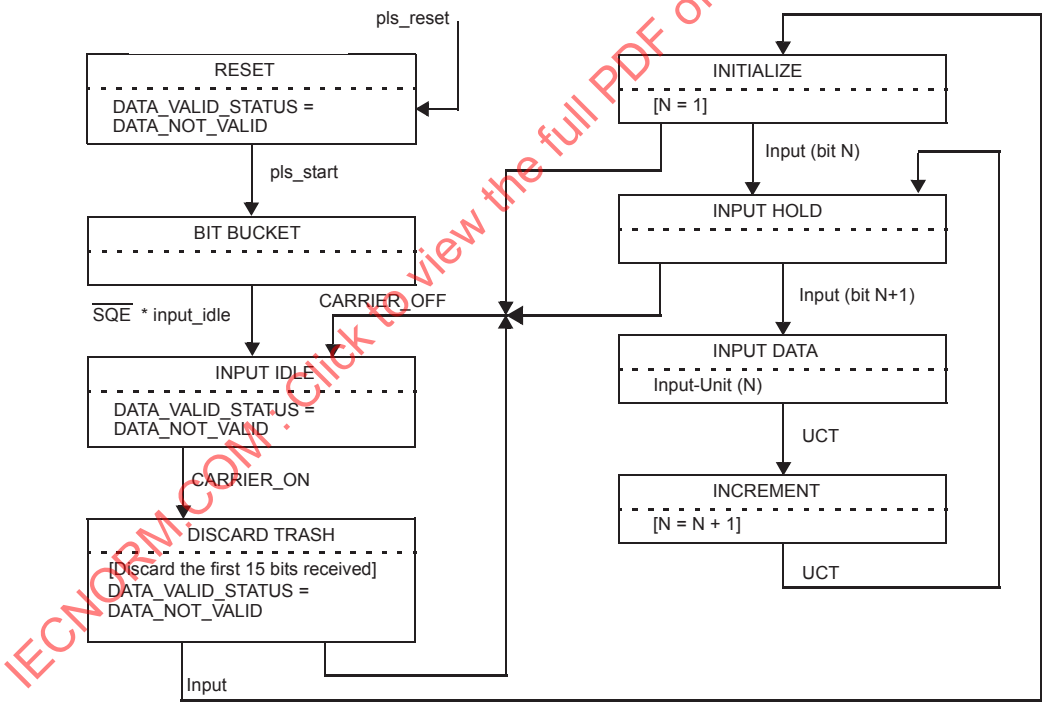

Figure 7–6—PLS Input and Data_Valid function

The monitor mode is intended to permit a network station to determine if it is the source of interference observed on the medium.

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NOTE—The monitor mode is intended to be used only by Network Management for fault isolation and network operation verification. It is intended that the *isolate* message provide direct control over the mode function so that these tasks can be performed. IMPROPER USE OF THE ISOLATE FUNCTION CAN CAUSE ERRONEOUS FRAMES. Clause 5, Layer Management, provides details on the proper use of this function.

7.2.4.3 Output function

The PLS sublayer Output function transparently performs the tasks of conditioning the MAU for output and data transfer from the MAC sublayer to the MAU. The state diagram of Figure 7–5 depicts the Output function operation.

At the conclusion of the Output function, if a collision has not occurred, a test is performed to verify operation of the signal quality detection mechanism in the MAU and to verify the ability of the AUI to pass the *signal_quality_error* message to the PLS sublayer. The operation of this test in the DTE is shown in Figure 7–8.

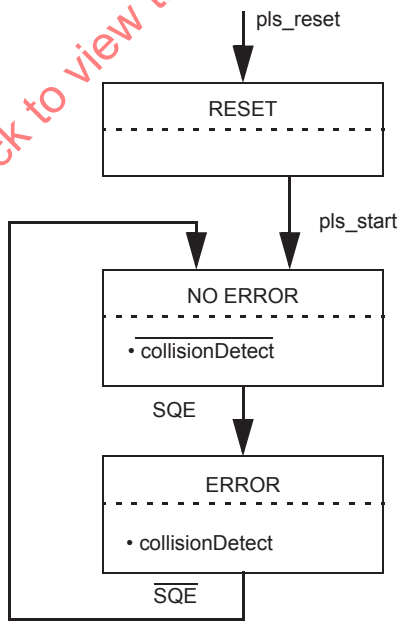
NOTE—In systems operating in full duplex mode, it is permitted, but not required, to implement the *signal_quality_error* message test.

7.2.4.4 Input function

The PLS sublayer Input function transparently performs the task of data transfer from the MAU to the MAC sublayer. Additionally, the Input function sends DATA_VALID_STATUS to the MAC sublayer, as appropriate. The state diagram of Figure 7–6 depicts the Input function operation.

7.2.4.5 Error Sense function

The PLS sublayer Error Sense function performs the task of sending collisionDetect to the MAC sublayer whenever the PLS receives the *signal_quality_error* message from the PMA sublayer. The state diagram of Figure 7–7 depicts the Error Sense function operation.



NOTE—SQE = *signal_quality_error*

Figure 7–7—PLS Error Sense function

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7.2.4.6 Carrier Sense function

The PLS sublayer Carrier Sense function performs the task of sending carrierSense and sqeTestError to the MAC sublayer. The state diagram of Figure 7–8 depicts the Carrier Sense function operation.[32]

Verification of the *signal_quality_error* detection mechanism occurs in the following manner (in the absence of a fault on the medium):

a) At the conclusion of the Output function, the DTE opens a time window during which it expects to see the *signal_quality_error* message asserted on the Control In circuit. The time window begins when carrierSense de-asserts and the variable transmitting is false. The duration of the window shall be at least 4.0 µs but no more than 8.0 µs. During the time window (depicted as carrier_inhibit_timer, Figure 7–8) the carrierSense function is inhibited.
b) The MAU, upon waiting Tw after the conclusion of output, activates as much of the *signal_quality_error* detecting mechanism as is possible without placing signals on the medium, thus sending the *signal_quality_error* message across the AUI for 10 bit times ± 5 bit times (10/BR seconds ± 5/BR seconds).
c) The DTE interprets the reception of the *signal_quality_error* message from the MAU as indication that the *signal_quality_error* detecting mechanism is operational and the *signal_quality_error* message may be both sent by the MAU and received by the DTE.

NOTE 1—The occurrence of multiple (overlapping) transmitters on the medium during the time that the test window is open, as specified above, will satisfy the test and will verify proper operation of the signal quality error detecting mechanism and sending and receiving of the appropriate physical error message.

NOTE 2—If *signal_quality_error* exists at the DTE before CARRIER_OFF occurs, then the Collision Presence test sequence within the PLS as described in 7.2.4.3 above shall be aborted as shown in Figure 7–8.

NOTE 3—In systems operating in full duplex mode, it is permitted, but not required, to implement the *signal_quality_error* message test.

7.3 Signal characteristics

7.3.1 Signal encoding

Two different signal encoding mechanisms may be used by the AUI. One of the mechanisms is used to encode data, the other to encode control.

7.3.1.1 Data encoding

Manchester encoding is used for the transmission of data across the AUI. Manchester encoding is a binary signaling mechanism that combines data and clock into "bit-symbols." Each bit-symbol is split into two halves with the second half containing the binary inverse of the first half; a transition always occurs in the middle of each bit-symbol. During the first half of the bit-symbol, the encoded signal is the logical complement of the bit value being encoded. During the second half of the bit-symbol, the encoded signal is the uncomplemented value of the bit being encoded. Thus, a CD0 is encoded as a bit-symbol in which the first half is HI and the second half is LO. A CD1 is encoded as a bit-symbol in which the first half is LO and the second half is HI. Examples of Manchester waveforms are shown in Figure 7–10.

[32]Formerly, this function utilized the variable output_in_process generated by the PLS output function described in Figure 7–5. For the sake of consistency with common implementation practice, the variable transmitting (see 4.3.3) is utilized directly by the PLS Carrier Sense function in recent editions of the standard.

The mapping between variable output_in_process and the variable transmitting is as follows. When output_in_process is true, transmitting is true; when output_in_process is false, transmitting is false.

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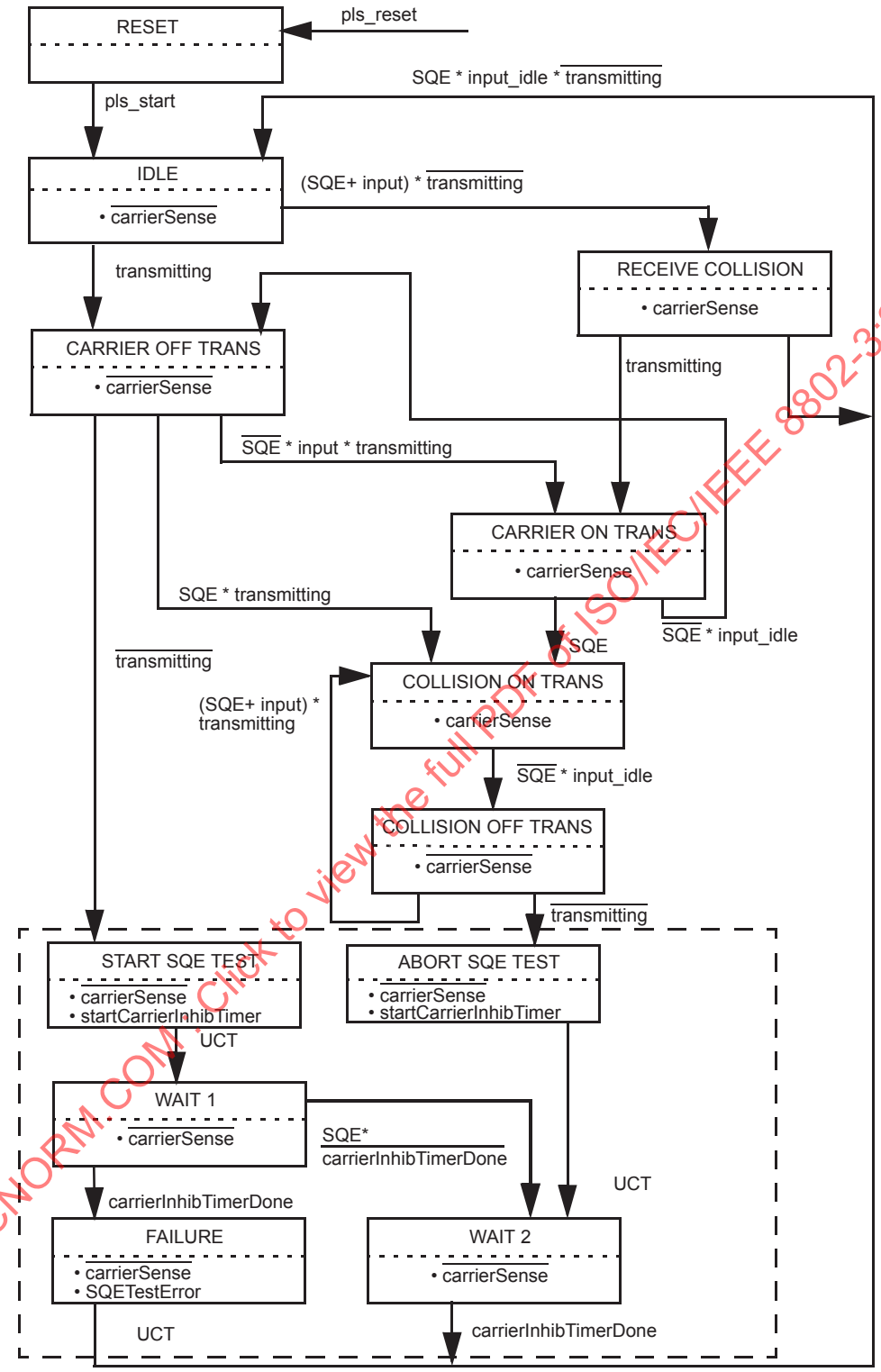

NOTE 1—UCT is unconditional transition; SQE is *signal_quality_error*.
NOTE 2—States within the dotted box are not implemented for the PLS sublayer within a repeater port.

Figure 7–8—PLS Carrier Sense function

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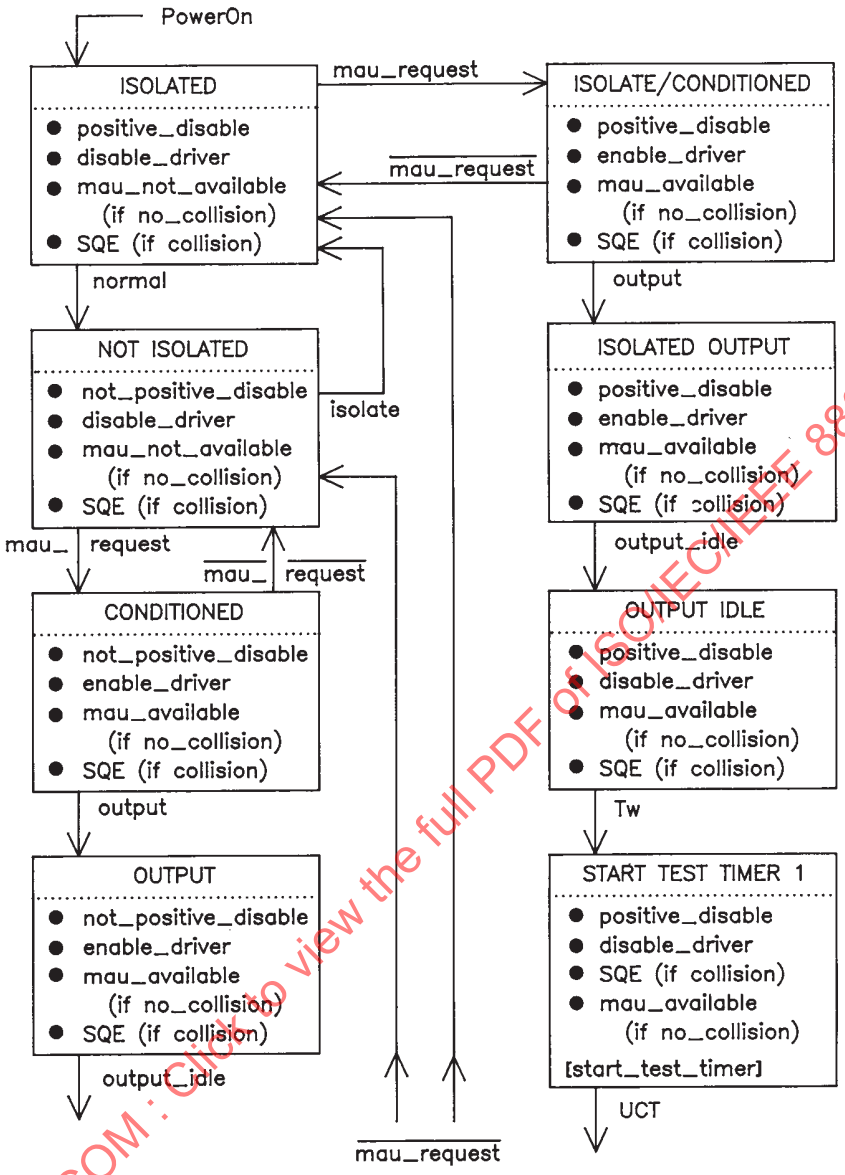

NOTE—See Figure 8–2 and Figure 8–3 for simple and isolate type MAUs.

a)

Figure 7–9—Interface function for MAU with conditioning

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The line condition IDL is also used as an encoded signal. An IDL always starts with a HI signal level. Since IDL always starts with a HI signal, an additional transition will be added to the data stream if the last bit sent was a zero. This transition cannot be confused with clocked data (CD0 or CD1) since the transition will occur at the start of a bit cell. There will be no transition in the middle of the bit cell. The IDL condition, as sent by a driver, shall be maintained for a minimum of 2 bit times. The IDL condition shall be detected within 1.6 bit times at the receiving device.

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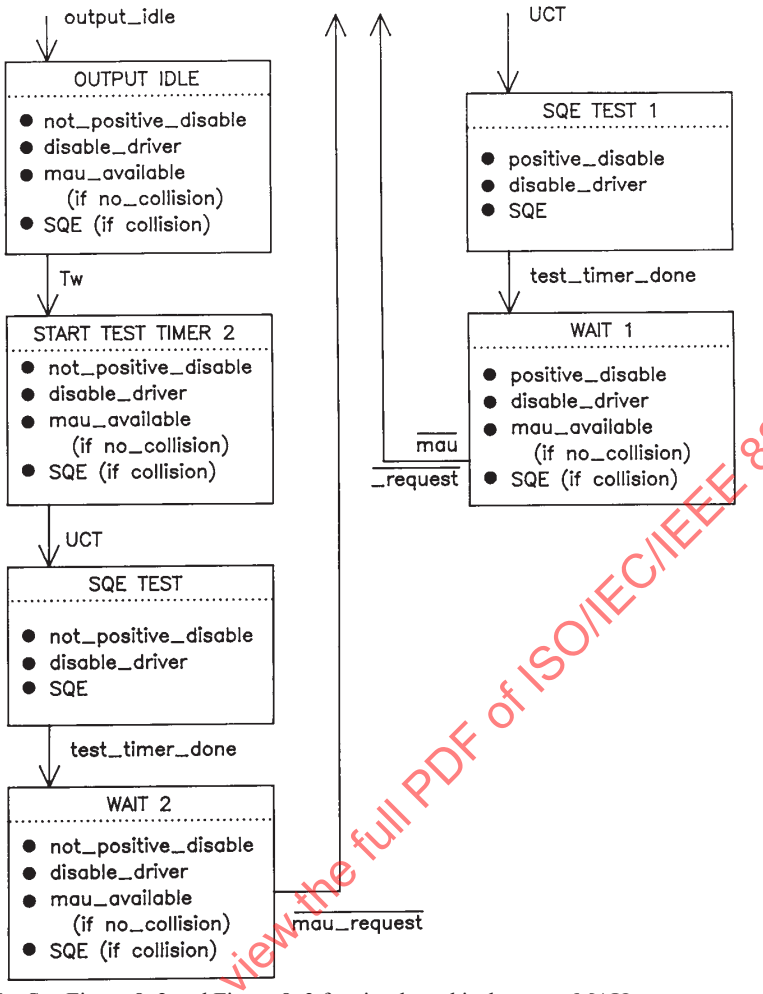

NOTE—See Figure 8–2 and Figure 8–3 for simple and isolate type MAUs.

b)

Figure 7–9—*(Continued)* Interface function for MAU with conditioning

a) System jitter considerations make detection of IDL (etd, end transmission delimiter) earlier than 1.3 bit times impractical. The specific implementation of the phase-locked loop or equivalent clock recovery mechanism determines the lower bound on the actual IDL detection time. Adequate margin between lower bound and 1.6 bit times should be considered.

b) Recovery of timing implicit in the data is easily accomplished at the receiving side of the interface because of the wealth of binary transitions guaranteed to be in the encoded waveform, independent of the data sequence. A phase-locked loop or equivalent mechanism maintains continuous tracking of the phase of the information on the Data circuit.

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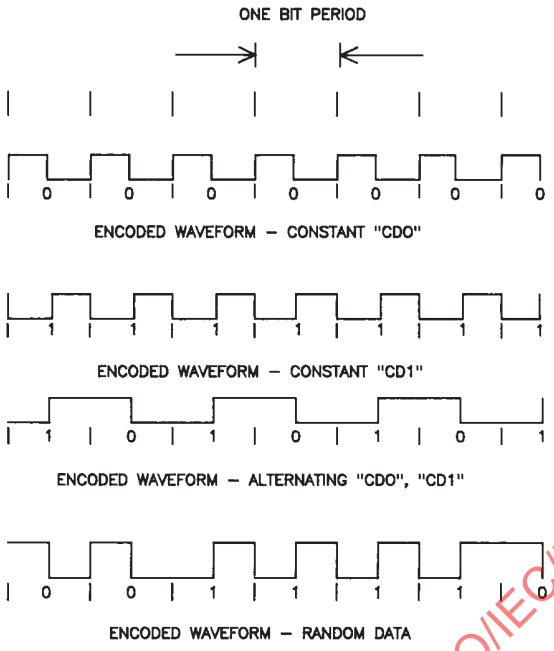

Figure 7–10—Examples of Manchester waveforms

7.3.1.2 Control encoding

A simpler encoding mechanism is used for control signaling than for data signaling. The encoded symbols used in this signaling mechanism are CS0, CS1, and IDL. The CS0 signal is a signal stream of frequency equal to the bit rate (BR). The CS1 signal is a signal stream of frequency equal to half of the bit rate (BR/2). If the interface supports more then one bit rate (see 4.2), the bit rate in use on the data circuits is the one to which the control signals are referenced. The IDL signal used on the control circuits is the same as the IDL signal defined for the data circuits (see 7.3.1.1). The Control Out circuit is optional (O) as is one message on Control In.

The frequency tolerance of the CS1 and CS0 signals on the CO circuit shall be ±5% and that of the CS1 signal on the CI circuit shall be ±15%. The duty cycle of the above signals is nominally 50%/50% and shall be no worse than 60%/40%. The CS0 signal on the CI circuit shall have a frequency tolerance of BR +25%, –15% with the pulse widths no less than 35 ns and no greater than 70 ns at the zero crossing points.

The meaning of the signals on the Control Out circuit (DTE to MAU) are as follows:

Signal	Message	Description
IDL	normal	Instructs the MAU to enter (remain in) normal mode
CS1	*mau_request* (O)	Requests that the MAU should be made available
CS0	*isolate* (O)	Instructs the MAU to enter (remain in) monitor mode

The meaning of the signals on the Control In circuit (MAU to DTE) are as follows:

Signal	Message	Description
IDL	mau_available	Indicates that the MAUs ready to output data
CS1	mau_not_available	Indicates that the MAU is not ready to output data
CS0	*signal_quality_error*	Indicates that the MAU has detected an error output data

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7.3.2 Signaling rate

Multiple signaling rates are encompassed by this standard. The signaling rate specified here is 10 million bits per second ±0.01%.

It is intended that a given MDI operate at a single data rate. It is not precluded that specific DTE and MAU designs be manually switched or set to alternate rates. A given local network shall operate at a single signaling rate. To facilitate the configuration of operational systems, DTE and MAU devices shall be labeled with the actual signaling rate used with that device.

7.3.3 Signaling levels

Exact voltage and current specifications are listed in 7.4.

7.4 Electrical characteristics

Terms BR and BR/2 have very specific meaning as used in this subclause. The term BR is used to mean the bit rate of the highest signaling rate supported by any one implementation of this interface, BR/2 is used to mean half the bit rate of the lowest signaling rate supported by any one implementation of this interface (see 7.3.2). An interface may support one or more signaling rates.

NOTE—The characteristics of the driver and receiver can be achieved with standard ECL logic with the addition of an appropriate coupling network; however, this implementation is not mandatory.

7.4.1 Driver characteristics

The driver is a differential driver capable of driving the specified 78 Ω interface cable. Only the parameters necessary to ensure compatibility with the specified receiver and to assure personnel safety at the interface connector are specified in the following subclauses.

7.4.1.1 Differential output voltage, loaded

Drivers shall meet all requirements of this subclause under *two* basic sets of test conditions (that is, each of two resistive values). For drivers located within a DTE, a combined inductive load of 27 µH ± 1% and either a 73 Ω or 83 Ω ± 1% resistive load shall be used. For a driver located within a MAU, a combined inductive load of 50 µH ± 1% and either 73 Ω or 83 Ω ± 1% resistive load shall be used.

The differential output voltage, V_{dm}, is alternately positive and negative in magnitude with respect to zero voltage. The value of V_{dm} into either of the two test loads identified above (R = 73 Ω or 83 Ω ± 1%) at the interface connector of the driving unit shall satisfy conditions defined by values V_{min} and V_{max} shown in Figure 7–11 for signals in between BR and BR/2 meeting the frequency and duty cycle tolerances specified for the signal being driven. The procedure for measuring and applying the test condition is as follows:

a) Construct a template representing the shaded area of Figure 7–11. Once constructed, the template may be shifted along the time axis in order to accommodate differences in the 10% to 50% and 50% to 90% transition times of the driver waveform.
b) Find the peak value of V_{dm}. This is V_{max}.
c) Find the minimum value of V_{dm} during the period between the shaded regions for the waveform's rising and falling transitions (time T1 in Figure 7–11). This minimum value is V_{min}.
d) V_{max} shall be < 1315 mV, V_{min} shall be > 450 mV, and V_{max}/V_{min} shall be < 1.37.
e) V_{dm} shall remain < 1170 mV 24 ns after a zero crossing.
f) The waveform shall remain within the shaded area limits.

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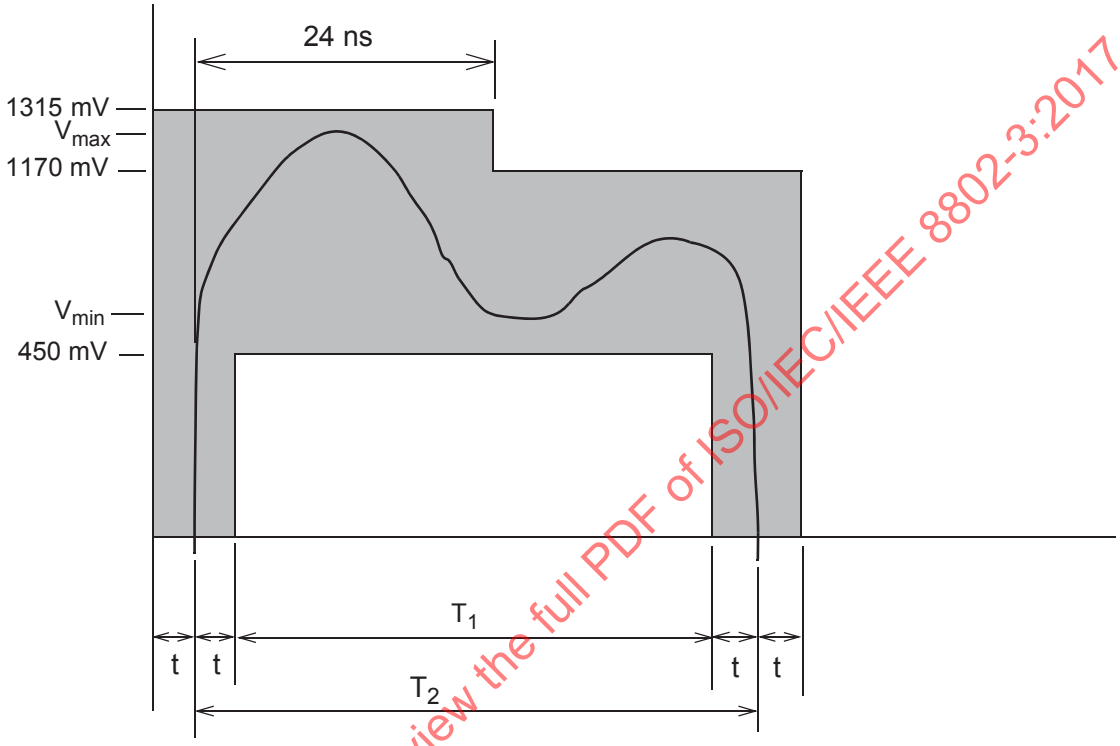
The differential output voltage magnitude, V_{dm}, into either of the two test loads identified above, at the interface connector of the driving unit during the idle state shall be within 40 mV of 0 V. The current into either of the two test loads shall be limited to 4 mA.

When a driver, connected to the appropriate two test loads identified above, enters the idle state, it shall maintain a minimum differential output voltage of at least 380 mV for at least 2 bit times after the last low to high transition.



t = 3.5 ns at 1–10 MHz data rates
T_2 = (BT or BT/2) ± 2 × T_j, where T_j is the amount of MAU–DTE permissible edge jitter
T_1 = T_2 – 7.0 ns

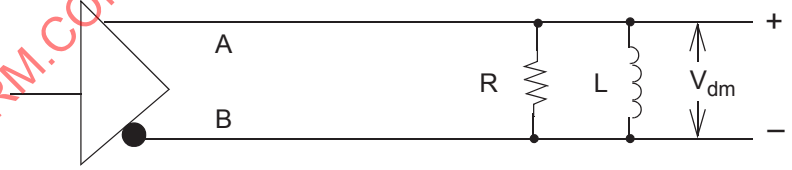


Figure 7–11—Differential output voltage, loaded

For drivers on either the CO or CI circuits, the first transition or the last positive going transition may occur asynchronously with respect to the timing of the following transitions or the preceding transition(s), respectively.

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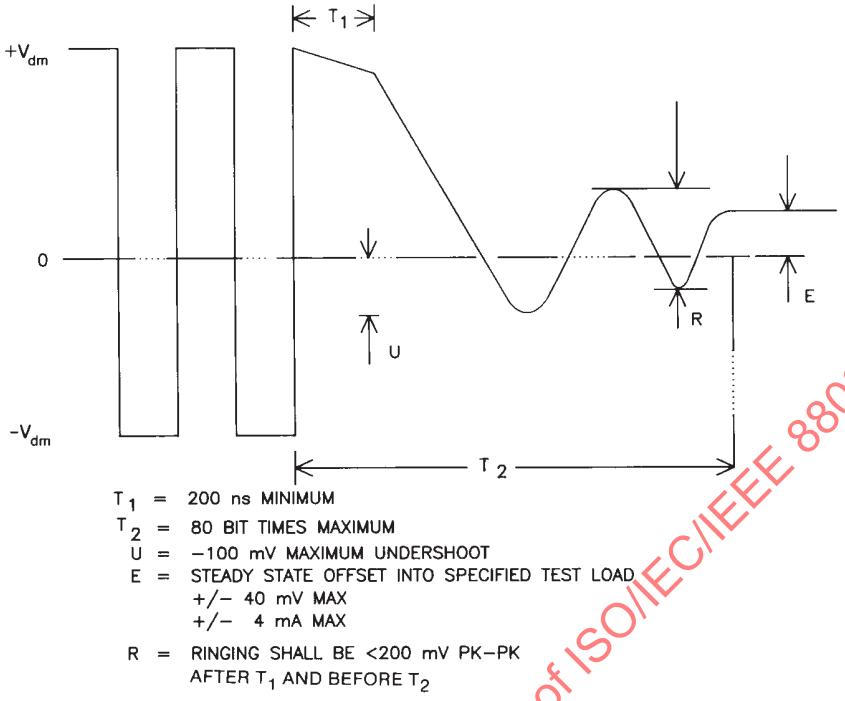

Figure 7–12—Generalized driver waveform

7.4.1.2 Requirements after idle

When the driver becomes nonidle after a period of idle on the interface circuit, the differential output voltage at the interface connector shall meet the requirements of 7.4.1.1 beginning with the second bit transmitted.The first bit sent over the driver circuit may contain phase violations or invalid data.

7.4.1.3 AC common-mode output voltage

The magnitude of the ac component of the common-mode output voltage of the driver, measured between the midpoint of a test load consisting of a pair of matched 39 Ω ± 1% resistors and circuit VC, as shown in Figure 7–13, shall not exceed 2.5 V peak from 30 Hz to 40 kHz and 160 mV peak from 40 kHz to BR.

7.4.1.4 Differential output voltage, open circuit

The differential output voltage into an open circuit, measured at the interface connector of the driving unit, shall not exceed 13 V peak.

7.4.1.5 DC common-mode output voltage

The magnitude of the dc component of the common-mode output voltage of the driver, measured between the midpoint of a test load consisting of a pair of matched 39 Ω ± 1% resistors and circuit VC, as shown in Figure 7–13, shall not exceed 5.5 V.

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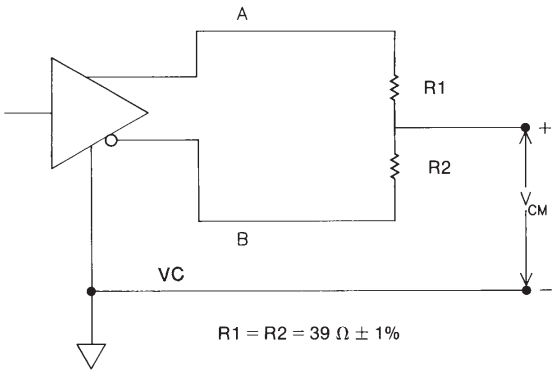
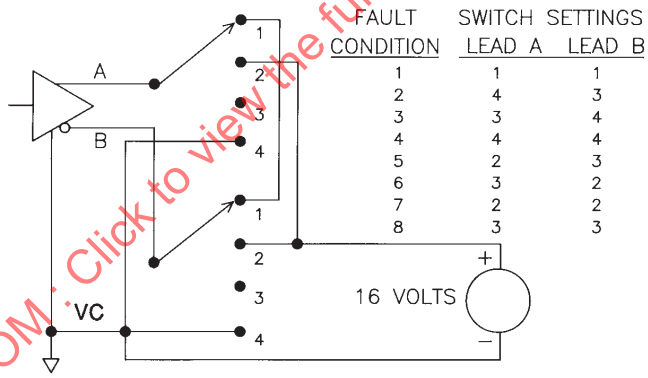


Figure 7–13—Com-

7.4.1.6 Fault tolerance

Any single driver in the interface, when idle or driving any permissible signal, shall tolerate the application of each of the faults specified by the switch settings in Figure 7–14 indefinitely, and after the fault condition is removed, the operation of the driver, according to the specifications of 7.4.1.1 through 7.4.1.5, shall not be impaired.

In addition, the magnitude of the output current from either output of the driver under any of the fault conditions specified shall not exceed 150 mA.



FAULT CONDITION	SWITCH SETTINGS LEAD A	LEAD B
1	1	1
2	4	3
3	3	4
4	4	4
5	2	3
6	3	2
7	2	2
8	3	3

Figure 7–14—Driver fault conditions

7.4.2 Receiver characteristics

The receiver specified terminates the interface cable in its characteristic impedance. The receiver shall function normally over the specified dc and ac common-mode ranges.

7.4.2.1 Receiver threshold levels

When the receiving interface circuit at the interface connector of the receiving equipment is driven by a differential input signal at either BR or BR/2 meeting the frequency and duty cycle tolerances specified for the receiving circuit, when the A lead is 160 mV positive with respect to the B lead, the interface circuit is in the HI state, and when the A lead is 160 mV negative with respect to the B lead, the interface circuit is in the

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LO state. The receiver output shall assume the intended HI and LO states for the corresponding input conditions.

If the receiver has a squelch feature, the specified receive threshold levels apply only when the squelch is allowing the signal to pass through the receiver.

NOTE—The specified threshold levels do not take precedence over the duty cycle and jitter tolerance specified elsewhere. Both sets of specifications must be met.

7.4.2.2 AC differential input impedance

The ac differential input impedance for AUI receivers located in MAUs shall have a real part of 77.83 Ω ± 6%, with the sign of the imaginary part positive, and the phase angle of the impedance in degrees less than or equal to 0.0338 times the real part of the impedance, when measured with a 10 MHz sine wave.

The ac differential input impedance for AUI receivers located in the DTE shall have a real part of 77.95 Ω ± 6%, with the sign of the imaginary part positive, and the phase angle of the impedance in degrees less than or equal to 0.0183 times the real part of the impedance, when measured with a 10 MHz sine wave.

A 78 Ω ± 6% resistor in parallel with an inductance of greater than 27 μH or 50 μH for receivers in the MAU and DTE respectively, satisfies this requirement.

7.4.2.3 AC common-mode range

When the receiving interface circuit at the receiving equipment is driven by a differential input signal at either BR or BR/2 meeting the frequency and duty cycle tolerances specified for the circuit being driven, the receiver output shall assume the proper output state as specified in 7.4.2.1, in the presence of a peak common-mode ac sine wave voltage either of from 30 Hz to 40 kHz referenced to circuit VC in magnitude from 0 V to 3 V, or in magnitude 0 V to 200 mV for ac voltages of from 40 kHz to BR as shown in Figure 7–15.

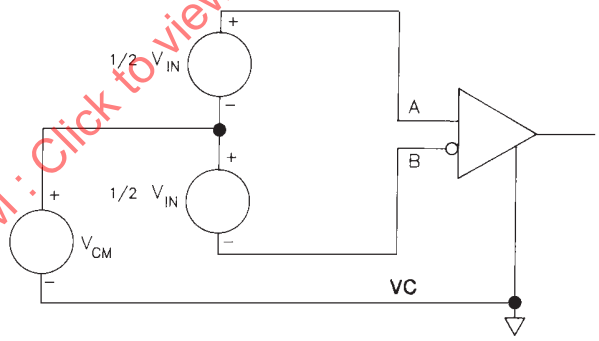

Figure 7–15—Common-mode input test

7.4.2.4 Total common-mode range

When the receiving interface circuit at the receiving equipment is driven by a differential input signal at either BR or BR/2 meeting the frequency and duty cycle tolerances specified for the circuit being driven, the receiver output shall assume the intended output state as specified in 7.4.2.1 in the presence of a total common-mode voltage, dc plus ac, referenced to circuit VC in magnitude from 0 V to 5.5 V, as shown in the test setup of Figure 7–15. The ac component shall not exceed the requirements of 7.4.2.3.

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The receiver shall be so designed that the magnitude of the current from the common-mode voltage source used in the test shall not exceed 1 mA.

7.4.2.5 Idle input behavior

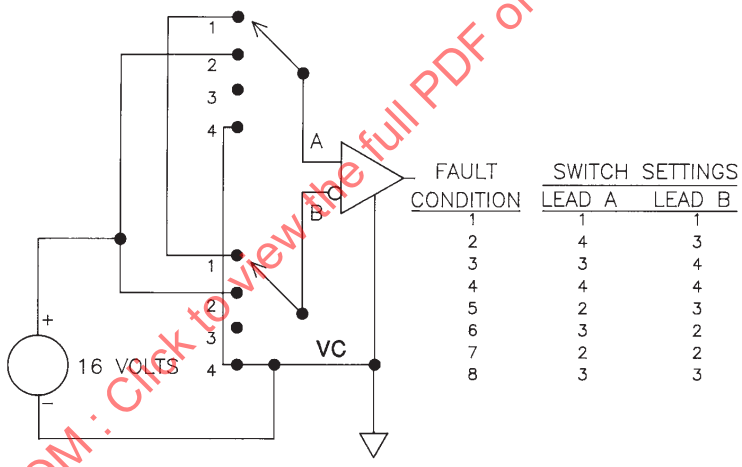
When the receiver becomes nonidle after a period of idle on the interface circuit, the characteristics of the signal at the output of the receiver shall stabilize within the startup delay allowed for the device incorporating the receiver so that it is not prevented from meeting the jitter specifications established for that device.

The receiving unit shall take precautions to ensure that a HI to idle transition is not falsely interpreted as an idle to nonidle transition, even in the presence of signal droop due to AC-coupling in the interface driver or receiver circuits.

7.4.2.6 Fault tolerance

Any single receiver in the interface shall tolerate the application of each of the faults specified by the switch settings in Figure 7–16 indefinitely, and after the fault condition is removed, the operation of the receiver according to the specifications of 7.4.2.1 through 7.4.2.6 shall not be impaired.

In addition, the magnitude of the current into either input of the receiver under any of the fault conditions specified shall not exceed 3 mA.



FAULT CONDITION	SWITCH SETTINGS LEAD A	LEAD B
1	1	1
2	4	3
3	3	4
4	4	4
5	2	3
6	3	2
7	2	2
8	3	3

Figure 7–16—Receiver fault conditions

7.4.3 AUI cable characteristics

The interface cable consists of individually shielded twisted pairs of wires with an overall shield covering these individual shielded wire pairs. These shields must provide sufficient shielding to meet the requirements of protection against rf interference and the following cable parameters. Individual shields for each signal pair are electrically isolated from the outer shield but not necessarily from each other.

The overall shield shall be returned to the MAU and DTE Units via the AUI connector shell as defined in 7.6.2 and 7.6.3. If a common drain wire is used for all the signal pair shields, then it shall be connected to pin 4 and pin 1. Individual drain wire returns for each signal pair may be used (see 7.6.3). It is recommended that individual drain wires be used on all control and data circuit shields to meet satisfactory crosstalk levels.

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If individual drain wires are used, they shall be interconnected within the AUI cable at each end and shall be connected at least to pin 4 and pin 1 at each end of the cable.

The presence of the Control Out signal pair is optional. If driver or receiver circuit components for CO are not provided, consideration should be given to properly terminating the CO signal pair within the DTE and MAU to preclude erroneous operation.

7.4.3.1 Conductor size

The dc power pair in the interconnecting cable, voltage common and voltage minus, shall be composed of a twisted pair of sufficient gauge stranded wires to result in a nominal dc resistance not to exceed 1.75 Ω per conductor.

Conductor size for the signal pairs shall be determined according to the ac related parameters in 7.4.3.2 through 7.4.3.6.

7.4.3.2 Pair-to-pair balanced crosstalk

The balanced crosstalk from one pair of wires to any other pair in the same cable sheath (when each pair is driven per 7.4.1.1 through 7.4.1.5) shall have a minimum value of 40 dB of attenuation measured over the range of BR/2 to BR.

7.4.3.3 Differential characteristic impedance

The differential characteristic impedance for all signal pairs shall be equal within 3 Ω and shall be 78 Ω ± 5 Ω measured at a frequency of BR.

7.4.3.4 Transfer impedance

a) The common-mode transfer impedance shall not exceed the values shown in Figure 7–17 over the indicated frequency range.
b) The differential mode transfer impedance for all pairs shall be at least 20 dB below the common-mode transfer impedance.

7.4.3.5 Attenuation

Total cable attenuation levels between driver and receiver (at separate stations) for each signal pair shall not exceed 3 dB over the frequency range of BR/2 to BR (Hz) for sinewave measurements.

7.4.3.6 Timing jitter

Cable meeting this specification shall exhibit edge jitter of no more than 1.5 ns at the receiving end when the longest legal length of the cable as specified in 7.4.3.1 through 7.4.3.7 is terminated in a 78 Ω ± 1% resistor at the receiving end and is driven with pseudorandom Manchester encoded binary data from a data generator which exhibits no more than 0.5 ns of edge jitter on half bit cells of exactly 1/2 BT and whose output meets the specifications of 7.4.1.1 through 7.4.1.5. This test shall be conducted in a noise-free environment. The above specified component is not to introduce more than 1 ns of edge jitter into the system.

7.4.3.7 Delay

Total signal delay between driver and receiver (at separate stations) for each signal pair shall not exceed 257 ns.

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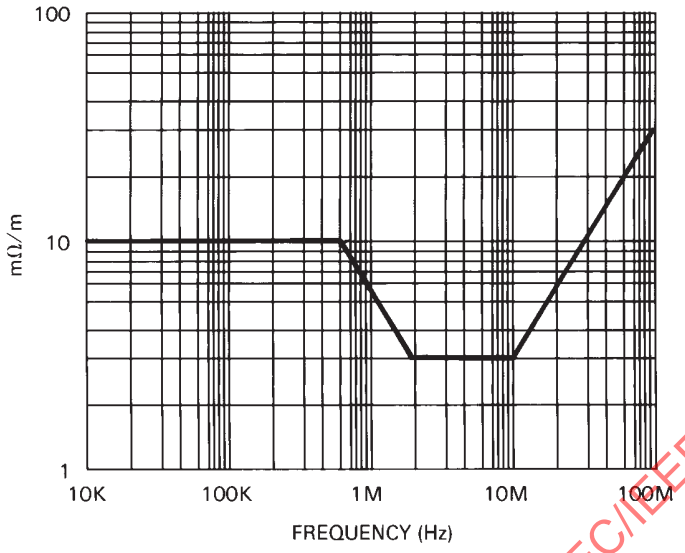

Figure 7–17—Common-mode transfer impedance

7.5 Functional description of interchange circuits

7.5.1 General

The AUI consists of either three or four differential signal circuits, power, and ground. Two of the circuits carry encoded data and two carry encoded control information. Circuits DO (Data Out) and CO (Control Out) are sourced by the DTE, and circuits DI (Data In) and CI (Control In) are sourced by the MAU. The interface also provides for power transfer from the DTE to the MAU. The CO circuit is optional.

7.5.2 Definition of interchange circuits

The following circuits are defined by this specification:

Circuit	Name	Signal direction		Remarks
		to MAU	from MAU	
DO	Data Out	X		Encoded Data
DI	Data In		X	Encoded Data
CO	Control Out	X		Encoded Control
CI	Control In		X	Encoded Control
VP	Voltage Plus	X		12 V
VC	Voltage Common	X		Return for VP
PG	Protective Ground	X		Shield

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7.5.2.1 Circuit DO–Data Out

The Data Out (DO) circuit is sourced by the DTE. It is a differential pair consisting of DO-A (Data Out circuit A) and DO-B (Data Out circuit B).

The signal transferred over this circuit is Manchester encoded. An *output* message containing a one bit is encoded as CD1. An *output_idle* message is encoded as an IDL.

The following symmetry requirements shall be met when the DTE transfers pseudorandom Manchester encoded binary data over a DO circuit loaded by the test load specified in 7.4.1.1.

Bit cells generated internal to the DTE are required to be 1 BT within the permitted tolerance on data rate specified in 7.3.2. Half bit cells in each data bit are the be exactly 1/2 BT (that is, the reference point for edge jitter measurements) within the permitted tolerance on the data rate specified in 7.3.2. Each transition on the DO circuit is permitted to exhibit edge jitter not to exceed 0.5 ns in each direction. This means that any transition may occur up to 0.5 ns earlier or later than this transition would have occurred had no edge jitter occurred on this signal.

7.5.2.2 Circuit DI–Data In

The Data In (DI) circuit is sourced by the MAU. It is a differential pair consisting of DI-A (Data In circuit A) and DI-B (Data In circuit B).

The signal transferred over this circuit is Manchester encoded. An *input* message containing a zero bit is encoded as CD0. An *input* message containing a one bit is encoded as CD1. An *input_idle* message is encoded as an IDL.

A DTE meeting this specification shall be able to receive, on the DI circuit without a detectable FCS error, normal preamble data arranged in legal length packets as sent by another station to the DTE. The test generator for the data on the DI circuit shall meet the requirements for drivers in MAUs specified in 7.4.1.1 through 7.4.1.5 and shall drive the DI circuit through a zero length AUI cable. Random amounts of edge jitter from 0 ns to 12 ns on either side of each transition shall be added by the test generator to transitions in bits in the preamble, and random amounts of edge jitter of from 0 ns to 18 ns on either side of each transition shall be added to the transitions in all bits in the frame. Preamble length from the test generator shall be 47 bits of preamble, followed by the 8 bit SFD.

NOTE—A significant portion of the system jitter may be nonrandom in nature and consists of a steady-state shift of the midbit transitions in either direction from their nominal placement. A 16.5 ns edge jitter is expected on the transmitted signal at the receiving DTE, worst case. The difference between 16.5 ns and 18 ns jitter represents receiver design margin.

7.5.2.3 Circuit CO–Control Out (optional)

The Control Out (CO) circuit is sourced by the DTE. It is a differential pair consisting of CO-A (Control Out circuit A) and CO-B (Control Out circuit B).

The signal transferred over this circuit is encoded as described in 7.3.1.2. A *mau_request* message is encoded as CS1. A *normal* message is encoded as IDL. An *isolate* message is encoded as CS0.

7.5.2.4 Circuit CI–Control In

The Control In (CI) circuit is sourced by the MAU. It is a differential pair consisting of CI-A (Control In circuit A) and CI-B (Control In circuit B).

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The signal transferred over this circuit is encoded as described in 7.3.1.2. A *mau_available* message is encoded as IDL. A *mau_not_available* message is encoded as CS1. A *signal_quality_error* message is encoded as a CS0.

7.5.2.5 Circuit VP–Voltage Plus

The Voltage Plus (VP) circuit is sourced from the DTE. It shall be capable of operating at one fixed level between + 12 V dc – 6% and + 15 V dc + 5% with respect to circuit VC at the DTE AUI for all currents from 0 to 500 mA. The source shall provide protection for this circuit against an overload condition. The method of overload protection is not specified; however, under no conditions of operation, either normal or overload, shall the source apply a voltage to circuit VP of less than 0 or greater than + 15.75 V dc as specified above. MAU designers are cautioned that protection means employed by power sources may cause the voltage at signal VP to drop below the minimum operational voltage specified without going completely to zero volts when loads drawing in excess of the current supplied are applied between VP and VC. Adequate provisions shall be made to ensure that such a condition does not cause the MAU to disrupt the medium.

7.5.2.6 Circuit VC–Voltage Common

Circuit VC is the ground return to the power source for circuit VP, capable of sinking 2.0 A. Also, all common-mode terminators for AUI circuits shall be made to circuit VC.

7.5.2.7 Circuit PG–Protective Ground

Circuit PG shall be connected to chassis ground through a maximum dc resistance of 20 mΩ at the DTE end.

7.5.2.8 Circuit shield terminations

Individual pin terminations shall meet the following requirements:

a) Pins 1, 4, 8, 11, 14 connected to logic ground in the DTE
b) Pins 1, 4, 8, 11, 14 capacitively coupled to VC in MAU
c) Impedance to ground < 5 Ω at the lowest operational BR/2 in the MAU and at the highest BR in the DTE

7.6 Mechanical characteristics

7.6.1 Definition of mechanical interface

All connectors used shall be as specified in 7.6.2. The DTE shall have a female connector and the MAU shall have a male connector. The MAU may be plugged directly into the DTE or may be connected by one or more cable segments whose total length is less than or equal to 50 m. All cable segments shall have a male connector on one end and a female connector on the other end. All female connectors shall have the slide latch, and all male connectors shall have the locking posts (as defined in Figure 7–18, Figure 7–19, and Figure 7–20) as the retention system.

7.6.2 Line interface connector

A 15-pole connector having the mechanical mateability dimensions as specified in IEC 60807-2 with gold-plated contacts shall be used for the line interface connector. The shells of these connectors shall be tin plated to ensure the integrity of the cable shield to chassis current path. The resistance of the cable shield to equipment chassis shall not exceed 5 mΩ, after a minimum of 500 cycles of mating and unmaking.

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In order to ensure intermateability of connectors obtained from different manufacturers, the connector with female contacts shall conform to IEC 60807-2 and have gold-plated contacts and tin-plated shells. All additions to provide for female shell to male shell conductivity shall be on the shell of the connector with male contacts. There should be multiple contact points around the sides of this shell to provide for shield continuity.

NOTE—Use of similar metallic surfaces on connector conductors and similar metallic surfaces on the connector shells minimizes galvanic action and reduced performance.

The connector is not specified to prevent operator contact with the shield, and precautions shall be taken at installation time to ensure that the installer is warned that the shield is not to be brought into contact with any hazardous voltage while being handled by operating personnel. See reference [B54].

7.6.3 Contact assignments

The following table shows the assignment of circuits to connector contacts.

Contact	Circuit	Use
3	DO-A	Data Out circuit A
10	DO-B	Data Out circuit B
11	DO-S	Data Out circuit shield
5	DI-A	Data In circuit A
12	DI-B	Data In circuit B
4	DI-S	Data In circuit shield
7	CO-A	Control Out circuit A
15	CO-B	Control Out circuit B
8	CO-S	Control Out circuit shield
2	CI-A	Control in circuit A
9	CI-B	Control In circuit B
1	CI-S	Control In circuit shield
6	VC	Voltage Common
13	VP	Voltage Plus
14	VS	Voltage Shield
Shell	PG	Protective Ground (Conductive Shell)

NOTE—Voltage Plus and Voltage Common use a single twisted pair in the AUI cable.

As indicated in 7.4.2.1, the A lead of a circuit is positive relative to the B lead for a HI signal and negative for a LO signal.

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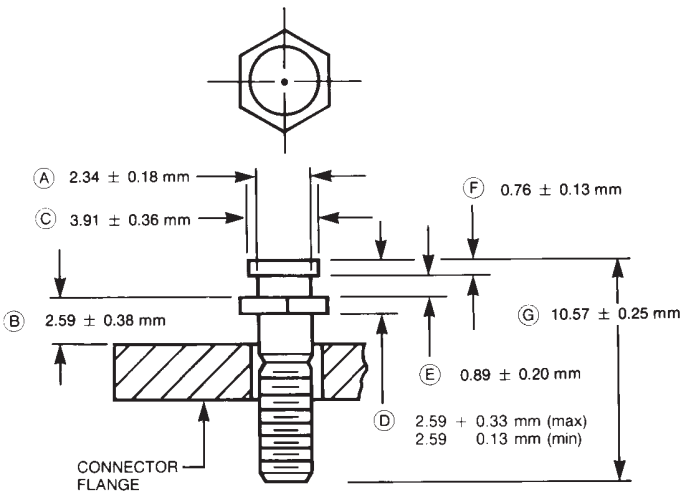

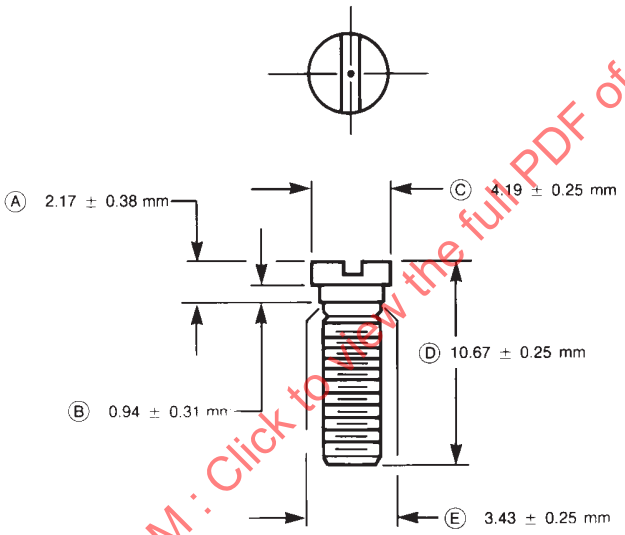

Figure 7–18—Connector locking posts

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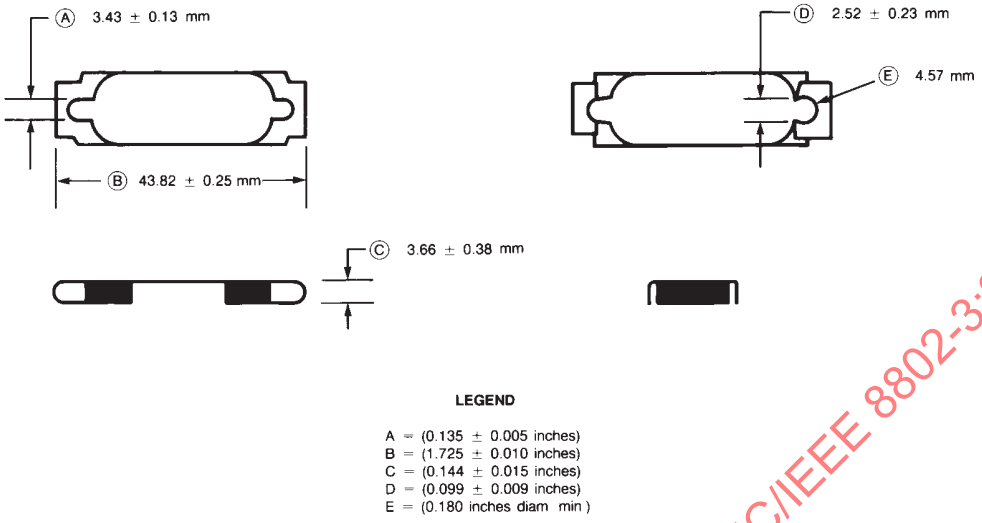

Figure 7–19—Connector slide latch

(material 24 gauge maximum)

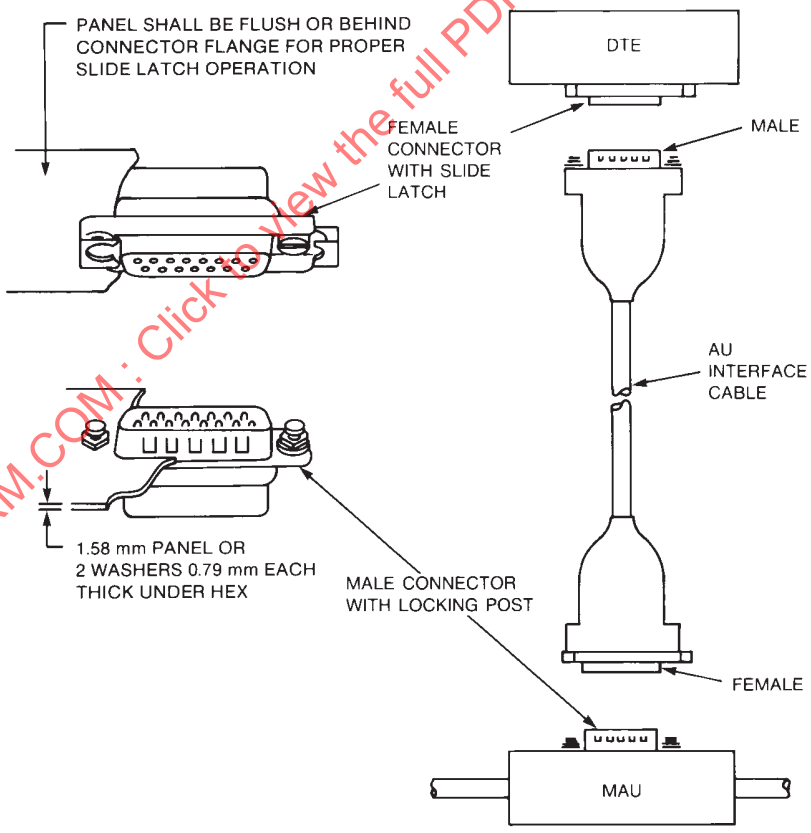

Figure 7–20—Connector hardware and AUI cable configuration

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8. Medium Attachment Unit and baseband medium specifications, type 10BASE5

NOTE—This MAU is not recommended for new installations. Since September 2003, maintenance changes are no longer being considered for this clause.

8.1 Scope

8.1.1 Overview

This standard defines the functional, electrical, and mechanical characteristics of the MAU and one specific medium for use with local networks. The relationship of this specification to the entire ISO/IEC Local Network International Standard is shown in Figure 8–1. The purpose of the MAU is to provide a simple, inexpensive, and flexible means of attaching devices to the local network medium.

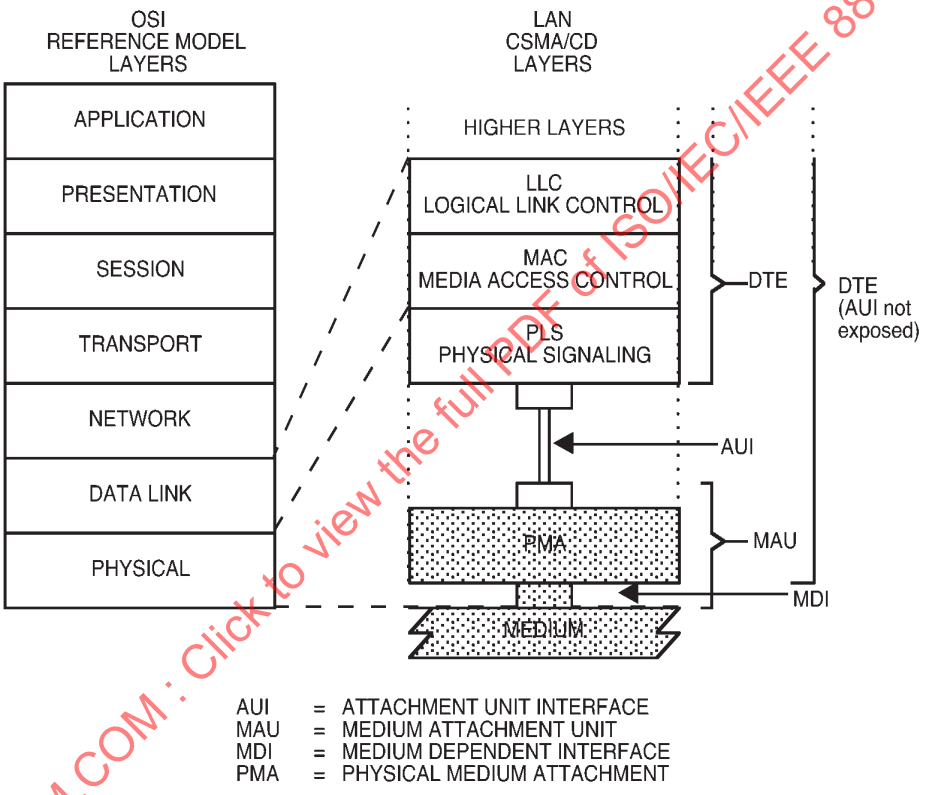

Figure 8–1—Physical Layer partitioning, relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model

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8.1.1 Medium Attachment Unit

The MAU has the following general characteristics:

a) Enables coupling the PLS by way of the AUI to the explicit baseband coaxial transmission system defined in this clause of the standard.
b) Supports message traffic at a data rate of 10 Mb/s (alternative data rates may be considered in future additions to the standard).
c) Provides for driving up to 500 m of coaxial trunk cable without the use of a repeater.
d) Permits the DTE to test the MAU and the medium itself.

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e) Supports system configurations using the CSMA/CD access mechanism defined with baseband signaling.
f) Supports a bus topology interconnection means.

8.1.1.2 Repeater unit

The repeater unit is used to extend the physical system topology, has the same general characteristics as defined in 8.1.1.1, and provides for coupling together two or more 500 m coaxial trunk cable segments. Multiple repeater units are permitted within a single system to provide a maximum trunk cable connection path of 2.5 km between any two MAUs.

8.1.2 Definitions

See 1.4.

8.1.3 Application perspective: MAU and MEDIUM objectives

This subclause states the broad objectives and assumptions underlying the specifications defined throughout this subclause of the standard.

8.1.3.1 Object

a) Provide the physical means for communication between local network data link entities.

NOTE—This standard covers a portion of the Physical Layer as defined in the OSI Reference Model and, in addition, the physical medium itself, which is beyond the scope of the OSI Reference Model.

b) Define a physical interface that can be implemented independently among different manufacturers of hardware and achieve the intended level of compatibility when interconnected in a common local network.
c) Provide a communication channel capable of high bandwidth and low bit error ratio performance. The resultant mean bit error ratio at the Physical Layer service interface should be less than one part in 10^8 (on the order of one part in 10^9 at the link level).
d) Provide for ease of installation and service.
e) Provide for high network availability (ability of a station to gain access to the medium and enable the data link connection in a timely fashion).
f) Enable relatively low-cost implementations.

8.1.3.2 Compatibility considerations

All implementations of this baseband coaxial system shall be compatible at the MDI.

This standard provides one explicit trunk cable medium specification for the interconnection of all MAU devices. The medium itself, the functional capability of the MAU, and the AUI are defined to provide the highest possible level of compatibility among devices designed by different manufacturers. Designers are free to implement circuitry within the MAU in an application-dependent manner provided the MD Interface and AUI specifications are satisfied.

Subsystems based on this specification may be implemented in several different ways provided compatibility at the medium is maintained. It is possible, for example, to design an integrated station where the MAU is contained within a physical DTE system component, thereby eliminating the AUI cable. The device designer (and system user) shall then consider such factors as topological flexibility, system availability, and configurability.

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8.1.3.3 Relationship to PLS and AU interface

This subclause defines the primary Physical Layer for the LAN, a layer comprised of both the physical medium and the rudimentary circuitry necessary to couple a station's message path directly to/from the medium. The complete logical Physical Layer of the LAN may reside physically in two distinct locations, the MAU and the DTE. Therefore, a close relationship exists between this subclause and Clause 7. This subclause specifies all of the physical medium parameters, all of the PMA logical functions residing in the physical MAU, and references the AUI associated with and defined throughout Clause 7.

NOTE—The design of a physical MAU component requires the use of both this subclause and Clause 7 for the PLS and AUI specifications.

8.1.3.4 Modes of operation

The MAU is capable of operating in either a "Normal" mode or an optional "Monitor" mode.

a) *Normal mode.* The MAU functions as a direct connection between the baseband medium and the DTE. Data output from the DTE is output to the coaxial trunk medium and all data on the coaxial trunk medium is input to the DTE. This mode is the "normal" mode of operation for the intended message traffic between stations.
b) *Monitor mode.* The MAU Transmit function is disabled to prevent data from being output on the trunk coaxial medium while the receive function and collision presence function remain active for purposes of monitoring medium message traffic. This mode also serves as a limited test mode at the same time it isolates the MAU transmitter from the medium. Under most local (that is, intrastation) fault conditions the monitor mode enables continued use of the network while the local station is being serviced.

8.2 MAU functional specifications

The MAU component provides the means by which signals on the four physically separate AUI signal circuits to/from the DTE and their associated interlayer messages are coupled to the single coaxial cable baseband signal line. To achieve this basic objective, the MAU component contains the following functional capabilities to handle message flow between the DTE and the baseband medium:

a) *Transmit function.* The ability to transmit serial data bit streams on the baseband medium from the local DTE entity and to one or more remote DTE entities on the same network.
b) *Receive function.* The ability to receive serial data bit streams over the baseband medium.
c) *Collision Presence function*. The ability to detect the presence of two or more stations' concurrent transmissions.
d) *Monitor function* (Optional). The ability to inhibit the normal transmit data stream to the medium at the same time the normal receive function and collision presence function remain operational.
e) *Jabber function.* The ability to automatically interrupt the transmit function and inhibit an abnormally long output data stream.

8.2.1 MAU Physical Layer functions

8.2.1.1 Transmit function requirements

At the start of a frame transmission on the coaxial cable, no more than 2 bits (2 full bit cells) of information may be received from the DO circuit and not transmitted onto the coaxial medium. In addition, it is permissible for the first bit sent to contain encoded phase violations or invalid data; however, all successive bits of the frame shall be reproduced with no more than the specified amount of jitter. The second bit cell transmitted onto the coaxial cable shall be carried from the DO signal line and transmitted onto the coaxial trunk

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cable medium with the correct timing and signal levels. The steady-state propagation delay between the DO circuit receiver input and the coaxial cable output shall not exceed one-half bit cell. At the start of transmission, the MAU bit loss plus steady-state propagation delay between the DO and the coaxial cable shall vary by less than 2 bits between successive packets separated by 96 bit times or less. There shall be no logical signal inversions between the branch cable DO circuit and the coaxial trunk cable (for example, a "high" logic level input to the MAU shall result in the less negative current flow value on the trunk coaxial medium). A positive signal on the A signal lead of the DO circuit shall result in a more positive voltage level on the trunk coaxial medium. It is assumed that the AUI shall provide adequate protection against noise. It is recommended that the designer provide an implementation in which a minimum threshold signal is required to establish a transmit bit stream.

The Transmit function shall output a signal on the trunk coaxial medium whose levels and waveform comply with 8.3.1.3.

In addition, when the DO circuit has gone idle after a frame is output, the MAU shall then activate the collision presence function as close to the trunk coaxial cable as possible without introducing an extraneous signal on the trunk coaxial medium. The MAU shall initiate the collision presence state within 0.6 μs to 1.6 μs after the start of the output idle signal and shall maintain an active collision presence state for a time equivalent to 10 bit cells ± 5 bit cells.

8.2.1.2 Receive function requirements

The signal from the coaxial trunk cable shall be directly coupled to the receiver and subsequently AC-coupled before reaching the receive circuit connected to the DTE. The receive function shall output a signal onto the DI circuit of the AUI cable that complies with the AUI specification for drivers in MAUs.

At the start of a frame reception from the coaxial cable, no more than 5 bits (five full bit cells) of information may be received from the coaxial cable and not transmitted onto the receive (DI) circuit. In addition, it is permissible for the first bit sent over the receive circuit to contain encoded phase violations or invalid data; however, all successive bits of the frame shall reproduce the incoming signal with no more than the above specified amount of jitter. This implies that the second bit cell sent onto the DI circuit presents valid data to the branch cable. The steady-state propagation delay between the coaxial cable and the receive (DI) circuit output shall not exceed one-half bit cell. At the start of reception, the MAU bit loss plus steady-state propagation delay between the coaxial cable and the DI circuit shall vary by less than 5 bits between successive packets separated by 96 bit times or less when the signal level on the coaxial cable is constant (that is, when both packets are transmitted by the same MAU). There are no logical signal inversions between the coaxial (trunk) cable and the MAU (branch) cable receive circuit.

A MAU meeting this specification shall exhibit edge jitter into the DI pair when terminated in the appropriate test load specified in 7.4.3.6, of no more than 8.0 ns in either direction when it is installed on the distant end of all lengths between 2.5 m and 500 m of the cable specified in 8.4.1.1 through 8.4.2.1.5 terminated at both ends with terminators meeting the impedance requirements of 8.5.2.1 and driven at one end with pseudorandom Manchester encoded binary data from a data generator that exhibits no more than 1.0 ns of edge jitter in either direction on half-bit cells of exactly 1/2 BT and whose output meets the specifications of 8.3.1.3 except that the risetime of the signal must be 30 ns + 0, – 2 ns. This test shall be conducted in a noise-free environment. The combination of coaxial cable and MAU receiver introduce no more than 6 ns of edge jitter into the system.

The local transmit and receive functions shall operate simultaneously while connected to the medium operating in the half duplex operating mode.

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8.2.1.3 Collision Presence function requirements

The signal presented to the CI circuit in the absence of a collision shall be the IDL signal except when the MAU is required to signal the CS1 signal.

The signal presented to the CI circuit during the presence of a collision shall be the CS0 signal encoded as specified in 7.3.1.2. Under no conditions shall the collision presence function generate an output when only one MAU is transmitting. Table 8–1 summarizes the allowable conditions under which collisions shall be detected.

a) Collision Assertion
   1) In the case where the MAU has been transmitting for at least 20 bit times before the arrival at the MAU on the coaxial cable of a transmission from another MAU, the CS0 signal shall be presented to the CI circuit no more than 17 bit times after the arrival at the MAU on the MDI of a transmission from another MAU. Arrival at the MAU shall be considered to be the time when the transmission of the other MAU causes the dc level on the MDI to become more negative.
   2) In all other cases where the MAU is transmitting, the CS0 signal shall be presented to the CI circuit no more than 29 bit times after the later of start of transmission by the MAU and the arrival of a transmission from another MAU.

b) Collision De-assertion
   1) In the case where a collision has occurred between the MAU and one other MAU, the IDL signal shall be presented to the CI circuit no more than 17 bit times after either the end of transmission by the MAU or the arrival of the end of transmission from the other MAU, whichever occurs earlier. The arrival of the end of transmission from the other MAU shall be the time when the cessation of transmission causes the dc level on the MDI to become less negative.
   2) In the case where a collision has occurred between more than two MAUs, the IDL signal shall be presented to the CI circuit no more than 29 bit times after the arrival of the end of transmission from all but one MAU.

These timing conditions shall be met for all data bit patterns and combinations of MDI, MAU transmit levels, and MAU locations on the segment.

The collision presence function may, in some implementations, be able to sense an abnormal (for example, open) medium.

Table 8–1—Generation of collision presence signal

MAU	Numbers of transmitters		
	<2	=2	>2
Transmitting	N	Y	Y
Not transmitting	N	Y	Y
Y= shall generate SQE message N= shall not generate SQE message			

8.2.1.4 Monitor function requirements (optional)

Upon receipt of the *isolate* message the MAU shall, within 20 ms (implementations: solid-state preferred, relay switched permitted), disable the transmit function in such a way as to prevent both the transmission of signals on the trunk coaxial medium and any abnormal loading by the disabled transmitter on the trunk coaxial medium itself. The monitor function is intended to prevent a malfunctioning active component (for example, transmit driver) from bringing down the network. The *isolate* message shall not interact with the

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receive or collision presence functions, thus permitting the normal operational mode wherein all data appearing on the trunk coaxial medium are carried to the DTE on the DI signal circuit.

NOTE—Verification for successful execution of the *isolate* message requires use of the trunk coaxial medium itself. This level of guaranteed performance requires use of system layers above the Physical Layer and implies some interruption of normal trunk coaxial medium message traffic.

8.2.1.5 Jabber function requirements

The MAU shall contain a self-interrupt capability to inhibit transmit data from reaching the medium. Hardware within the MAU (with no external message other than the detection of output data, bits, or leakage, by way of the transmit function) shall provide a nominal window of at least 20 ms to at most 150 ms during which time a normal data link frame may be transmitted. If the frame length exceeds this duration, the jabber function shall inhibit further output data from reaching the medium.

When the transmit function has been positively disabled, the MAU shall then activate the collision presence function as close to the trunk coaxial medium as possible without introducing an extraneous signal on the trunk coaxial medium. A MAU without the monitor function may reset the jabber and collision presence functions on power reset. Alternatively, a MAU without the monitor function may reset these functions after a period of 0.5 s ± 50% if the monitor function has not been implemented. If the monitor function has been implemented then it shall be used to reset the collision presence and jabber functions.

8.2.2 MAU interface messages

8.2.2.1 DTE Physical Layer to MAU Physical Layer messages

The following messages can be sent by the DTE Physical Layer entities to the MAU Physical Layer entities:

Message	Circuit	Signal	Meaning
output	DO	CD1, CD0	Output information
output_idle	DO	IDL	No data to be output
normal	CO	IDL	Assume the nonintrusive state on the trunk coaxial medium
(Optional circuit)			
isolate	CO	CS0(BR)	Positively disable the trunk coaxial medium transmitter

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8.2.2.2 MAU Physical Layer to DTE Physical Layer

The following messages can be sent by the MAU Physical Layer entities to the DTE Physical Layer entities:

Message	Circuit	Signal	Meaning
input	DI	CD1, CD0	Input information
input_idle	DI	IDL	No information to be input
mau_available	CI	IDL	MAU is available for output
signal_quality_error	CI	CS0	Error detected by MAU

8.2.2.2.1 *input* message

The MAU Physical Layer sends an *input* message to the DTE Physical Layer when the MAU has a bit of data to send to the DTE. The physical realization of the input message is a CD0 or CD1 sent by the MAU to the DTE on the data in circuit. The MAU sends CD0 if the *input* bit is a zero or CD1 if the *input* bit is a one. No retiming of the CD1 or CD0 signals takes place within the MAU.

8.2.2.2.2 *input_idle* message

The MAU Physical Layer sends an *input_idle* message to the DTE Physical Layer when the MAU does not have data to send to the DTE. The physical realization of the *input_idle* message is the IDL signal sent by the MAU to the DTE on the data in circuit.

8.2.2.2.3 *mau_available* message

The MAU Physical Layer sends the *mau_available* message to the DTE Physical Layer when the MAU is available for output. The *mau_available* message is always sent by a MAU that is always prepared to output data unless the *signal_quality_error* message shall be sent instead. Such a MAU does not require *mau_request* to prepare itself for data output. The physical realization of the *mau_available* message is an IDL signal sent by the MAU to the DTE on the control in circuit.

8.2.2.2.4 *signal_quality_error* message

The *signal_quality_error* message shall be implemented in the following fashion:

a) The *signal_quality_error* message shall not be sent by the MAU if no MAU or only one MAU is transmitting on the trunk coaxial medium in the normal mode.
b) If two or more remote MAUs are transmitting on the trunk coaxial medium, but the MAU connected to the local node is not transmitting, then the local MAU shall send the *signal_quality_error* message.
c) When the local MAU is transmitting on the trunk coaxial medium, all occurrences of one or more additional MAUs transmitting shall cause the *signal_quality_error* message to be sent by the local MAU to its DTE.
d) When the MAU has completed each output frame it shall perform an SQE test sequence, as defined in Figure 8–2 and Figure 8–3.
e) When the MAU has inhibited the transmit function it shall send the *signal_quality_error* message in accordance with the jabber function requirements of 8.2.1.5.

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The physical realization of the *signal_quality_error* message is the CS0 signal sent by the MAU to the DTE on the control in circuit. See 8.2.1.3 for timing requirements on the assertion and de-assertion of the CS0 signal in a collision.

Note that the MAU is required to assert the *signal_quality_error* message at the appropriate times whenever the MAU is powered and not just when the DTE is providing output data.

8.2.3 MAU state diagrams

The state diagrams, Figure 8–2 (a–d), Figure 8–3, and Figure 8–4, depict the full set of allowed MAU state functions relative to the control circuits of the DTE-MAU interface for MAUs without conditioning requirements. Messages used in these state diagrams are explained below:

a) *positive_disable.* Activates the positive means provided in the MAU transmitter to prevent interference with the trunk coaxial medium.
b) *enable_driver.* Activates the path employed during normal operation to cause the MAU transmitter to impress data onto the trunk coaxial medium.
c) *disable_driver.* Deactivates the path employed during normal operation to cause the MAU transmitter to impress data onto the trunk coaxial medium.
d) *no_collision.* Signifies that the condition of multiple transmitters simultaneously active on the trunk coaxial medium does not exist.
e) *collision.* Signifies that the condition of multiple transmitters simultaneously active on the trunk coaxial medium does exist.
f) *not_positive_disable.* Deactivates the positive means provided in the MAU transmitter to prevent interference with the trunk coaxial medium.

When no state is asserting the message *signal_quality_error*, the message *MAU_input_idle* is sent.

8.3 MAU–medium electrical characteristics

8.3.1 MAU-to-coaxial cable interface

The following subclauses describe the interface between the MAU and the coaxial cable. Negative current is defined as current into the MAU (out of the center conductor of the cable).

8.3.1.1 Input impedance

The shunt capacitance presented to the coaxial cable by the MAU circuitry (not including the means of attachment to the coaxial cable) is recommended to be no greater than 2 pF. The resistance to the coaxial cable shall be greater than 100 kΩ.

The total capacitive load due to MAU circuitry and the mechanical connector as specified in 8.5.3.2 shall be no greater than 4 pF.

These conditions shall be met in the power-off and power-on, not transmitting states (over the frequencies BR/2 to BR).

The magnitude of the reflection from a MAU shall not be more than that produced by a 4 pF capacitance when measured by both a 25 ns rise time and 25 ns fall time waveform. This shall be met in both the power on and power off, not transmitting states.

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8.3.1.2 Bias current

The MAU shall draw (from the cable) between +2 µA and –25 µA in the power-off and the power-on, not transmitting states.

8.3.1.3 Coaxial cable signaling levels

The signal on the coaxial cable due to a single MAU as measured at the MAU transmitter output is composed of an ac component and an offset component. Expressed in terms of current immediately adjacent to the MAU connection (just prior to splitting the current flow in each direction) the signal has an offset component (direct current including the effects of timing distortion) of from –37 mA minimum to –45 mA maximum and an ac component from +28 mA up to the offset value.

The current drive limit shall be met even in the presence of one other MAU transmitter. A MAU shall be capable of maintaining at least 2.2 V of average dc level on the coaxial cable in the presence of two or more other MAUs transmitting concurrently. The MAU shall, in addition, sink no more than ±250 µA when the voltage on the center conductor of the cable drops to –10 V when the MAU is transmitting.

The MAU shall sink no more than –25 µA when the voltage on the center conductor of the cable drops to –7 V when the MAU is transmitting.

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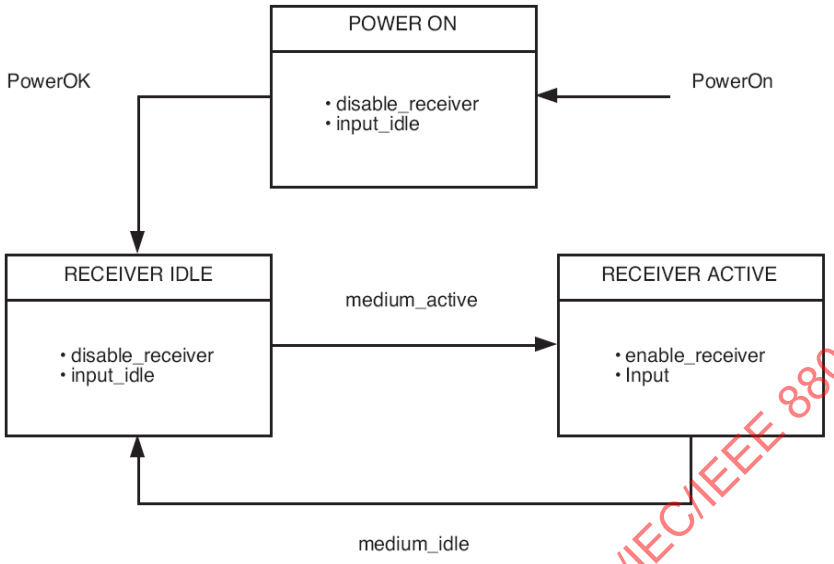
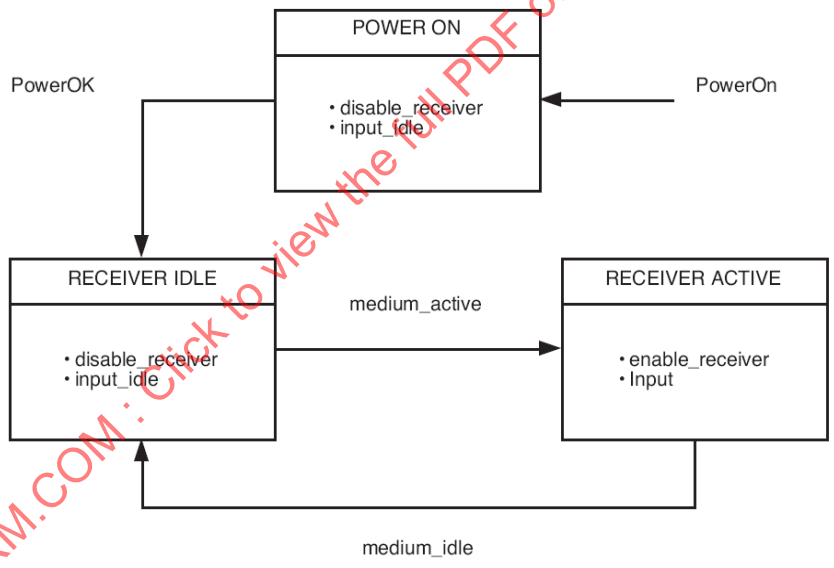


a) Receive function state diagram



b) Collision Presence function state diagram

Figure 8–2—Interface function: Simple MAU without isolate capability

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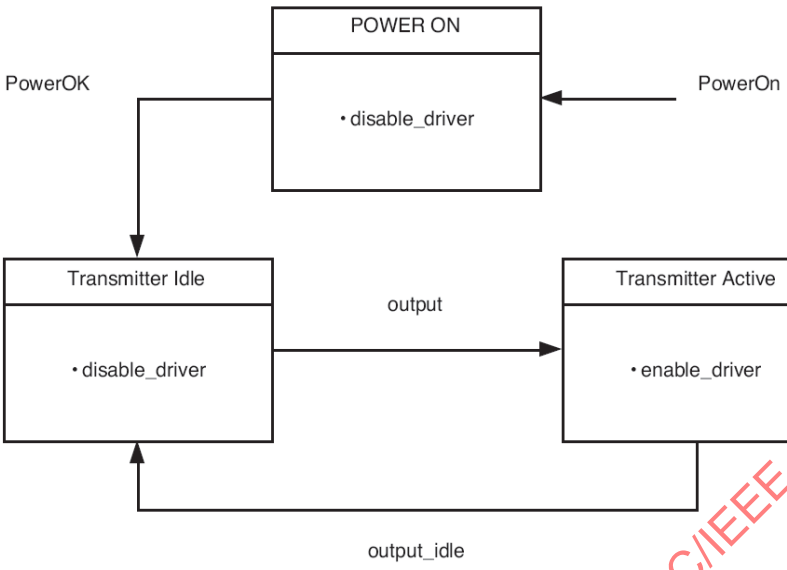
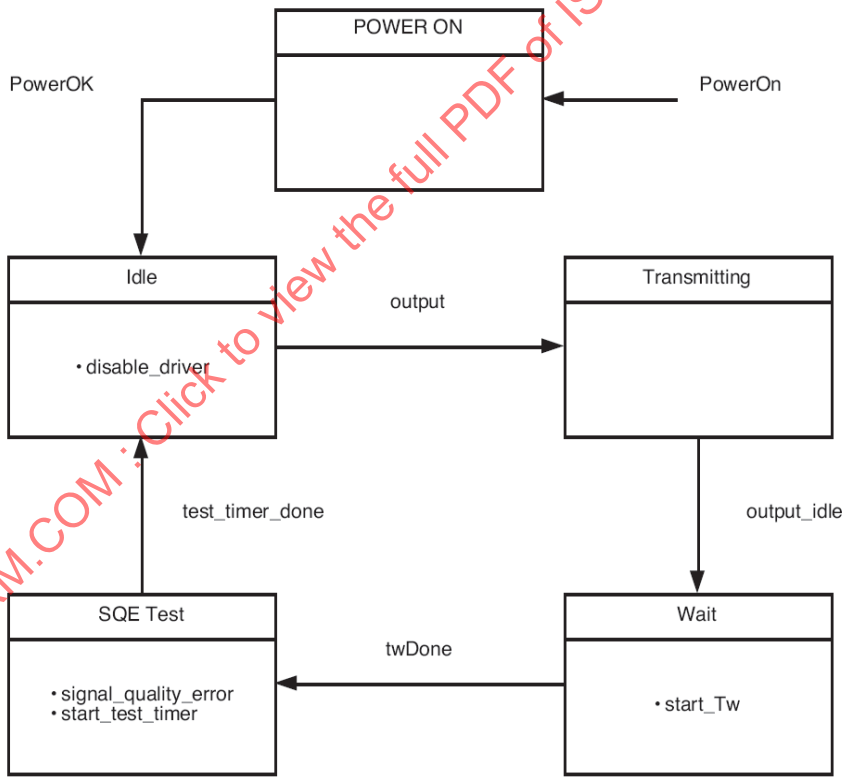


c) Transmit function state diagram



d) SQE test state diagram

Figure 8–2—*(Continued)*
Interface function: Simple MAU without isolate capability

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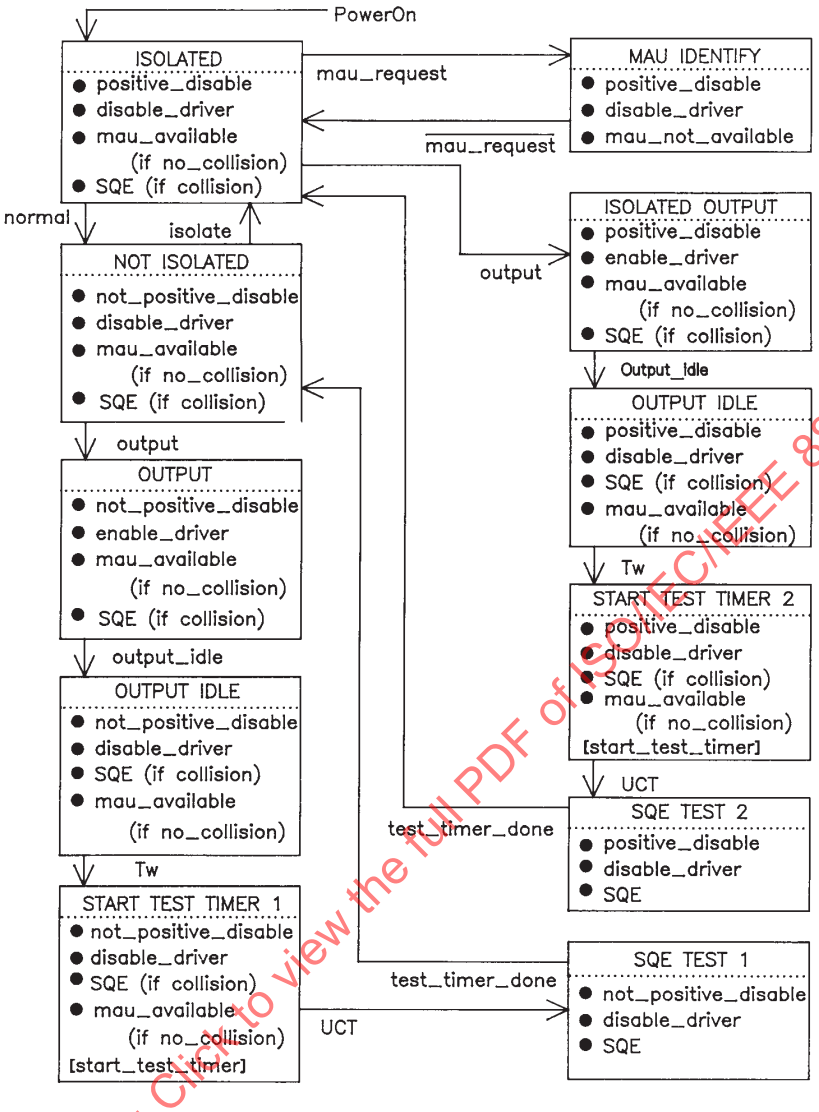

NOTE: UCT = unconditional transition
Tw = wait time, see 8.2.1.1

Figure 8–3—Interface function: Simple MAU with isolate capability

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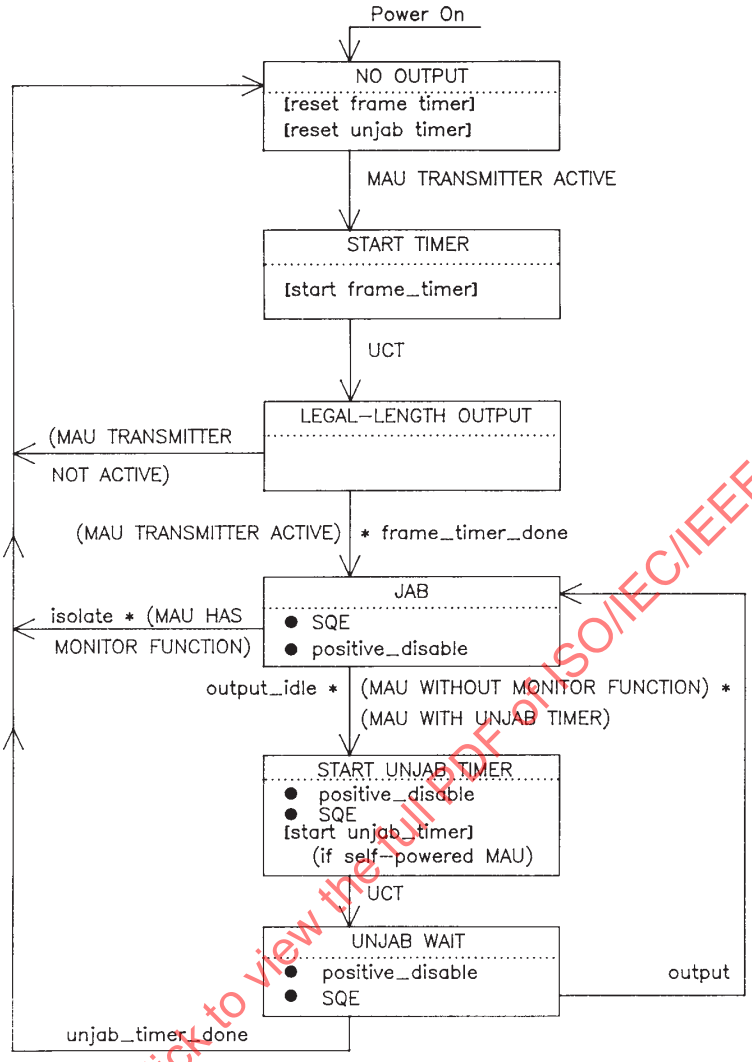

Figure 8–4—Jabber function

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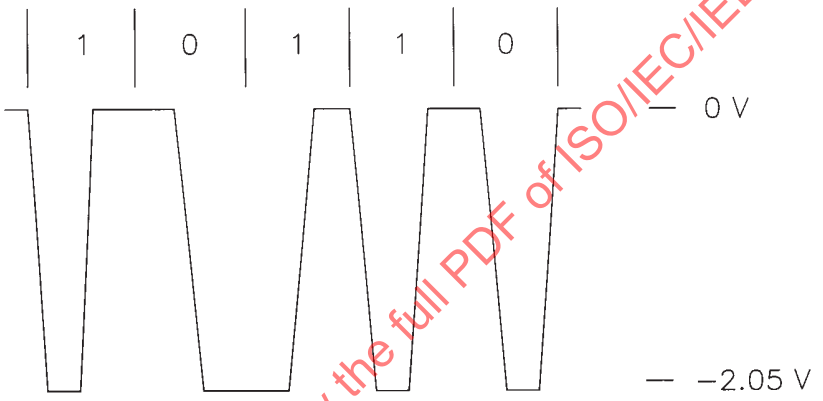
The actual current measured at a given point on the cable is a function of the transmitted current and the cable loss to the point of measurement. Negative current is defined as current out of the center conductor of the cable (into the MAU). The 10–90% rise/fall times shall be 25 ns ± 5 ns at 10 Mb/s. The rise and fall times shall match within 2 ns. Figure 8–5 and Figure 8–6 shows typical waveforms present on the cable. Harmonic content generated from the BR fundamental periodic input shall meet the following requirements:

2nd and 3rd Harmonics:at least 20 dB below fundamental
4th and 5th Harmonics:at least 30 dB below fundamental
6th and 7th Harmonics:at least 40 dB below fundamental
All higher Harmonics:at least 50 dB below fundamental

NOTE—Even harmonics are typically much lower.

The above specifications concerning harmonics cannot be satisfied by a square-wave with a single-pole filter, nor can they be satisfied by an output waveform generator employing linear ramps without additional waveshaping. The signals as generated from the encoder within PLS shall appear on the coaxial cable without any inversions (see Figure 8–6).



NOTES: (1) Voltages given are nominal, for a single transmitter
(2) Rise and fall time is 25 ns nominal at 10 Mb/s rate
(3) Voltages are measured on terminated coaxial cable adjacent to transmitting MAU
(4) Manchester coding

Figure 8–5—Typical coaxial trunk cable signal waveform

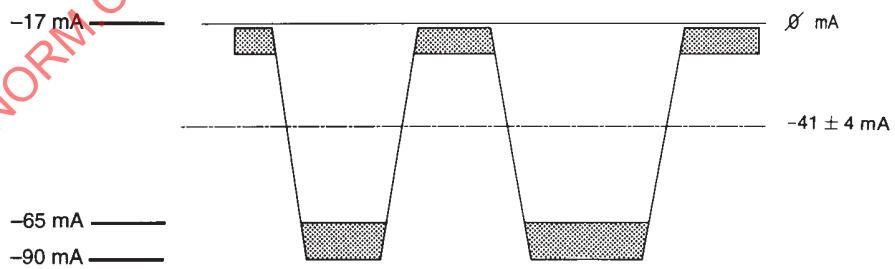


Figure 8–6—Recommended driver current signal levels

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8.3.1.4 Transmit output levels symmetry

Signals received from the AUI DO circuit shall be transmitted onto the coaxial cable with the characteristics specified in 8.3.1.3. Since the coaxial cable proceeds in two directions from the MAU, the current into the MAU is nominally twice the current measured on the coaxial cable.

The output signal of a MAU meeting this specification shall exhibit edge jitter of no more than 2.5 ns into a 25 Ω ± 1% resistor substituted for the connection to the coaxial cable when the DO circuit into the MAU is driven through a zero length AUI cable with pseudorandom Manchester encoded binary data from a data generator that exhibits no more than 0.5 ns of edge jitter on half bit cells of exactly 1/2 BT whose output meets the specifications of 7.4.1.1 through 7.4.1.5. The above specified component is not to introduce more than 2 ns of edge jitter into the system.

The MAU shall not transmit a negative going edge after cessation of the CD output data stream on DO or before the first edge of the next frame on the DO circuit.

8.3.1.5 Collision detect thresholds

Receive mode collision detection indicates that a nontransmitting MAU has the capability to detect collisions when two or more MAUs are transmitting simultaneously. For receive mode collision detection, the MAU's collision detection threshold shall be within the range –1448 mV to –1590 mV. The actual dc voltage on the cable during a noncollision transmission has a maximum value of –1293 mV. The lower threshold limit of –1448 mV allows 55 mV for sending end overshoot during preamble and filter impulse response during the remainder of the packet. These limits take account of up to 12% collision detect filter impulse response. If a specific filter implementation has a higher value of impulse response, the lower threshold limit of 1448 mV shall be replaced by 1293 mV × [1 + impulse response].

All MAUs are required to implement receive mode collision detection.

NOTE—The above threshold limits are measured at the coaxial cable center conductor with respect to the shield at the MAU connector. The MAU designer must take into account circuit offsets, low-frequency noise (for example, 50 Hz, 60 Hz), and 5 MHz ripple at the filter output in determining the actual internal threshold value and its tolerance.

8.3.2 MAU electrical characteristics

8.3.2.1 Electrical isolation

The MAU must provide isolation between the AUI cable and the coaxial trunk cable. This isolation shall withstand at least one of the following electrical strength tests:

a) 1500 V rms at 50 Hz to 60 Hz for 60 s, applied as specified in 5.3.2 of IEC 60950: 1991.
b) 2250 Vdc for 60 s, applied as specified in 5.3.2 of IEC 60950: 1991.
c) A sequence of ten 2400 V impulses of alternating polarity, applied at intervals of not less than 1 s. The shape of the impulses shall be 1.2/50 μs (1.2 μs virtual front time, 50 μs virtual time of half value), as defined in IEC 60060.

There shall be no isolation breakdown, as defined in 5.3.2 of IEC 60950: 1991, during the test. The resistance after the test shall be at least 2 MΩ, measured at 500 Vdc. In addition, the isolation impedance between the DTE and the coaxial cable shield shall be less than 15 Ω between 3 MHz and 30 MHz.

CAUTION

The current electrical isolation requirement is a change that was incorporated into IEEE Std 802.3-1996. Older editions of IEEE Std 802.3 had a significantly lower isolation requirement.

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8.3.2.2 Power consumption

The current drawn by the MAU shall not exceed 0.5 A as powered by the AUI source. The MAU shall be capable of operating from all possible voltage sources as supplied by the DTE through the resistance of all permissible AUI cables. The MAU shall not disrupt the trunk coaxial medium should the DTE power source fall below the minimum operational level under abnormal MAU load conditions.

The MAU shall be labeled externally to identify the maximum value of current required by the device at any specified input voltage.

8.3.2.3 Reliability

The MAU shall be designed to provide an MTBF of at least 1 million hours of continuous operation without causing communication failure among other stations attached to the local network medium. Component failures within the MAU electronics should not prevent communication among other MAUs on the coaxial cable. Connectors and other passive components comprising the means of connecting the MAU to the coaxial cable shall be designed to minimize the probability of total network failure.

It should be noted that a fault condition that causes a MAU to draw in excess of 2 mA may cause communication failure among other stations.

8.3.3 MAU–DTE electrical characteristics

The electrical characteristics for the driver and receiver components connected to the branch cable within the MAU shall be identical to those as specified in Clause 7 of this standard.

8.3.4 MAU–DTE mechanical connection

The MAU shall be provided with a 15-pin male connector as specified in detail in the AUI specification, Clause 7.

8.4 Characteristics of the coaxial cable

The trunk cable is of constant impedance, coaxial construction. It is terminated at each end by a terminator (see 8.5.2), and provides the transmission path for MAU device connection. Coaxial cable connectors are used to make the connection from the cable to the terminators, and between cable sections (if needed). The cable has various electrical and mechanical requirements that shall be met to ensure proper operation.

8.4.1 Coaxial cable electrical parameters

8.4.1.1 Characteristic impedance

The average characteristic cable impedance shall be 50 ± 2 Ω, measured at 10 MHz according to IEC 60096-1: 1986 and Amd. 2: 1993. Periodic variations in impedance along a single piece of cable may be up to ±3 Ω sinusoidal centered around the average value, with a period of less than 2 m.

NOTE—If the requirements of 8.4.2.1.1 item b), 8.4.2.1.2, 8.4.2.1.3, and 8.4.2.1.4 item b) are met, then it is expected that the characteristic impedance periodicity requirement shall be considered met.

8.4.1.2 Attenuation

The attenuation of a 500 m cable segment shall not exceed 8.5 dB (17 dB/km) measured with a 10 MHz sine wave, nor 6.0 dB (12 dB/km) measured with a 5 MHz sine wave.

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8.4.1.3 Velocity of propagation

The minimum required velocity of propagation is 0.77 c.

8.4.1.4 Edge jitter, untapped cable

Untapped coaxial cable meeting this specification shall exhibit edge jitter of no more the 8.0 ns in either direction at the receiving end when 500 m of the cable is terminated at both ends with terminators meeting the impedance requirements of 8.5.2.1 and is driven at one end with pseudorandom Manchester-encoded binary data from a data generator that exhibits no more than 1.0 ns of edge jitter in either direction on half bit cells of exactly 1/2 BT and whose output meets the specifications of 8.3.1.3 except that the rise time of the signal must be 30 ns + 0, – 2 ns, and no offset component in the output current is required. This test shall be conducted in a noise-free environment. The above specified component is not to introduce more than 7 ns of edge jitter into the system.

8.4.1.5 Transfer impedance

The coaxial cable medium shall provide sufficient shielding capability to minimize its susceptibility to external noise and also to minimize the generation of interference by the medium and related signals. While the cable construction is not mandated, it is necessary to indicate a measure of performance expected from the cable component. A cable's EMC performance is determined, to a large extent, by the transfer impedance value of the cable. See reference [B53].

The transfer impedance of the cable shall not exceed the values shown in Figure 8–7 as a function of frequency.

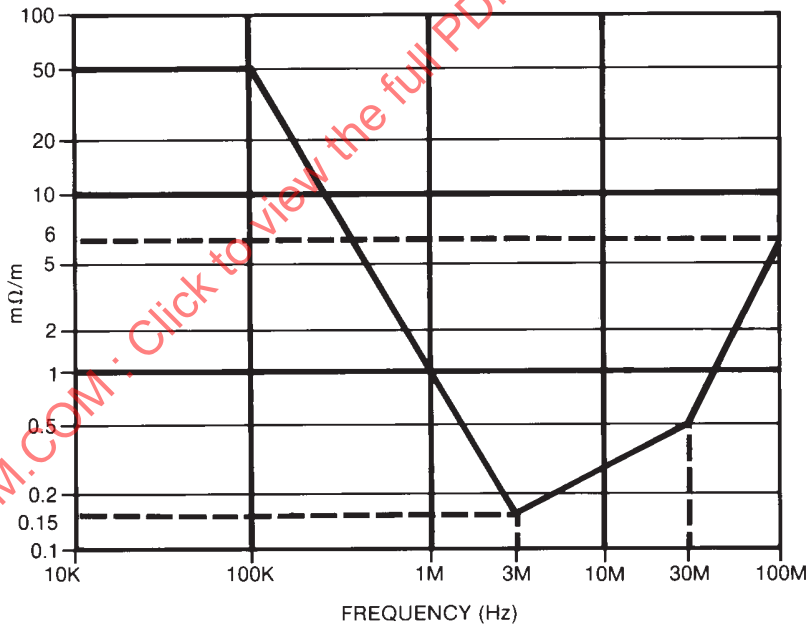

Figure 8–7—Maximum coaxial cable transfer impedance

8.4.1.6 Cable dc loop resistance

The sum of the center conductor resistance plus the shield resistance, measured at 20 °C, shall not exceed 10 mΩ/m.

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8.4.2 Coaxial cable properties

8.4.2.1 Mechanical requirements

The cable used should be suitable for routing in various environments, including but not limited to, dropped ceilings, raised floors, cable troughs, and throughout open floor space. The jacket shall provide insulation between the cable sheath and any building structural metal. Also, the cable shall be capable of accepting coaxial cable connectors, described in 8.5. The cable shall conform to the following requirements.

8.4.2.1.1 General construction

a) The coaxial cable shall consist of a center conductor, dielectric, shield system, and overall insulating jacket.
b) The concentricity (for example, positional relationship between center conductor to shield system and outer jacket) of the coaxial cable elements shall be greater than 92% as measured in accordance with the following general configuration:

$$\frac{(\text{jacket radius}) - (\text{center offset})}{\text{jacket radius}} \times 100 \geq 92\%$$

It is assumed that the offset and radius values are worst case at any point within the measured system.
c) The coaxial cable jacket, shield system, and dielectric material shall be pierceable either by means of the connector type specified in 8.5.3.2 or by an external core tool. Overall cable system pierceability (the ability of a tap probe to pierce the jacket, shields, and dielectric cable system without substantial dielectric deformation and without causing a short circuit between center conductor and shield system) is a vital parameter affecting tap connection reliability.

Pierceability of the cable system can be measured in terms of the probe's load versus displacement signature. A pierceable cable exists where the displacement is ≥ 1.52 mm (0.06 in) between rupture (piercing) of the shield system and contact with the center conductor.
d) The coaxial cable shall be sufficiently flexible to support a bend radius of 254 mm (10 in).

8.4.2.1.2 Center conductor

The center conductor shall be 2.17 mm ± 0.013 mm (0.0855 in ± 0.0005 in) diameter tinned or plain solid copper.

8.4.2.1.3 Dielectric material

The dielectric may be of any type provided the conditions of 8.4.1.2, 8.4.1.3, and 8.4.2.1.1item d) are met.

8.4.2.1.4 Shielding system

a) The shielding system may contain both braid and foil elements sufficient to meet the transfer impedance of 8.4.1.5 and the EMC specifications of 8.7.2.
b) The inside diameter of the innermost shield shall be 6.00 mm (0.236 in) minimum.
c) The outside diameter of the outermost shield shall be 8.00 mm ± 0.40 mm (0.315 in ± 0.016 in).
d) The outermost shield shall be a tinned copper braid. The percent coverage shall be sufficient to meet 8.4.1.5, 8.4.1.6, 8.5.3.2.3, and 8.7.2.

8.4.2.1.5 Overall jacket

a) Any one of several jacket materials shall be used provided the specifications of 8.4.1 and 8.4.2 are met.

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b) Either of two jacket dimensions may be used for the two broad classes of materials, provided the specification of 8.4.2.1.1 are met:
   1) Polyvinyl Chloride (for example, PVC) or equivalent having an OD of 10.3 mm ± 0.25 mm (0.406 nominal ± 0.010 in).
   2) Fluoropolymer (for example, FEP, E-CTFE) or equivalent having an OD of 9.525 mm ± 0.254 mm (0.375 nominal ± 0.010 in).

The cable shall meet applicable flammability and smoke criteria and local and national codes for the installed environment. See 8.7.4. Different types of cable sections (for example, polyvinyl chloride and fluoropolymer dielectric) may be interconnected, while meeting the sectioning requirements of 8.6. See references [B19] and [B61].

8.4.2.2 Jacket marking

The cable jacket shall be marked in a color contrasting with the background color of the jacket. The markings shall be spaced at 2.5 m ± 5 cm regularly along the entire length of the cable. It is permissible for the 2.5 m spacing to be interrupted at discontinuities between cable sections joined by connectors. (See 8.6.2.2 for MAU placement rules that mandate cable markings.) It is recommended that the base color of the jacket itself be a bright color (for example, yellow) other than that normally used for power mains.

8.4.3 Total segment dc loop resistance

The sum of the center conductor, connectors, and shield resistance shall not exceed 5 Ω total per segment.

Each in-line connector pair or MAU shall be no more than 10 mΩ. Use of these components reduces the overall allowable segment length accordingly. Values given above are at 20 °C. For temperature variations, cable length shall be adjusted accordingly such that the 5 Ω total is not exceeded.

If a trunk coaxial cable segment consists of several cable sections, then all connectors and internal resistance of the shield and center conductor shall be included in the loop resistance measurement.

8.5 Coaxial trunk cable connectors

The trunk coaxial medium requires termination and may be extended or partitioned into sections. Devices to be attached to the medium as MAUs require a means of connection to the medium. Two basic connector types provide the necessary connection means:

a) Standard Type N connectors (IEC 60169-16)
b) A coaxial "tap" connector

All Type N connectors shall be of the 50 Ω constant impedance type. Since the frequencies present in the transmitted data are well below UHF range (being band-limited to approximately 20 MHz), high-quality versions of the connectors are not required (but are recommended).

All of the coaxial tap connectors shall follow the requirements as defined in 8.5.3.

8.5.1 Inline coaxial extension connector

All coaxial cables shall be terminated with the Type N plug connectors. A means shall be provided to ensure that the connector shell (which connects to the cable sheath) does not make contact with any building metal or other unintended conductor. An insulating sleeve or boot slipped over the connector at installation time is suitable.

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Inline coaxial extensions between two sections of coaxial cable shall be made with a pair of Type N receptacle connectors joined together to form one "barrel." An insulating sleeve or boot shall also be provided with each barrel assembly.

8.5.2 Coaxial cable terminator

8.5.2.1 Termination

Coaxial cable terminators are used to provide a termination impedance for the cable equal in value to its characteristic impedance, thereby minimizing reflection from the ends of the cables. Terminators shall be packaged within an inline female receptacle connector. The termination impedance shall be 50 Ω ± 1% measured from 0 MHz to 20 MHz, with the magnitude of the phase angle of the impedance not to exceed 5°. The terminator power rating shall be 1 W or greater.

8.5.2.2 Earthing

Either the coaxial cable terminator or inline extension connector provides a convenient location for meeting the earth grounding requirement of 8.6.2.3. It is recommended that a ground lug with current rating of at least 1500 ampacity be provided on one of the two terminators or on one extension connector used within a cable segment.

NOTE 1—A single ground return lug on an inline connector located in the center of the cable transmission system may be used to satisfy this requirement.

NOTE 2—Alternatively, terminators might be supplied in pairs, one with and one without the ground lug connection point.

8.5.3 MAU-to-coaxial cable connection

A means shall be provided to allow for attaching a MAU to the coaxial cable. The connection shall not disturb the transmission line characteristics of the cable significantly; it shall present a predictably low shunt capacitance, and therefore a negligibly short stub length. This is facilitated by the MAU being located as close to its cable connection as possible; the MAU and connector are normally considered to be one assembly. Long (greater than 30 mm) connections between the coaxial cable and the input of the MAU jeopardize this objective.

Overall system performance is dependent largely on the MAU-to-coaxial cable connection being of low shunt capacitance.

If the design of the connection is such that the coaxial cable is to be severed to install the MAU, the coaxial cable segment shall still meet the sectioning requirements of 8.6.2.1. Coaxial connectors used on a severed cable shall be Type N, as specified in 8.5.1.

The Type N connectors selected should be of high quality (that is, low contact resistance) to minimize the impact on system performance.

If the design of the connection is such that the piercing tap connector is to be used without severing the cable, then the tap connector and cable assembly shall conform to the mechanical and electrical requirements as defined throughout 8.5.3.1 and 8.5.3.2.

8.5.3.1 Electrical requirements

Requirements for the coaxial tap connector are as follows:

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a) *Capacitance:* 2 pF nominal connector loading measured at 10 MHz.

NOTE—**Total** capacitance of tap and active circuitry connected directly shall be no greater than 4 pF. Specific implementations may allocate capacitance between tap and circuitry as deemed appropriate.

b) *Contact resistance (*applies to center conductor and shield contacts): 50 mΩ maximum for both shield and center conductor over useful connector lifetime.
c) *Contact material:* surface material on signal probe or shield sufficient to meet contact resistance requirements in environment and over time.
d) *Voltage rating:* 600 V dc or ac rms maximum.
e) *Insulation:* dc leakage resistance of tap housing shall be higher than 1 GΩ between braid and external conductors in the normal operating environment.
f) *Probe current rating:* 0.1 A per contact (probe and shield).
g) *Shield current rating:* 1 A surge for 1 s.

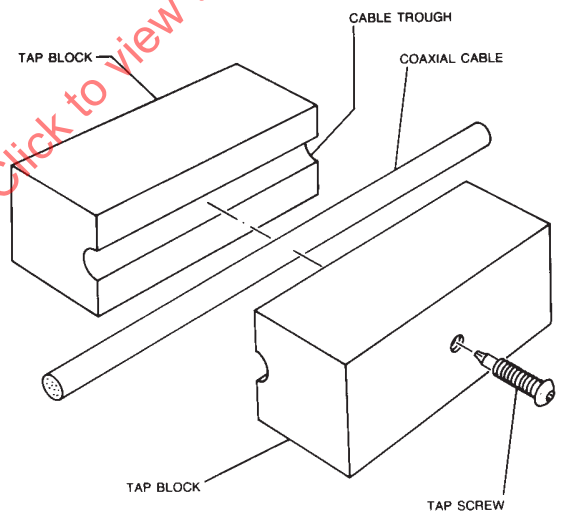
8.5.3.2 Mechanical requirements

8.5.3.2.1 Connector housing

Shielding characteristics: > 40 dB at 50 MHz.

8.5.3.2.2 Contact reliability

Overall performance of the LAN system depends to a large extent on the reliability of the coaxial cable medium and the connection to that medium. Tap connection systems should consider the relevant electrical and mechanical parameters at the point of electrical connection between tap probe and cable center conductor to ensure that a reliable electrical contact is made and retained throughout the useful life of these components. It is recommended that some means be provided to ensure relatively constant contact loading over time, with creep, in temperature, and typical environment. Typical coaxial tap connector configurations are shown in Figure 8–8 and Figure 8–9. See references [B3], [B1], and [B2].



NOTE: **Tutorial only** and **not** part of specification

Figure 8–8—Coaxial tap connector configuration concepts

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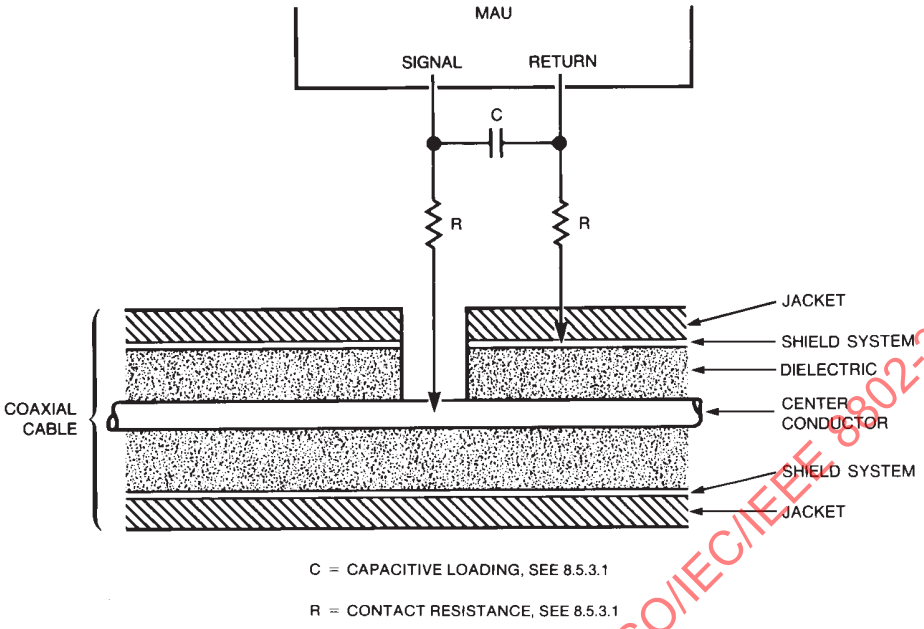

Figure 8–9—Typical coaxial tap connection circuit

8.5.3.2.3 Shield probe characteristics

The shield probe shall penetrate the cable jacket and outer layer(s) of the shield system to make effective capture of the outer braid (pick 2 or more typical strands).

8.6 System considerations

8.6.1 Transmission system model

The maximum configuration for the physical transmission system is as follows:

a) A trunk coaxial cable, terminated in its characteristic impedance at each end, constitutes a coaxial cable segment. A coaxial cable segment may contain a maximum of 500 m of coaxial cable and a maximum of 100 MAUs. The propagation velocity of the coaxial cable is assumed to be 0.77 c minimum (c = 300 000 km/s). The maximum end-to-end propagation delay for a coaxial cable segment is 2165 ns.

b) Repeater sets are required for segment interconnection. Repeater sets occupy MAU positions on coaxial cable segments and count toward the maximum number of MAUs on a coaxial cable segment. Repeater sets may be located in any MAU position on a coaxial cable segment.

c) The repeater unit specified in Clause 9 provides the means for connecting 10 Mb/s baseband segments into a CSMA/CD network. The proper operation of a CSMA/CD network requires network size to be limited to control round-trip propagation delay to meet the requirements of 4.2.3.2.3 and 4.4.2, and the number of repeaters between any two DTEs to be limited in order to limit the shrinkage of interpacket gap as it travels through the network. Configuration rules, which ensure that these limits are not exceeded, are given in Clause 13.

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8.6.2 Transmission system requirements

8.6.2.1 Cable sectioning

The 500 m maximum length coaxial cable segment need not be made from a single, homogeneous length of cable. The boundary between two cable sections (joined by coaxial connectors: two male plugs and a barrel) represents a signal reflection point due to the impedance discontinuity caused by the batch-to-batch impedance tolerance of the cable. Since the worst-case variation from 50 Ω is 2 Ω, a possible worst-case reflection of 4% may result from the joining of two cable sections. The configuration of long cable segments (up to 500 m) from smaller sections must be made with care. The following *recommendations* apply, and are *given in order of preference*:

a) If possible, the total segment should be made from one homogeneous (no breaks) cable. This is feasible for short segments, and results in minimal reflections from cable impedance discontinuities.
b) If cable segments are built up from smaller sections, it is recommended that all sections come from the same manufacturer and lot. This is equivalent to using a single cable, since the cable discontinuities are due to extruder limitations, and not extruder-to-extruder tolerances. There are no restrictions in cable sectioning if this method is used. However, if a cable section in such a system is later replaced, it shall be replaced either with another cable from the same manufacturer and lot, or with one of the standard lengths described below.
c) If uncontrolled cable sections must be used in building up a longer segment, the lengths should be chosen so that reflections, when they occur, do not have a high probability of adding in phase. This can be accomplished by using lengths that are odd integral multiples of a half wavelength in the cable at 5 MHz; this corresponds to using lengths of 23.4 m, 70.2 m, and 117 m (± 0.5 m) for all sections. These are considered to be the standard lengths for all cable sections. Using these lengths exclusively, any mix or match of cable sections may be used to build up a 500 m segment without incurring excessive reflections.

NOTE—If cable segments are to be added to existing installations, then care shall be taken (explicit physical or TDR measurements) to ensure that no more than a 500 m cable segment results.

d) As a last resort, an arbitrary configuration of cable sections may be employed, if it has been confirmed by analysis or measurement that the worst-case signal reflection due to the impedance discontinuities at any point on the cable does not exceed 7% of the incident wave when driven by a MAU meeting these specifications.

8.6.2.2 MAU placement

MAU components and their associated connections to the cable cause signal reflections due to their noninfinite bridging impedance. While this impedance shall be implemented as specified in Clause 7, placement of MAUs along the coaxial cable must also be controlled to ensure that reflections from the MAU do not add in phase to a significant degree.

Coaxial cables marked as specified in 8.4.2.2 have marks at regular 2.5 m spacing; a MAU shall only be placed at a mark on the cable. This guarantees both a minimum spacing between MAUs of 2.5 m, and controlling the relative spacing of MAUs to ensure nonalignment on fractional wavelength boundaries.

The total number of MAUs on a cable segment shall not exceed 100.

8.6.2.3 Trunk cable system grounding

The *shield conductor* of each coaxial cable segment *shall make electrical contact with an effective earth reference* (see [B13], Articles 250 and 800) *at one point and shall not make electrical contact with earth elsewhere* on such objects as building structural metal, ducting, plumbing fixture, or other unintended

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conductor. Insulators may be used to cover any coaxial connectors used to join cable sections and terminators, to ensure that this requirement is met. A sleeve or boot attached at installation time is acceptable.

This specification is intended for use within (intraplant) buildings. Applications requiring interplant connections by way of external (outdoors) means may require special consideration beyond the scope of the standard.

The sheath conductor of the AUI cable shall be connected to the earth reference or chassis of the DTE.

8.6.3 Labeling

It is recommended that each MAU (and supporting documentation) be labeled in a manner visible to the user with at least these parameters:

a) Data rate capability in megabits per second
b) Power level in terms of maximum current drain
c) Safety warning (for example, shock hazard)

8.7 Environmental specifications

8.7.1 General safety requirements

All stations meeting this standard shall conform to IEC 60950: 1991.

8.7.2 Network safety requirements

This subclause sets forth a number of recommendations and guidelines related to safety concerns, the list is neither complete nor does it address all possible safety issues. The designer is urged to consult the relevant local, national, and international safety regulations to ensure compliance with the appropriate standards. References [B13] and [B25] provide additional guidance.

LAN trunk cable systems as described in this standard are subject to at least four direct electrical safety hazards during their use. These hazards are

a) Direct contact between local network components and power or lighting circuits.
b) Static charge buildup on local network cables and components.
c) High-energy transients coupled onto the local network cabling system.
d) Potential differences between safety grounds to which various network components are connected.

These electrical safety hazards, to which all similar cabling systems are subject, should be alleviated properly for a local network to perform properly. In addition to provisions for properly handling these faults in an operational system, special measures must be taken to ensure that the intended safety features are not negated during installation of a new network or during modification of an existing network.

Proper implementation of the following provisions will greatly decrease the likelihood of shock hazards to persons installing and operating the LAN.

8.7.2.1 Installations

Sound installation practice, as defined by applicable local codes and regulations, shall be followed in every instance in which such practice is applicable.

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8.7.2.2 Grounding

The shield of the trunk coaxial cable shall be effectively grounded at only one point along the length of the cable. Effectively grounded means permanently connected to earth through a ground connection of sufficiently low impedance and having sufficient ampacity to prevent the building up of voltages that may result in undue hazard to connected equipment or to persons.

8.7.2.3 Safety

All portions of the trunk cabling system that are at the same potential as the trunk cable shall be insulated by adequate means to prevent their contact by either persons or by unintended conductors or grounds. The insulation employed shall provide the same or greater dielectric resistance to current flow as the insulation required between the outermost shield of the trunk cable and the above-mentioned unintended conductors. The use of insulating boots is permitted, provided that such boots (or sleeves) are mechanically and electrically equivalent to the trunk cable outer insulation characteristics and are not removed easily (that is, they shall prevent inadvertent removal by a system operator).

The MAU shall be so designed that the provisions of 8.7.2.3 and 8.7.2.4 are not defeated if the connector affixing the AUI cable to the MAU is removed.

Portions of the trunk cabling system that may become live during the dissipation of a high-energy transient by the cabling system shall also be insulated as described in 8.7.2.3.

8.7.2.4 Breakdown path

MAUs meeting this standard should provide a controlled breakdown path that will shunt high-energy transients to an effective ground either through a separate safety ground connection or through the overall shield of the branch cable. The breakdown voltage of this controlled breakdown path must meet the isolation requirements for the MAU specified in 8.3.2.1.

8.7.2.5 Isolation boundary

The isolation boundary between the branch cable and trunk cable specified in 8.3.2.1 shall be maintained to properly meet the safety requirements of this standard.

WARNING

It is assumed that the DTE equipment is properly earthed and not left floating or serviced by "doubly insulated ac power distribution system." The use of floating or insulated DTEs is beyond the scope of this standard.

8.7.2.6 Installation and maintenance guidelines

a) When exposing the shield of the trunk coaxial cable for any reason, care shall be exercised to ensure that the shield does not make electrical contact with any unintended conductors or grounds. Personnel performing the operation should not do so if dissipation of a high energy transient by the cabling system is likely during the time the shield is to be exposed. Personnel should not contact both the shield and any grounded conductor at any time.
b) Before breaking the trunk coaxial cable for any reason, a strap with ampacity equal to that of the shield of the coaxial cable shall be affixed to the cable shield in such a manner as to join the two pieces and to maintain continuity when the shield of the trunk cable is severed. This strap shall not be removed until after normal shield continuity has been restored.
c) At no time should the shield of any portion of the coaxial trunk cable to which an MAU or MAUs are attached be permitted to float without an effective ground connection. If a section of floating

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cable is to be added to an existing cable system, the installer shall take care not to complete the circuit between the shield of the floating cable section and the grounded cable section through body contact.

d) The installation instructions for network components shall contain language which familiarizes the installer with the cautions mentioned in the above paragraphs.

e) Network components shall contain prominent warning labels that refer installers and service personnel to the safety notes in the installation instructions.

8.7.3 Electromagnetic environment

8.7.3.1 Susceptibility levels

Sources of interference from the environment include electromagnetic fields, electrostatic discharge, transient voltages between earth connections, and similar interference. Multiple sources of interference may contribute to voltage buildup between the coaxial cable and the earth connection of a DTE.

The physical channel hardware shall meet its specifications when operating in either of the following conditions:

a) Ambient plane wave field of 2 V/m from 10 kHz through 30 MHz, 5 V/m from 30 MHz through 1 GHz.

NOTE—Levels typically l km from broadcast stations.

b) Interference voltage of 1 V/ns peak slope, between coaxial cable shield and DTE earth connection; for example, 15.8 V peak for a 10 MHz sine wave with a 50 Ω source resistance.

MAUs meeting this standard should provide adequate rf ground return to satisfy the referenced EMC specifications.

8.7.3.2 Emission levels

The physical MAU and trunk cable system shall comply with applicable local and national codes such as FCC Docket 20780-1980 [B29] in the USA. Equipment shall comply with local and national requirements for limitation of electromagnetic interference. Where no local or national requirements exist, equipment shall comply with CISPR 22: 1993.

8.7.4 Temperature and humidity

The MAU and associated connector/cable systems are expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling such as shock and vibration. Specific requirements and values for these parameters are considered to be beyond the scope of this standard. Manufacturers are requested to indicate in the literature associated with the MAU (and on the MAU if possible) the operating environment specifications to facilitate selection, installation, and maintenance of these components. See reference [B26] for specification terminology.

8.7.5 Regulatory requirements

The design of MAU and medium components should take into consideration applicable local or national requirements. See references [B13], [B19], [B20], [B25], [B29], and Annex B for helpful resource material.

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8.8 Protocol implementation conformance statement (PICS) proforma for Clause 8, Medium Attachment Unit and baseband medium specifications, type 10BASE5[33]

8.8.1 Overview

The supplier of a protocol implementation that is claimed to conform to Clause 8, Medium Attachment Unit and baseband medium specifications, type 10BASE5, shall complete the following PICS proforma.

A completed PICS proforma is the PICS for the implementation in question. The PICS is a statement of which capabilities and options of the protocol have been implemented. The PICS can be used for a variety of purposes by various parties, including the following:

— As a checklist by the protocol implementer, to reduce the risk of failure to conform to the standard through oversight;
— As a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard PICS proforma, by the supplier and acquirer, or potential acquirer, of the implementation;
— As a basis for initially checking the possibility of interworking with another implementation by the user, or potential user, of the implementation (note that, while interworking can never be guaranteed, failure to interwork can often be predicted from incompatible PICs);
— As the basis for selecting appropriate tests against which to assess the claim for conformance of the implementation, by a protocol tester.

8.8.2 Abbreviations and special symbols

8.8.2.1 Status symbols

The following abbreviations are used in the PICS proforma tables:

M mandatory

O optional

O. <n> optional, but support of at least one of the group of options labeled by the same numeral <n> is required

X prohibited

<item>: conditional-item symbol, dependent upon the support for <item>

! logical negation, applied to a conditional item symbol

8.8.2.2 Abbreviations

Ref reference section

8.8.3 Instructions for completing the PICS proforma

8.8.3.1 General structure of the PICS proforma

The structure of this PICS proforma is based on the guidelines given in ISO/IEC 9646-1: 1994 and ISO/IEC 9646-2: 1994. The first part of the PICS proforma, Implementation Identification and Protocol Summary, is

[33] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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to be completed as indicated with the information necessary to identify fully both the supplier and the particular MAU.

The main part of the PICS proforma is a fixed-format questionnaire. Each item is identified by an item reference in the first column; the second column contains the question to be asked or the parameter to be measured; the third column contains the reference(s) to the material that specifies the item in the main body of this standard; the fourth column records the status of the item—whether support is mandatory, optional, prohibited, or conditional—and provides space for the answers; the fifth column provides additional comments and/or value(s) for measurable parameters. The tables below group related items into separate subclauses. This satisfies the requirement of ISO/IEC 9646-2 that all PICS proforma clauses be individually identified.

A supplier wishing to submit a 10BASE5 MAU for conformance testing against this standard must fill in the column headed Support in the PICS proforma tables and submit the resulting PICS with the equipment for test. One of the boxes in this column must be checked, with Yes indicating that the implementation is intended to meet the particular mandatory or optional requirement, No indicating that the option has not been implemented (or enabled where switchable) or that the requirement is not met, or N/A indicating the item is not applicable (for example, an item that is conditional). It should be noted that any instances of No checked against a mandatory requirement will result in the implementation failing the static conformance test.

8.8.3.2 Additional information

Any additional information that is needed to ensure that the MAU or the coaxial cable submitted for test is configured as a 10BASE5 MAU or coaxial cable should be entered into the PIXIT (Protocol Implementation eXtra Information for Testing) document supplied by the conformance testing organization. Relevant information on 10BASE5 MAUs includes the following:

a) Enable/disable mechanisms for SQE Test
b) Enable/disable mechanisms for features that allow compatibility with nonstandard implementations
c) Operational instructions for DTEs or repeaters in cases where the MAU is embedded
d) Environmental conditions
e) Power supply voltage range

The above list is illustrative and is neither mandatory nor exhaustive.

8.8.3.3 Exception information

It may occasionally happen that a supplier will wish to answer an item with mandatory or prohibited status (after any conditions have been applied) in a way that conflicts with the indicated requirement. No preprinted answer will be found in the Support column for this. Instead, the supplier shall write the missing answer into the Support column, together with an X<i> reference to an item of Exception Information, and shall provide the appropriate rationale in the Exception item itself.

An implementation for which an Exception item is required in this way does not conform to this standard.

8.8.3.4 Conditional items

The PICS proforma contains a number of conditional items. These are items for which both the applicability of the item itself, and its status if it applies—mandatory, optional, or prohibited—are dependent upon whether or not certain other items are supported.

Individual conditional items are indicated by a conditional symbol of the form “<item>:<s>” in the Status column, where “<item>” is the section number and item reference that appears in the first column of the

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table for some other item, and "<s>" is a status symbol, M, O, O.<n>, or X. The "!" symbol, prefixed to an item reference, means logical negation.

If the item referred to by the conditional symbol is marked as supported, the conditional item is applicable, and its status is given by "<s>"; the support column is to be completed in the usual way. Otherwise, the conditional item is not relevant and the Not Applicable (N/A) answer is to be marked.

Each item whose reference is used in a conditional symbol is indicated by an asterisk in the Item column.

8.8.4 Identification

8.8.4.1 Implementation identification

The MAU supplier shall complete the relevant fields in this section to identify the supplier and the particular MAU.

Supplier	
Contact point for inquiries about the PICS	
Implementation name(s) and version(s)	

8.8.4.2 Protocol summary

The supplier will complete this section to identify the precise protocol implemented.

Identification of protocol standard	IEEE Std 802.3-2015, Clause 8, Medium Attachment Unit and baseband medium specifications, type 10BASE5
Identification of amendments and corrigenda to this PICS proforma which have been completed as part of this PICS	
Have any Exception items been required? (The answer Yes means that the implementation does not conform to this standard.)	Yes [ ] No [ ]

Date of Statement	

8.8.5 Global statement of conformance

The supplier must indicate below whether or not the implementation implements all the mandatory requirements. Answering No to this question indicates nonconformance to the protocol specification. Nonsupported mandatory capabilities are to be identified in the PICS, with an explanation of why the implementation is non-conforming.

This implementation meets all mandatory requirements	Yes [ ] No [ ]

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8.8.6 PICS proforma tables for MAU

8.8.6.1 MAU compatibility

Item	Parameter	Reference	Status	Support	Value/Comment
*1	MAU intended for attachment to repeater		O	Yes [ ]No [ ]	
*2	Monitor Function supported		O	Yes [ ]No [ ]	
*3	AUI Circuit CO supported		8.8.6.1/2 :M !8.8.6.1/2 :O	N/A [ ] Yes [ ]No [ ] N/A [ ] Yes [ ]No [ ]	Required for Monitor function
4	SQE Test supported	9.4.1	8.8.6.1/1 :X !8.8.6.1/1 :M	N/A [ ] Yes [ ]No [ ] N/A [ ] Yes [ ]No [ ]	Function not performed for MAUs attached to repeaters

8.8.6.2 Transmit function

Item	Parameter	Reference	Status	Support	Value/Comment
1	Transmit path	8.2.1.1	M	Yes [ ]No [ ]	DO circuit to coaxial cable
2	Transmit signal polarity	8.2.1.1	M	Yes [ ] No [ ]	DO A positive relative to DO B causes more positive voltage on the coaxial medium
3	Start-up bit loss (DO to coaxial cable)	8.2.1.1	M	Yes [ ]No [ ]	2 bits max
4	Transmit settling time	8.2.1.1	M	Yes [ ]No [ ]	Second and following bits meet amplitude and jitter specifications
5	Transmit steady-state delay	8.2.1.1	M	Yes [ ]No [ ]	1/2 bit times max
6	Start-up bit loss (DO to coaxial cable) variability	8.2.1.1	M	Yes [ ]No [ ]	2 bits max between packets separated by ≤ 96 BT
7	No extraneous signal on the coaxial media after DO idle	8.2.1.1	M	Yes [ ]No [ ]	
8	Start collision presence state	8.2.1.1	M	Yes [ ]No [ ]	Within 0.6 µs to 1.6 µs after idle
9	Collision presence state duration	8.2.1.1	M	Yes [ ]No [ ]	5–15 bit times

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8.8.6.3 Receive function

Item	Parameter	Reference	Status	Support	Value/Comment
1	Direct coupling of signal from medium to the receiver	8.2.1.2	M	Yes [ ] No [ ]	
2	AC-coupling from the receiver to AUI interface	8.2.1.2	M	Yes [ ] No [ ]	
3	Start-up bit loss (coaxial cable to DI)	8.2.1.2	M	Yes [ ] No [ ]	5 bits max
4	Receive settling time	8.2.1.2	M	Yes [ ] No [ ]	Second and following bits meet jitter specifications
5	Receive steady-state delay	8.2.1.2	M	Yes [ ] No [ ]	1/2 bit times max
6	Start-up bit loss (coaxial cable to DI) variability	8.2.1.2	M	Yes [ ] No [ ]	5 bits max between packets separated by ≤ 96 BT
7	Receive signal polarity	8.2.1.2	M	Yes [ ] No [ ]	More positive voltage on the coaxial cable will convert as DI A positive relative to DI B on the DI circuits
8	Edge jitter	8.2.1.2	M	Yes [ ] No [ ]	MAU receiver + cable introduce ≤ 6 ns
9	Receive function while transmitting	8.2.1.2	M	Yes [ ] No [ ]	

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8.8.6.4 Collision function

Item	Parameter	Reference	Status	Support	Value/Comment
1	Collision absence	8.2.1.3	M	Yes [ ] No [ ]	IDL signal on the CI circuit, unless sending *mau_not_available*
2	Collision Presence function require-ments	8.2.1.3	8.8.6.1/1 :X !8.8.6.1/1 :M	N/A [ ] Yes [ ] No [ ] N/A [ ] Yes [ ] No [ ]	CS0 on CI circuit at BR +25%, −15% with a duty cycle not worse than 40/60 ratio with ≥ 2 MAUs transmitting
3	No collision detection with single transmitter	8.2.1.3 8.2.2.2.4	M	Yes [ ] No [ ]	No CS0 on CI
4	Collision assertion after transmission of ≥ 20 bit times	8.2.1.3 8.2.2.2.4	8.8.6.1/1 :X !8.8.6.1/1 :M	N/A [ ] Yes [ ] No [ ] N/A [ ] Yes [ ] No [ ]	CS0 on CI ≤ 17 BT after collision
5	Collision assertion by transmission < 20 bit times	8.2.1.3 8.2.2.2.4	8.8.6.1/1 :X !8.8.6.1/1 :M	N/A [ ] Yes [ ] No [ ] N/A [ ] Yes [ ] No [ ]	CS0 on CI ≤ 29 BT after collision
6	Collision deassertion after end of collision between second MAU	8.2.1.3	M	Yes [ ] No [ ]	IDL on CI ≤ 17 BT after arrival of end of transmission
7	Collision deassertion after end of collision between more than two MAUs	8.2.1.3	M	Yes [ ] No [ ]	IDL on CI ≤ 29 BT after arrival of end of transmission from all but one MAU

8.8.6.5 Monitor function

Item	Parameter	Reference	Status	Support	Value/Comment
1	Signal path	8.2.1.4	8.8.6.1/2 :M	N/A [ ] Yes [ ] No [ ]	From DTE to MAU through CO circuit
2	Transmit disable delay	8.2.1.4	8.8.6.1/2 :M	N/A [ ] Yes [ ] No [ ]	≤ 20 ms
3	MAU function in isolated state	8.2.1.4	8.8.6.1/2 :M	N/A [ ] Yes [ ] No [ ]	Receive and collision functions are normal, XMIT disabled

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8.8.6.6 Jabber function

Item	Parameter	Reference	Status	Support	Value/Comment
1	Jabber function implementation	8.2.1.5	M	Yes [ ] No [ ]	Self-interruption of the transmitter
2	Frame timer range	8.2.1.5	M	Yes [ ] No [ ]	20 ms min, 150 ms max
3	CI circuit during jabber	8.2.1.5 8.2.2.2.4	8.8.6.1/1 :X !8.8.6.1/1 :M	N/A [ ] Yes [ ] No [ ] N/A [ ] Yes [ ] No [ ]	CS0 signal
4	Collision presence function activated after transmit disable	8.2.1.5	M	Yes [ ] No [ ]	No extraneous signal on the coaxial media
5	Unjab timer range	8.2.1.5	O	Yes [ ] No [ ]	0.5 s ± 50%
6	MAU unjab (reset) with monitor function	8.2.1.5	8.8.6.1/2 :M	N/A [ ] Yes [ ] No [ ]	Isolate message
7	MAU jabber lockup protection	9.4.1	8.8.6.1/1 :M !8.8.6.1/1 :O	N/A [ ] Yes [ ] No [ ] N/A [ ] Yes [ ] No [ ]	Jabber function not activated under worst case conditions in 9.6.5

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8.8.6.7 MAU to coaxial cable interface

Item	Parameter	Reference	Status	Support	Value/Comment
1	Input impedance	8.3.1.1	M	Yes [ ] No [ ]	R ≥ 100 kΩ
2	Total capacitive load	8.3.1.1	M	Yes [ ] No [ ]	C ≤ 4 pF
3	Bias current	8.3.1.2	M	Yes [ ] No [ ]	Max +2 µA Min –25 µA
4	Transmit offset current	8.3.1.3	M	Yes [ ] No [ ]	–37 mA to –45 mA
5	Transmit ac component	8.3.1.3	M	Yes [ ] No [ ]	+28 mA to offset value
6	Transmitter sink current during collision	8.3.1.3	M	Yes [ ] No [ ]	No more than –25 µA at –7 V; no more than ±250 µA at –10 V
7	Rise and fall time at 10 Mb/s	8.3.1.3	M	Yes [ ] No [ ]	25 ns ± 5 ns (10–90%)
8	Rise and fall time match	8.3.1.3	M	Yes [ ] No [ ]	Within 2 ns at 10 Mb/s
9	Harmonic content at BR	8.3.1.3	M	Yes [ ] No [ ]	2nd and 3rd harmonics ≥ 20 dB below fundamental, 4th and 5th harmonics ≥ 30 dB below fundamental, 6th and 7th harmonics ≥ 40 dB below fundamental, all higher harmonics ≥ 50 dB below fundamental
10	Transmit signal polarity	8.3.1.4	M	Yes [ ] No [ ]	No inversion of signal from PLS to coaxial cable
11	Transmit signal edge jitter	8.3.1.4	M	Yes [ ] No [ ]	MAU introduce no more than 2 ns of edge jitter
12	Receive collision detection threshold	8.3.1.5	M	Yes [ ] No [ ]	–1.448 V to –1.59 V
13	Receive collision detection threshold, large impulse response	8.3.1.5	M	Yes [ ] No [ ]	–1293 mV * [1+ impulse response] if filter impulse response is larger than nominal
14	No negative edge transmission	8.3.1.4	M	Yes [ ] No [ ]	After cessation of CD output stream on DO or before first edge of next frame on DO

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8.8.6.8 MAU electrical characteristics

Item	Parameter	Reference	Status	Support	Value/Comment
1	Isolation impedance between MDI and AUI cable (each conductor, including shields)	8.3.2.1	M	Yes [ ] No [ ]	> 250 kΩ at 60 Hz, < 15 Ω for 3 MHz to 30 MHz
2	Breakdown voltage	8.3.2.1	M	Yes [ ] No [ ]	≥ 1.5 kV ac, rms
3	Current drawn from AUI sources	8.3.2.2	M	Yes [ ] No [ ]	≤ 0.5 A
4	Operation over VP voltage range	8.3.2.2	M	Yes [ ] No [ ]	11.28–15.75 V, any permissible AUI cable
5	Low VP circuit behavior	8.3.2.2	M	Yes [ ] No [ ]	No disruption of media
6	MAU current labeling	8.3.2.2	M	Yes [ ] No [ ]	Current consumption shall be labeled externally
7	Reliability	8.3.2.3	M	Yes [ ] No [ ]	MTBF ≥ 1 million hours of continuous operation

8.8.6.9 MAU-DTE requirements

Item	Parameter	Reference	Status	Support	Value/Comment
1	AUI electrical characteristics	8.3.3	M	Yes [ ] No [ ]	As specified in Clause 7; refer to 8.8.7.1–5
2	AUI mechanical connection	8.3.4	M	Yes [ ] No [ ]	As specified in Clause 7; refer to 8.8.7.6

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8.8.6.10 MAU to coaxial cable connection

Item	Parameter	Reference	Status	Support	Value/Comment
1	Standard N-type connector	8.5	O.1	Yes[ ] No [ ]	50 Ω, according to IEC 60169-16: 1982 and Amd. 1: 1996
*2	Coaxial tap connector	8.5.3	O.1	Yes[ ] No [ ]	
3	Capacitance	8.5.3.1	8.8.6.10/2 :M	N/A[ ] Yes[ ] No [ ]	2 pF nominal at 10 MHz
4	Contact resistance	8.5.3.1	8.8.6.10/2 :M	N/A[ ] Yes[ ] No [ ]	≤ 50 mΩ for shield and center conductor
5	Voltage rating	8.5.3.1	8.8.6.10/2 :M	N/A[ ] Yes[ ] No [ ]	600 V dc or ac rms max
6	Dc leakage resistance between braid and external conductors	8.5.3.1	8.8.6.10/2 :M	N/A[ ] Yes[ ] No [ ]	≥ 1 GΩ
7	Probe current rating	8.5.3.1	8.8.6.10/2 :M	N/A[ ] Yes[ ] No [ ]	0.1 A per contact (probe and shield)
8	Shield current rating	8.5.3.1	8.8.6.10/2 :M	N/A[ ] Yes[ ] No [ ]	1 A surge for 1 s
9	Connector housing	8.5.3.2.1	8.8.6.10/2 :M	N/A[ ] Yes[ ] No [ ]	Shielding > 40 dB at 50 MHz
10	Shield probe characteristics	8.5.3.2.3	8.8.6.10/2 :M	N/A[ ] Yes [ ] No [ ]	Effective capture of outer braid

8.8.6.11 Safety requirements

Item	Parameter	Reference	Status	Support	Value/Comment
1	MAU labeling	8.6.3	O	Yes [ ] No [ ]	Data rate, current, any applicable safety warnings (recommended)
2	General safety	8.7.1	M	Yes [ ] No [ ]	Conforms to IEC 60950: 1991
3	Susceptibility levels	8.7.3.1	M	Yes [ ] No [ ]	Either ambient plane wave field of 2 V/m from 10 kHz through 30 MHz, 5 V/m from 30 MHz through 1 GHz, or interference voltage of 1 V/ns peak slope, between coaxial cable shield and DTE earth connection
4	Emission levels	8.7.3.2	M	Yes [ ] No [ ]	Comply with applicable local and national standards

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8.8.7 PICS proforma tables for MAU AUI characteristics

8.8.7.1 Signal characteristics

Item	Parameter	Reference	Status	Support	Value/Comment
1	Signaling rate (stated on label)	7.3.2	M	Yes [ ] No [ ]	10 Mb/s
2	CS0 signal frequency (on CI)	7.3.1.2	M	Yes [ ] No [ ]	10 MHz +25%, –15%
3	CS0 signal duty cycle	7.3.1.2	M	Yes [ ] No [ ]	60:40 worst case

8.8.7.2 DI and CI driver characteristics

Item	Parameter	Reference	Status	Support	Value/Comment
1	Differential output voltage, loaded	7.4.1.1	M	Yes [ ] No [ ]	Figure 7–11
2	Differential output voltage, idle state	7.4.1.1	M	Yes [ ] No [ ]	≤ 40 mV into test load
3	Differential output voltage, start of idle	7.4.1.1	M	Yes [ ] No [ ]	Figure 7–12
4	Current into test load while idle	7.4.1.1	M	Yes [ ] No [ ]	4 mA max after 80 BT
5	Requirements after idle	7.4.1.2	M	Yes [ ] No [ ]	Second bit to Figure 7–11
6	Common-mode output voltage, ac	7.4.1.3	M	Yes [ ] No [ ]	≤ 40 mV peak, Figure 7–13
7	Differential output voltage, open circuit	7.4.1.4	M	Yes [ ] No [ ]	13 V peak max
8	Common-mode output voltage, dc	7.4.1.5	M	Yes [ ] No [ ]	≤ 5.5 V, Figure 7–13
9	Fault tolerance	7.4.1.6	M	Yes [ ] No [ ]	Figure 7–14
10	Fault current	7.4.1.6	M	Yes [ ] No [ ]	≤ 150 mA, any Figure 7–14 state

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8.8.7.3 DO receiver characteristics

Item	Parameter	Reference	Status	Support	Value/Comment
1	Unsquelched threshold	7.4.2.1	M	Yes [ ] No [ ]	160 mV max differential
2	High-to-idle transition on DO circuit	7.4.1.1	M	Yes [ ] No [ ]	Must not cause output
3	Differential input impedance at 10 MHz	7.4.2.2	M	Yes [ ] No [ ]	Real part: 77.83 Ω ± 6%; 0 ≤ phase angle (deg) ≤ real part × 0.0338
4	Common-mode range, ac	7.4.2.3	M	Yes [ ] No [ ]	3 V min 30 Hz to 40 kHz, 100 mV min 40 kHz to 10 MHz
5	Total common-mode range	7.4.2.4	M	Yes [ ] No [ ]	Magnitude of 0 to 5.5 V ac + dc
6	Common-mode current limit	7.4.2.4	M	Yes [ ] No [ ]	≤ 1 mA
7	IDL detection	7.3.1.1	M	Yes [ ] No [ ]	≤ 16 bit times
8	Requirements after idle	7.4.2.5	M	Yes [ ] No [ ]	Receiver in spec after start-up delay
9	Receiver fault tolerance	7.4.2.6	M	Yes [ ] No [ ]	Figure 7–16
10	Input fault current	7.4.2.6	M	Yes [ ] No [ ]	3 mA max

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8.8.7.4 CO receiver characteristics

Item	Parameter	Reference	Status	Support	Value/Comment
1	Unsquelched threshold	7.4.2.1	8.8.6.1/3 :M	N/A[ ] Yes[ ] No [ ]	160 mV max differential
2	High-to-idle transition on DO circuit	7.4.1.1	8.8.6.1/3 :M	N/A[ ] Yes[ ] No [ ]	Must not cause output
3	Differential input impedance at 10 MHz	7.4.2.2	8.8.6.1/3 :M	N/A[ ] Yes[ ] No [ ]	Real part: 77.83 Ω ± 6%; 0 ≤ phase angle (deg) ≤ real part × 0.0338
4	Common-mode range, ac	7.4.2.3	8.8.6.1/3 :M	N/A[ ] Yes[ ] No [ ]	3 V min 30 Hz to 40 kHz, 100 mV min 40 kHz to 10 MHz
5	Total common-mode range	7.4.2.4	8.8.6.1/3 :M	N/A[ ] Yes[ ] No [ ]	Magnitude of 0 to 5.5 V ac + dc
6	Common-mode current limit	7.4.2.4	8.8.6.1/3 :M	N/A[ ] Yes[ ] No [ ]	≤ 1 mA
7	IDL detection	7.3.1.1	8.8.6.1/3 :M	N/A[ ] Yes[ ] No [ ]	≤ 1.6 bit times
8	Requirements after idle	7.2.4.5	8.8.6.1/3 :M	N/A[ ] Yes[ ] No [ ]	Receiver in spec after start-up delay
9	Receiver fault tolerance	7.4.2.6	8.8.6.1/3 :M	N/A[ ] Yes[ ] No [ ]	Figure 7–16
10	Input fault current	7.4.2.6	8.8.6.1/3 :M	N/A[ ] Yes[ ] No [ ]	3 mA max

8.8.7.5 Circuit termination

Item	Parameter	Reference	Status	Support	Value/Comment
1	Common-mode termination	7.4.2.6	M	Yes [ ] No [ ]	If used, must be to VC
2	Pins 1, 4, 8, 11, 14 impedance to VC circuit	7.5.2.8	M	Yes [ ] No [ ]	≤ 5 Ω at 5 MHz
3	Pins 1, 4, 8, 11, 14 coupling to VC circuit	7.5.2.8	M	Yes [ ] No [ ]	Capacitive

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8.8.7.6 Mechanical characteristics

Item	Parameter	Reference	Status	Support	Value/Comment
1	D-type connector dimensions	7.6.2	M	Yes [ ] No [ ]	IEC 60807-2: 1992 15-pole male
2	Shell plating material	7.6.2	M	Yes [ ] No [ ]	Conductive
3	Shell multiple contact points	7.6.2	O	Yes [ ] No [ ]	Number not defined (recommended)
4	Shell life expectancy	7.6.2	M	Yes [ ] No [ ]	≤ 5 mΩ/500 matings
5	Locking posts and mounting	7.6.1	M	Yes [ ] No [ ]	Figures 7–18, 7–20
	Pin connections:				Circuit
6	3	7.6.3	M	Yes [ ] No [ ]	Data out A
7	10	7.6.3	M	Yes [ ] No [ ]	Data out B
8	11	7.6.3	M	Yes [ ] No [ ]	Capacitor to VC
9	5	7.6.3	M	Yes [ ] No [ ]	Data in A
10	12	7.6.3	M	Yes [ ] No [ ]	Data in B
11	4	7.6.3	M	Yes [ ] No [ ]	Capacitor to VC
12	7	7.6.3	M	Yes [ ] No [ ]	Control out A
13	15	7.6.3	M	Yes [ ] No [ ]	Control out B
14	8	7.6.3	M	Yes [ ] No [ ]	Capacitor to VC
15	2	7.6.3	M	Yes [ ] No [ ]	Control in A
16	9	7.6.3	M	Yes [ ] No [ ]	Control in B
17	1	7.6.3	M	Yes [ ] No [ ]	Capacitor to VC
18	6	7.6.3	M	Yes [ ] No [ ]	Voltage common
19	13	7.6.3	M	Yes [ ] No [ ]	Voltage plus
20	14	7.6.3	M	Yes [ ] No [ ]	Capacitor to VC
21	Shell	7.6.3	M	Yes [ ] No [ ]	Protective ground (conductive shell)

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8.8.8 PICS proforma tables for 10BASE5 coaxial cable

8.8.8.1 10BASE5 coaxial cable characteristics

Item	Parameter	Reference	Status	Support	Value/Comment
1	Characteristic impedance	8.4.1.1	M	Yes [ ] No [ ]	50 Ω ± 2 Ω, measured according to IEC 60096-1: 1986 and Amd. 2: 1993
2	Impedance variation per 2 m segment	8.4.1.1	O	Yes [ ] No [ ]	±3 Ω
3	Attenuation of 500 m segment	8.4.1.2	M	Yes [ ] No [ ]	≤8.5 dB with 10 MHz sine wave, ≤6.0 dB with 5 MHz sine wave
4	Velocity of propagation	8.4.1.3	M	Yes [ ] No [ ]	Min 0.77 c
5	Edge jitter of 500 m cable	8.4.1.4	M	Yes [ ] No [ ]	≤7 ns
6	Transfer impedance	8.4.1.5	M	Yes [ ] No [ ]	According to Figure 8–7
7	Cable DC loop resistance (center conductor plus shield)	8.4.1.6	M	Yes [ ] No [ ]	≤10 mΩ/m at 20 °C
Coaxial cable properties:					
8	a) Center conductor, dielectric, shield system, insulating jacket	8.4.2.1.1	M	Yes [ ] No [ ]	
9	b) Concentricity	8.4.2.1.1	M	Yes [ ] No [ ]	≥ 92%
10	c) Jacket, shield, dielectric	8.4.2.1.1	M	Yes [ ] No [ ]	pierceable
11	d) Cable flexibility	8.4.2.1.1	M	Yes [ ] No [ ]	support bend radius of 254 mm
12	Center conductor	8.4.2.1.2	M	Yes [ ] No [ ]	2.17 mm ± 0.013 mm
13	Dielectric material	8.4.2.1.3	M	Yes [ ] No [ ]	meets 8.4.1.2, 8.4.1.3 and 8.4.2.1.1 c)
Shielding system:					
14	a) Inside diameter	8.4.2.1.4	M	Yes [ ] No [ ]	≥ 6.15 mm
15	b) Outside diameter	8.4.2.1.4	M	Yes [ ] No [ ]	8.28 mm ± 0.178 mm
16	c) Outermost shield	8.4.2.1.4	M	Yes [ ] No [ ]	> 90% coverage
17	Jacket material	8.4.2.1.5	M	Yes [ ] No [ ]	meets 8.4.1 and 8.4.2 specs

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Item	Parameter	Reference	Status	Support	Value/Comment
18	Jacket dimensions, Polyvinyl Chloride	8.4.2.1.5	O.2	Yes [ ] No [ ]	OD of 10.287 mm ± 0.178 mm
19	Jacket dimensions, Fluoropolymer	8.4.2.1.5	O.2	Yes [ ] No [ ]	OD of 9.525 mm ± 0.254 mm
20	Flammability and smoke criteria	8.4.2.1.5	M	Yes [ ] No [ ]	Meet applicable local and national codes
21	Jacket marking	8.4.2.2	M	Yes [ ] No [ ]	Annular rings spaced 2.5 m ± 5 cm
22	Color of jacket	8.4.2.2	O	Yes [ ] No [ ]	Bright (example: yellow)
Total segment dc loop resistance:					
23	a) Sum of center conductor, connector and shield	8.4.3	M	Yes [ ] No [ ]	≤5 Ω at 20° C
24	b) Inline connector pair or MAU	8.4.3	M	Yes [ ] No [ ]	≤10 mΩ at 20° C
25	Inline coaxial extension connector	8.5.1	M	Yes [ ] No [ ]	Type N plug connector
26	Coaxial cable termination	8.5.2.1	M	Yes [ ] No [ ]	50 Ω ± 1% at 0–20 MHz, phase angle ≤ 5°, power rating ≥1 Ω

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9. Repeater unit for 10 Mb/s baseband networks

NOTE—This repeater is not recommended for new installations. Since September 2011, maintenance changes are no longer being considered for this clause.

9.1 Overview

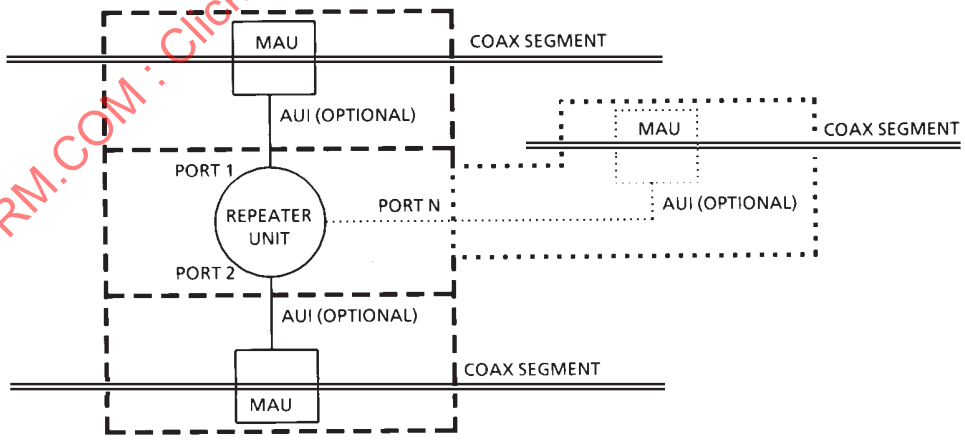
This clause specifies a repeater for use with IEEE 802.3 10 Mb/s baseband networks. A repeater for any other IEEE 802.3 network type is beyond the scope of this clause.

A repeater set connects segments of network medium together, thus allowing larger topologies and a larger MAU base than are allowed by rules governing individual segments.

Repeater sets are used to extend the network length and topology beyond what could be achieved by a single mixing segment. Mixing segments may be connected directly by a repeater set (Figure 9–1) or by several repeater units that are, in turn, connected by link segments. Repeater sets are also used as the hub in a star topology network in which DTEs attach directly to link segments (e.g., 10BASE-T, Clause 14). Allowable topologies shall contain only one operative signal path between any two points on the network. The proper operation of a CSMA/CD network requires network size to be limited to control round-trip propagation delay to meet the requirements of 4.2.3.2.3 and 4.4.2, and the number of repeaters between any two DTEs to be limited in order to limit the shrinkage of interpacket gap as it travels through the network. The method for validating networks with respect to these requirements is specified in Clause 13.

If the repeater set uses MAUs connected via AUIs to a repeater unit, these MAUs shall not perform the *signal_quality_error* Test function. A manufacturer may, optionally, integrate one or all MAUs into a single package with the repeater unit (internal MAUs). In all cases, the MAU portion of the repeater set must be counted toward the maximum number of MAUs on each segment. A repeater set is not a station and does not count toward the overall limit of 1024 stations on a network.

A repeater set can receive and decode data from any segment under worst-case noise, timing, and signal amplitude conditions. It retransmits the data to all other segments attached to it with timing and amplitude restored. The retransmission of data occurs simultaneously with reception. If a collision occurs, the repeater set propagates the collision event throughout the network by transmitting a Jam signal.



NOTE: The AUI is not necessarily exposed when the MAU is, optionally, part of the physical repeater.

Figure 9–1—Repeater set, coax-to-coax configuration

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9.2 References

See 1.3.

9.3 Definitions

See 1.4.

9.4 Compatibility interface

The repeater shall attach to its network segments by any of the means specified below.

9.4.1 AUI compatibility

The repeater unit shall be compatible at its AUI connector (if so equipped) as specified in Clause 7 with the exception of the *signal_quality_error* message Test, 7.2.1.2.3, which shall not be implemented.

10BASE5 and 10BASE2 MAUs associated with the repeater unit shall be as specified in Clause 8 for type 10BASE5 and Clause 10 for type 10BASE2 with the following restrictions:

a) The MAU shall implement receive mode collision detect as defined in 8.3.1.5 or 10.4.1.5.
b) The MAU shall not implement the *signal_quality_error* Message Test function as defined in 8.2.1.1 and 10.3.1.1. The MAU shall not activate its Jabber function when operated under the worst-case Jabber Lockup Protection condition as specified in 9.6.5.
c) The MAU shall operate only in the normal mode as defined in 8.1.3.4, not in the monitor mode.

All other MAUs associated with the repeater unit shall be as specified in their respective clauses and shall not perform the *signal_quality_error* Message Test function.

9.4.2 Mixing segment compatibility

The repeater set, which includes MAUs integrated with the repeater package (internal MAUs), may have any of the interfaces specified in the following subclauses. The MAUs associated with the repeater that are connected in this manner shall be subject to the restrictions of MAUs as specified in 9.4.1.

9.4.2.1 Direct coaxial cable attachment compatibility

The repeater shall be compatible at its coaxial tap connector (if so equipped) as specified in 8.5.3 of the 10BASE5 standard.

9.4.2.2 "N" connector compatibility

The repeater shall be compatible at its Type N connector (if so equipped) as specified in 8.5.

9.4.2.3 BNC compatibility

The repeater shall be compatible at its BNC connector (if so equipped) as specified in 10.6.

9.4.2.4 BFOC/2.5 (10BASE-FP) compatibility

The repeater shall be compatible at its BFOC/2.5 10BASE-FP connector (if so equipped) as specified in 15.3.2 (also see 15.1).

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9.4.3 Link segment compatibility

The compatibility interfaces for link segments including IRL segments are either vendor-dependent, as specified in 9.4.3.1, or are vendor-independent MDI, as defined in the remainder of this clause. The MAUs associated with the repeater that are connected in this manner shall be subject to the restrictions of MAUs as specified in 9.4.1.

9.4.3.1 Vendor-dependent IRL

The budget allowances for the topology supported by the IRL shall ensure that the total network round-trip delay requirement is met and the maximum collision frame size of 511 bits is not exceeded. (See 13.4.1.)

9.4.3.2 Fiber optic FOIRL compatibility

The repeater shall be compatible at its FSMA connector (if so equipped) as specified in 9.9.

9.4.3.3 Twisted-pair jack compatibility

The repeater set shall be compatible at its 8-pin modular jack (if so equipped), as specified in 14.5.

9.4.3.4 Fiber optic 10BASE-FB and 10BASE-FL compatibility

The repeater shall be compatible at its BFOC/2.5 (10BASE-FB and/or 10BASE-FL) connector (if so equipped) as specified in 15.3.2 (also see 15.1).

9.5 Basic functions

9.5.1 Repeater set network properties

The repeater set shall be transparent to all network acquisition activity and to all DTEs. The repeater set shall not alter the basic fairness criterion for all DTEs to access the network or weigh it toward any DTE or group of DTEs regardless of network location. A repeater set shall not attempt to be a packet store and forward device.

Repeaters are not addressable. An addressable station on the network that controls a repeater is outside the scope of this standard.

9.5.2 Signal amplification

The repeater set (including its associated or integral MAUs) shall ensure that the amplitude characteristics of the signals at the MDI outputs of the repeater set are within the tolerance of the specification for the appropriate MAU type. Therefore, any loss of signal-to-noise ratio due to cable loss and noise pickup is regained at the output of the repeater set as long as the incoming data is within the system specification.

9.5.3 Signal symmetry

The repeater set shall ensure that the symmetry characteristics of the signals at the MDI outputs of a repeater set are within the tolerance of the specification for the appropriate MAU type. Therefore, any loss of symmetry due to MAUs and media distortion is regained at the output of the repeater set.

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9.5.4 Signal retiming

The repeater unit shall ensure that the encoded data output from the repeater unit is within the jitter tolerance of a transmitting DTE as specified in 7.3. Therefore jitter cannot accumulate over multiple segments.

9.5.5 Data handling

The repeater unit, when presented a packet at any of its ports, shall pass the data frame of said packet intact and without modification, subtraction, or addition to all other ports connected with the repeater unit. The only exceptions to this rule are when contention exists among any of the ports or when the receive port is partitioned as defined in 9.6.6. Between unpartitioned ports, the rules for collision handling (9.5.6) take precedence.

9.5.5.1 Start-of-packet propagation delays

The start-of-packet propagation delay for a repeater set is the time delay between the first edge transition of the packet on its repeated from (input) port to the first edge transition of the packet on its repeated to (output) port (or ports).

For a repeater unit with AUI connectors at input and output ports, this time shall be less than or equal to 8 bit times.

For a repeater set with internal MAUs on input and output ports, additional delays shall be allowed as enumerated in Table 9–1.

Table 9–1—Start-of-packet propagation delays
(Repeater unit delay of 8 BT plus)

MAU type	Input (BT)	Output (BT)
10BASE5	6.5	3.5
10BASE2	6.5	3.5
FOIRL	3.5	3.5
10BASE-T	8	5
10BASE-FP	3	4
10BASE-FB	2	2
10BASE-FL	5	5

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9.5.5.2 Start-of-packet variability

The start-of-packet variability, defined as the total worst-case difference between start-of-packet propagation delays for successive packets separated by 96 bit times or less, shall be less than 4 bit times for a repeater unit. For a 10BASE-FB repeater set the total worst-case difference between start-of-packet propagation delays for successive packets separated by 96 bit times or less, shall be less than 2 bit times for a repeater set, all of which is allocated to the repeater unit.

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9.5.6 Collision handling

9.5.6.1 Collision presence

All MAUs connected to the repeater unit shall provide uninterrupted Carrier Sense. Uninterrupted Carrier Sense means that the input messages remain valid during activity on the medium even in the presence of a collision. 10BASE5 and 10BASE2 MAUs shall provide this capability by implementing Receive Mode Collision Detection.

9.5.6.2 Jam generation

If a collision is detected on any of the ports to which the repeater set is transmitting, the repeater set shall transmit a Jam to all of the ports to which it is connected. The Jam shall be transmitted in accordance with the Repeater Unit State Diagram in Figure 9–2 and shall be as specified in 4.2.3.2.4 with the further constraint that the first 62 bits transmitted to any port shall be a pattern of alternate 1's and 0's starting with the first bit transmitted as a 1.

9.5.6.3 Collision-jam propagation delays

The start-of-collision propagation delay for a repeater set is the time delay between the first edge transition of the *signal_quality_error* signal on any of its ports to the first edge transition of the Jam on its (output) port (or ports).

For a repeater unit with AUI connectors at input and output ports, this time shall be less than or equal to 6.5 bit times.

For a repeater set with internal MAUs on input and output ports, additional delays shall be allowed as enumerated in Table 9–2.

Table 9–2—Start-of-collision jam delays (repeater unit delay of 6.5 BT plus)

MAU type	Input (BT)	Output (BT)
10BASE5	9[a]	3.5
10BASE2	9[a]	3.5
FOIRL	3.5	3.5
10BASE-T	9	5
10BASE-FP	11.5	1
10BASE-FB	3.5	2
10BASE-FL	3.5	5

[a] This does not include collision rise time on the coaxial media. For the worst-case round-trip delay calculation, collision rise time plus MAU propagation delay = 17 bit times.

The cessation-of-jam propagation delay for a repeater unit is the time delay between the input signals at its ports reaching a state such that Jam should end at a port and the last transition of Jam at that port. The states of the input signals that should cause Jam to end are covered in detail in the repeater state diagrams.

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For a repeater unit with AUI connectors at input and output ports, this time shall be less than or equal to 5 bit times when not extending fragments. When extending fragments, this delay may be longer as required by the fragment extension algorithm. See 9.6.4.

For a repeater set with internal MAUs on input and output ports, an additional allowance for cessation-of-Jam propagation shall be allowed as specified in Table 9–3.

For a repeater set with internal MAUs on its input ports, an additional delay allowance for DI and for *signal_quality_error* de-assertion shall be made as specified in Table 9–3.

Table 9–3—Cessation-of-jam delays (repeater unit delay of 5 BT plus)

MAU type	Cessation-of-Collision jam from DI (BT)		Cessation-of-Collision jam from SQE (BT)	
	Input	Output	Input	Output
10BASE5	0.5	0.5	20	0.5
10BASE2	0.5	0.5	20	0.5
FOIRL	0.5	0.5	7	0.5
10BASE-T	2	2	9	2
10BASE-FP	3	3	36	3
10BASE-FB	5	2	5	2
10BASE-FL	2	2	7	2

9.5.6.4 Transmit recovery time

It is essential that the repeater unit not monitor a port for input for a short time after the repeater stops transmitting to that port. This recovery time prevents the repeater from receiving its own transmission as a new receive activity. The minimum recovery time allowable for a repeater is implementation-dependent, but must be greater than the sum of the delays in the transmit and receive paths for the port. In all cases the recovery time must be less than 10 bit times from the last transition on the transmitting AU interface.

9.5.6.5 Carrier recovery time

During a collision, the *input_idle* signal is unreliable for short periods of time (bits) because of the possibility of signal cancellation on the collision segment. In order to prevent premature detection of the true end of the collision, the repeater unit must wait for data to become sensed from a port for a short time after *signal_quality_error* has gone inactive from that port. This recovery time prevents the repeater from prematurely ending a Jam on an active network. The minimum carrier recovery time allowable for a repeater is implementation-dependent, but shall be greater than the CARRIER ON time after *signal_quality_error* is de-asserted. In all cases, the carrier recovery time shall be less than 4 bit times from the last transition on the AU Interface.

9.5.7 Electrical isolation

Network segments that have different isolation and grounding requirements shall have those requirements provided by the port-to-port isolation of the repeater set.

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9.6 Detailed repeater functions and state diagrams

A precise algorithmic definition is given in this subclause, providing a complete procedural model for the operation of a repeater, in the form of state diagrams. Note that whenever there is any apparent ambiguity concerning the definition of repeater operation, the state diagrams should be consulted for the definitive statement.

The model presented in this subclause is intended as a primary specification of the functions to be provided by any repeater unit. It is important to distinguish, however, between the model and a real implementation. The model is optimized for simplicity and clarity of presentation, while any realistic implementation should place heavier emphasis on such constraints as efficiency and suitability to a particular implementation technology.

It is the functional behavior of any repeater unit implementation that shall match the standard, not the internal structure. The internal details of the procedural model are useful only to the extent that they help specify the external behavior clearly and precisely. For example, the model uses a separate Transmit Timer state diagram for each port. However, in an actual implementation, the hardware may be shared.

9.6.1 State diagram notation

The notation used in the state diagrams (Figure 9–2 through Figure 9–5) follows the conventions in 1.2.1.

Description of state diagram variables

Input/Output variables

DataIn (X)
: Status of DataIn input at port X.
Values: **II** ; *input_idle*; i.e., indicates no activity
–II ; indicates activity
Note that DataIn (X) may be undefined during collision but that it is a don't care in all instances when this is true.

CollIn (X)
: Status of ControlIn input at port X.
Values: **SQE** ; *signal_quality_error*; i.e., indicates collision
–SQE ; indicates no collision

Out (X)
: Type of output repeater is sourcing at port X.
Values: **Idle** ; Repeater is not transmitting
–Idle ; Repeater is transmitting Preamble Pattern or Data or Jam or TwoOnes.
Preamble Pattern ; Repeater is sourcing alternating 1's and 0's on port X.
Data ; Repeater is repeating data frame on port X.
Jam ; Repeater is sourcing Jam on port X.
TwoOnes ; Repeater is sourcing two consecutive Manchester-encoded ones on port X.

DisableOut (X)
: Override of Out (X)
Values: **ON** ; Disable repeater transmission regardless of value of Out (X).
–ON ; Repeater transmission depends on the value of Out (X).

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Port variables

TT (X)

Transmit Timer indicates number of bits transmitted on port X.
Values: Positive integers

Inter-Process flags

AllDataSent

All received data frame bits have been sent.

Bit Transmitted

Indicates a bit has been transmitted by the repeater unit.

DataRdy

Indicates the repeater has detected the SFD and is ready to send the received data. The search for SFD shall not begin before 15 bits have been received. Note, transmit and receive clock differences shall also be accommodated.

Tw1

Wait Timer for the end of transmit recovery time (see 9.5.6.4). It is started by StartTw1. Tw1Done is satisfied when the end of transmit recovery time is completed.

Tw2

Wait Timer for the end of carrier recovery time (see 9.5.6.5). It is started by StartTw2. Tw2Done is satisfied when the timer has expired.

Tw3

Wait Timer for length of continuous output (see 9.6.5). It is started by StartTw3. Tw3Done is satisfied when the timer has expired.

Tw4

Wait Timer for time to disable output for Jabber Lockup Protection (see 9.6.5). It is started by StartTw4. Tw4Done is satisfied when the timer has expired.

Port functions

Port (*Test*)

A function that returns the designation of a port passing the test condition. For example, Port (CollIn=SQE) returns the designation: X for a port that has SQE true. If multiple ports meet the test condition, the Port function will be assigned one and only one of the acceptable values.

Port designation

Ports are referred to by number. Port information is obtained by replacing the X in the desired function with the number of the port of interest. Ports are referred to in general as follows:

ALL Indicates all repeater ports are to be considered. All ports shall meet test conditions in order for the test to pass.

ANY Indicates all ports are to be considered. One or more ports shall meet the test conditions in order for the test to pass.

ONLY1 Indicates all ports are to be considered. One, but not more than one, port shall meet the test condition in order for the test to pass.

X Generic port designator. When X is used in a state diagram, its value is local to that diagram and not global to the set of state diagrams.

N Is defined by the Port function on exiting the IDLE state of Figure 9–2. It indicates a port that caused the exit from the IDLE state.

M Is defined by the Port function on exiting the TRANSMIT COLLISION state of Figure 9–2. It indicates the only port where CollIn=SQE.

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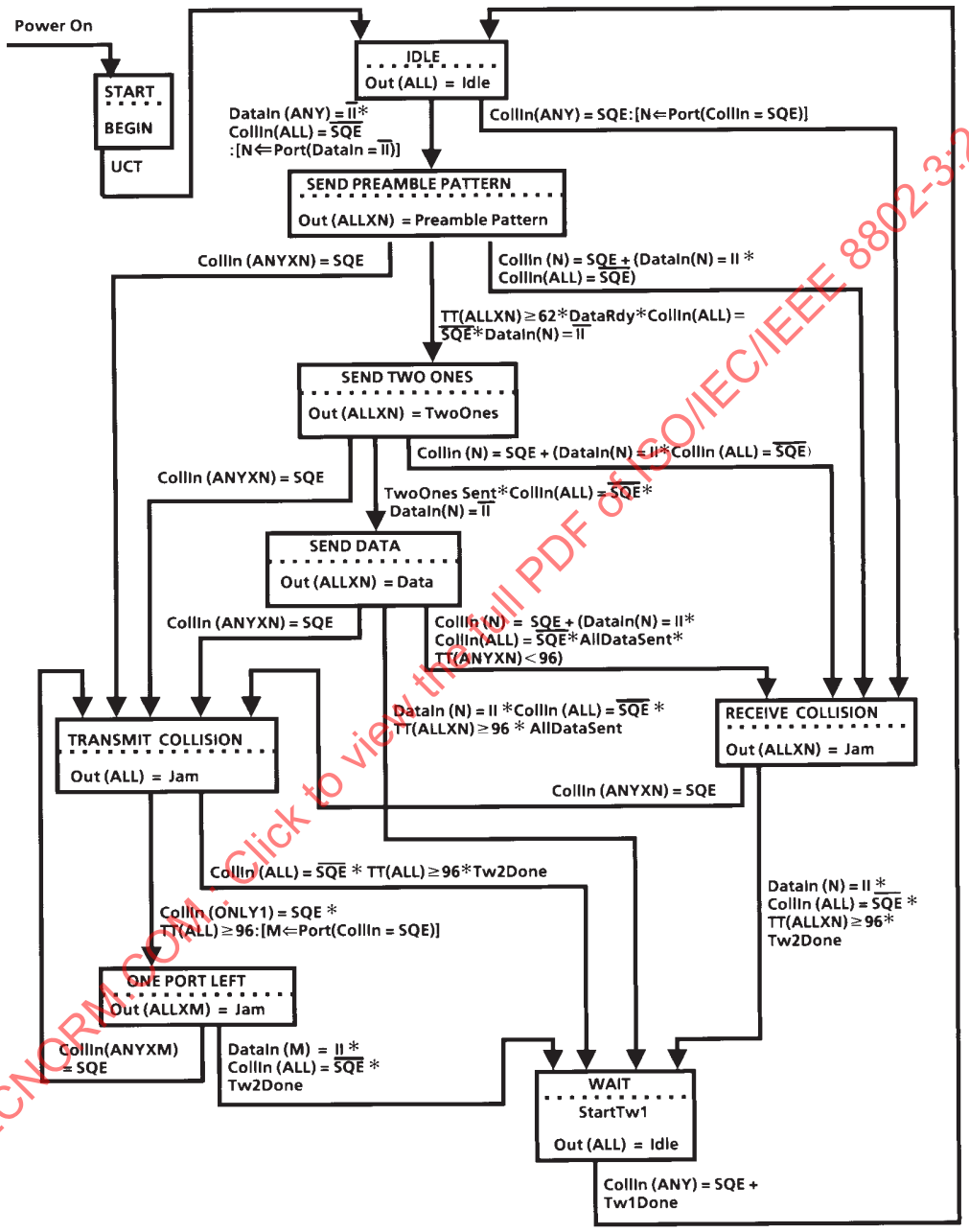
ALLXN Indicates all ports except N should be considered. All ports considered shall meet the test conditions in order for the test to pass.

ALLXM Indicates all ports except M should be considered. All ports considered shall meet the test conditions in order for the test to pass.

ANYXN Indicates any port other than N meeting the test conditions shall cause the test to pass.

ANYXM Indicates any port other than M meeting the test conditions shall cause the test to pass.



NOTE: Out (X) = Idle in all instances unless specified otherwise.

Figure 9–2—Repeater unit state diagram

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9.6.2 Data and collision handling

The repeater unit shall implement the CARRIER_ON function for all its ports. Upon detection of carrier from one port, the repeater unit shall repeat all received signals in the Data Frame from that port to the other port (or ports).

The repeater unit data and collision-handling algorithm shall be as defined in Figure 9–2.

9.6.3 Preamble regeneration

The repeater unit shall output at least 56 bits of preamble followed by the SFD. When the repeater unit must send more than 56 bits, the maximum length preamble pattern it shall send is the number received plus 8. If the receive port is type 10BASE-FB, then the maximum length preamble pattern it shall send is the number received plus 2.

NOTE—Type 10BASE-FB ports always receive at least 56 bits of preamble due to the constraints on the transmitter and link.

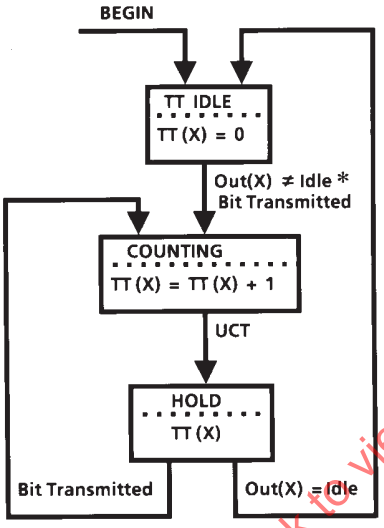

Figure 9–3—Transmit timer state diagram for Port X

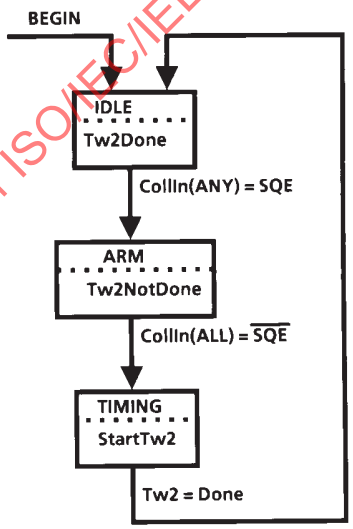

Figure 9–4—Tw2 state diagram

9.6.4 Fragment extension

If the received bit sequence from CARRIER_ON to CARRIER_OFF is fewer than 96 bits in length, including preamble, the repeater unit shall extend the output bit sequence with Jam such that the total number of bits output from the repeater unit shall equal 96.

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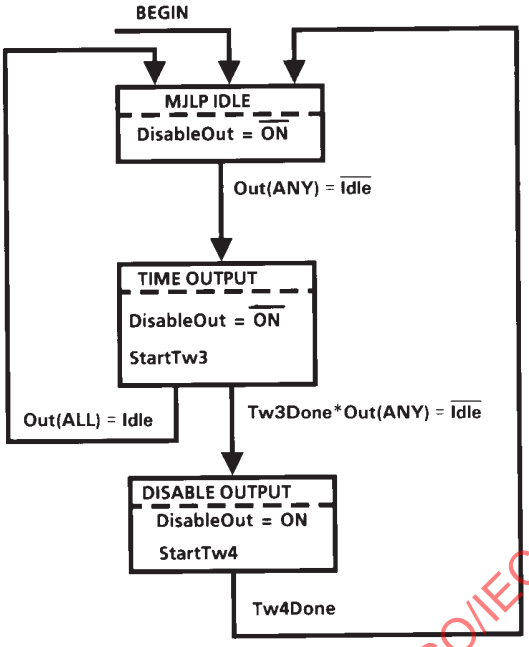

Figure 9–5—MAU jabber lockup protection state diagram

9.6.5 MAU Jabber Lockup Protection

MAU Jabber Lockup Protection must operate as shown in the MAU Jabber Lockup Protection state diagram. The repeater unit shall interrupt its output if it has transmitted continuously for longer than 5 ms or 50 000 bit times – 20% + 50%. The repeater unit shall then, after 96 to 116 bit times (9.6 to 11.6 μs), re-enable transmissions.

9.6.6 Auto-Partitioning/Reconnection (optional)

9.6.6.1 Overview

In large multisegment networks it may be desirable that the repeater unit protect the network from some fault conditions that would halt all network communication. A potentially likely cause of this condition could be due to a cable break, a faulty connector, or a faulty or missing termination.

In order to isolate a faulty segment's collision activity from propagating through the network, the repeater unit may optionally implement an auto-partition algorithm and, on detection of the malfunction being cleared, an auto-reconnection algorithm.

9.6.6.2 Detailed auto-partition/reconnection algorithm state diagram

Repeater sets with 10BASE-T MAUs shall implement an auto-partition/reconnection algorithm on those parts. The repeater unit may optionally implement an auto-partition/reconnection algorithm that protects the rest of the network from an open-circuited segment. If the repeater unit provides this function, it shall conform to the state diagram of Figure 9–6.

The algorithm defined in Figure 9–6 shall isolate a segment from the network when one of the following two conditions has occurred on the segment:

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a) When a consecutive collision count has been reached; or
b) When a single collision duration has exceeded a specific amount of time.

When a segment is partitioned, DataIn (X) and CollIn (X) from that segment are forced to II (input idle) and –SQE (no collision), respectively, so that activity on the port will not affect the repeater unit. Output from the repeater to the segment is not blocked.

The segment will be reinstated when the repeater has detected activity on the segment for more than the number of bits specified for Tw5 without incurring a collision.

Description of state diagram variables and constants

Port constants

CCLimit
: The number of consecutive collisions that must occur before a segment is partitioned. The value shall be greater than 30.

Input/Output variables

DIPresent(X)
: Data in from the MAU on port X. (This input is gated by the partition state diagram to produce DataIn (X) to the main state diagram.)
Values: II = *input_idle* ; no activity
–II = Input not idle ; activity

CIPresent(X)
: Control input from the MAU on port X. (This input is gated by the partition state diagram to produce CollIn (X) to the main state diagram.)
Values: SQE = *signal_quality_error* ; indicates collision
–SQE ; indicates no collision

Port variables

CC(X)
: Consecutive port collision count on a particular port X. Partitioning occurs on a terminal count of CCLimit being reached.
Values: Positive integers up to a terminal count of CCLimit.

Inter-Process Flags

Tw5
: Wait Timer for length of packet without collision. Its value shall be between 450 and 560 bit times. It is started by StartTw5. Tw5Done is satisfied when the timer has expired.

Tw6
: Wait Timer for excessive length of collision. Its value shall be between 1000 and 30 000 bit times. It is started by StartTw6. Tw6Done is satisfied when the timer has expired.

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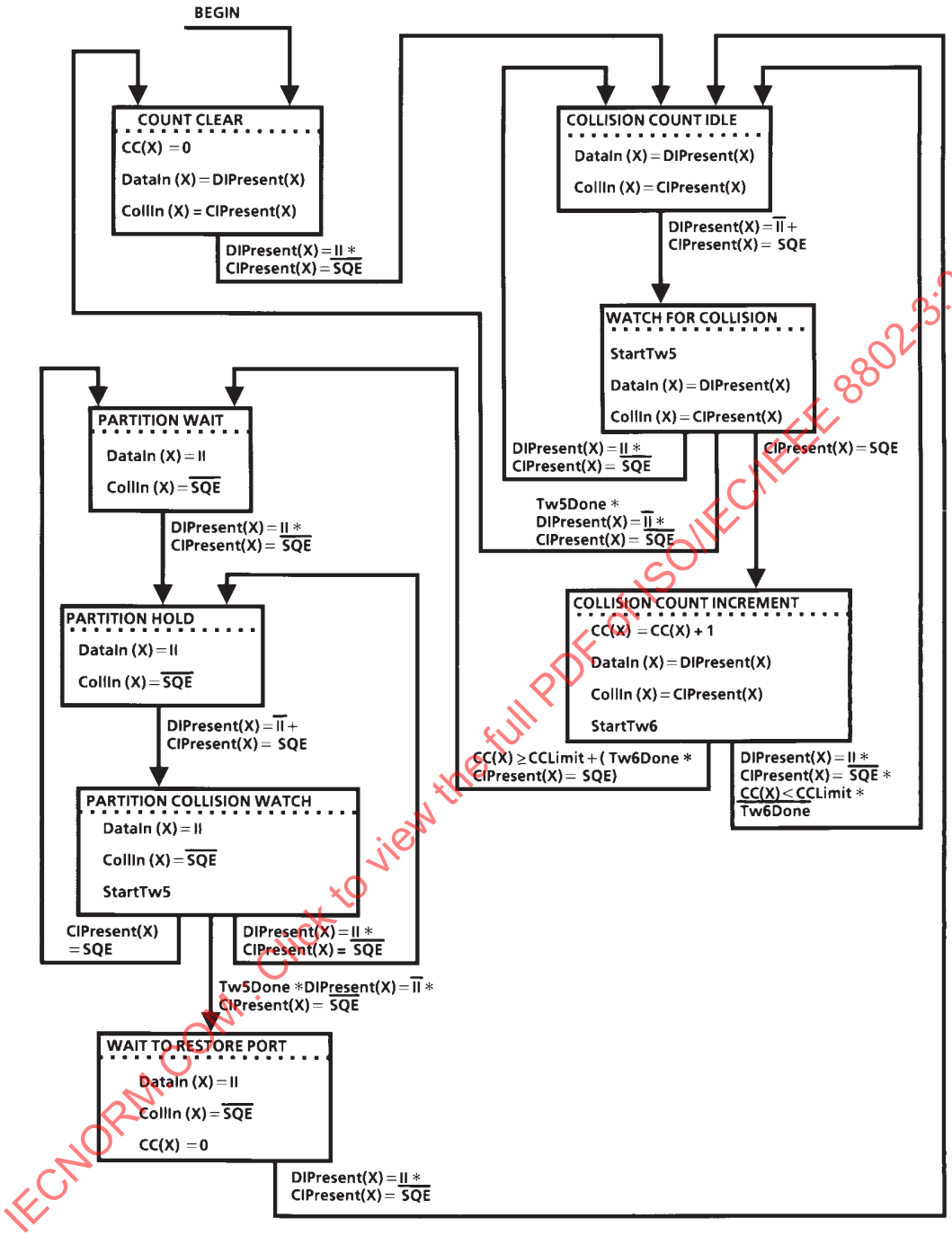

Figure 9–6—Partitioning state diagram for Port X

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9.7 Electrical isolation

There are two electrical power distribution environments to be considered that require different electrical isolation properties.

Environment A—When a LAN or LAN segment, with all its associated interconnected equipment, is entirely contained within a single low-voltage power distribution system and within a single building.

Environment B—When a LAN crosses the boundary between separate power distribution systems or the boundaries of a single building.

The repeater unit shall comply with applicable local and national codes related to safety. See [B25].

9.7.1 Environment A requirements

Attachment of network segments via repeaters (sets) possessing internal MAUs requires electrical isolation of 500 V rms, 1 min withstand, between the segment and the protective ground of the repeater unit.

For repeater ports that connect to external MAUs via an AU Interface, the requirement for isolation is encompassed within the isolation requirements of the basic MAU/medium standard. (See 8.3.2.1, 9.9.3.1, 10.4.2.1, 14.3.1.1, and 15.3.4.) The repeater unit shall not require any electrical isolation between exposed AU Interfaces or between exposed AU Interfaces and chassis ground of the repeater unit. No isolation boundary need therefore exist at any AUI compatible interface (that is, "D" connector) provided by a repeater unit.

9.7.2 Environment B requirements

The attachment of network segments, which cross environment A boundaries, requires electrical isolation of 1500 V rms, 1 min withstand, between each segment and all other attached segments and also the protective ground of the repeater unit.

If segments are of an electrically conductive medium, it is recommended that this isolation be provided by the use of external MAUs connected by AU Interfaces. If internal MAUs are used for attachment to conductive media segments, then the segments shall be installed such that it is not possible for an equipment user to touch the trunk cable screen or signal conductor. A repeater of this variety requires professional installation.

The requirements for interconnected electrically conducting LAN segments that are partially or fully external to a single building environment may require additional protection against lightning strike hazards. Such requirements are beyond the scope of this standard.

It is recommended that the above situation be handled by the use of a nonelectrically conducting LAN segment (see 9.9 or Clause 15).

9.8 Reliability

A 2-port repeater set shall be designed to provide a mean time between failure (MTBF) of at least 50 000 hours of continuous operation without causing a communication failure among stations attached to the network medium. Repeater sets with more than two ports shall add no more than 3.46×10^{-6} failures per hour for each additional port.

The repeater set electronics shall be designed to minimize the probability of component failures within the repeater electronics that prevent communication among the other MAUs on the individual coaxial cable

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segments. Connectors and other passive components comprising the means of connecting the repeater to the coaxial cable shall be designed to minimize the probability of total network failure.

9.9 Medium attachment unit and baseband medium specification for a vendor-independent FOIRL

9.9.1 Scope

9.9.1.1 Overview

A vendor-independent FOIRL provides a standard means for connecting a repeater via optical fiber to another repeater or to a DTE. It thus extends the network length and topology beyond that which could be achieved by interconnecting coaxial cable segments via repeater sets only, as defined in 8.6 or 10.7. A vendor-independent FOIRL is suited for interconnecting repeaters and their respective segments located in different buildings. FOMAUs that are used for the DTE end of the link segment are beyond the scope of this clause. See Clause 18.

NOTE—The FOMAU specified in 9.9 has been superseded by the specification to be found in Clause 18. The new specification is fully compatible (except for media connector) with the specifications of 9.9 at the MDI. The new specification calls out more recent practice in connectors and state machines. It also provides improved performance for long link segments and reflects more recent industry input on flux parameters.

In particular, this clause defines the following:

a) The functional, optical, electrical, and mechanical characteristics of a fiber optic MAU (FOMAU) suitable for interfacing to a repeater unit, either directly (FOMAU and repeater unit integrated into a single package) or via an AUI mechanical connection.
b) Various optical fiber sizes suitable for connecting only two FOMAUs.

A schematic of the vendor-independent FOIRL and its relationship to the repeater unit is shown in Figure 9–7. The vendor-independent FOIRL comprises an optical fiber cable link segment, a vendor-independent FOMAU at each end of the link segment and, if present, AUI cables.

The purpose of this specification is to enable interoperability of FOMAUs that originate from different manufacturers, thereby facilitating the development of simple and inexpensive inter-repeater links (IRLs). To satisfy this objective, the FOMAU has the following general characteristics:

— Enables coupling the repeater unit PLS directly, or by way of the AUI mechanical connection, to the explicit baseband optical fiber cable link segment defined in this clause of the standard.
— Supports signaling at a data rate of 10 Mb/s.
— Provides for driving up to 1000 m of an optical fiber cable link segment.
— Operates indistinguishably from other types of repeater set MAUs, as defined in their respective 10 Mb/s baseband MAU sections when viewed from the AU Interface.
— Supports 10 Mb/s baseband system configurations as defined in Clause 13 of this standard.
— Allows integration of the FOMAU into a single package with the repeater unit, thereby eliminating the need for an AUI mechanical connection.

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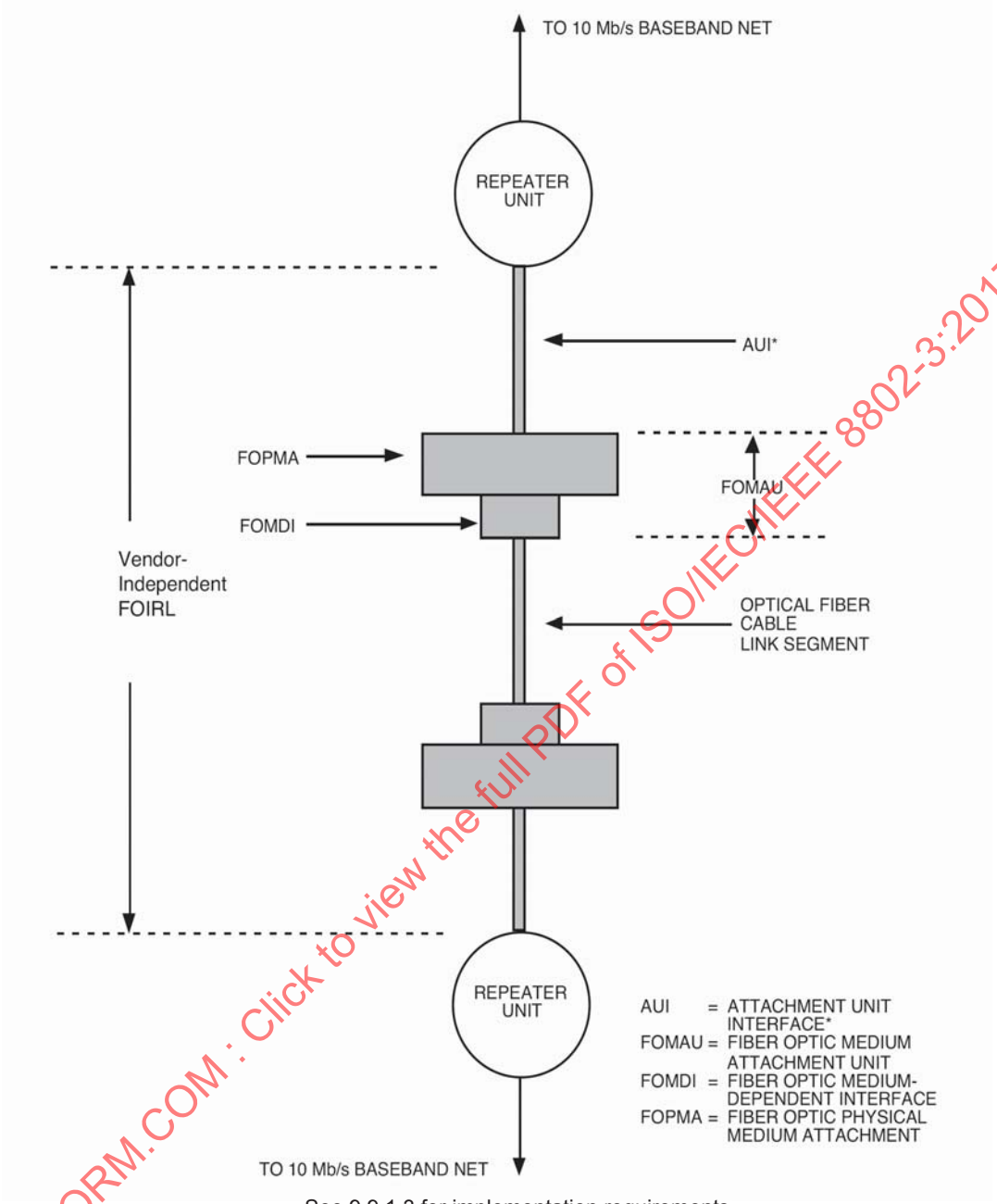

See 9.9.1.3 for implementation requirements

Figure 9–7—Schematic of the vendor-independent FOIRL and its relationship to the repeater unit

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9.9.1.2 Application perspective: FOMAU and medium objectives

This clause states the broad objectives underlying the vendor-independent FOIRL specification defined throughout this clause of the standard. These are as follows:

a) Provide the physical means for connecting a repeater via fiber to another repeater or to a DTE.
b) Define a physical interface for the vendor-independent FOMAU component of the vendor-independent FOIRL that can be implemented independently among different manufacturers of hardware and achieve the intended level of compatibility when interconnected in a common IRL.
c) Provide a communication channel capable of high bandwidth and low bit error ratio performance. The resultant BER of the FOIRL should be less than one part in 10^{10}.
d) Provide a means to prevent packet transmission through an FOIRL when transmission capability in one or both directions is disrupted.

9.9.1.3 Compatibility considerations

All implementations of the vendor-independent FOMAU shall be compatible at the FOMDI and at the AUI (when physically and mechanically implemented).

This standard provides an optical fiber cable link segment specification for the interconnection of only two FOMAU devices. The medium itself, the functional capability of the FOMAU, and the AUI are defined to provide the highest possible level of compatibility among devices designed by different manufacturers. Designers are free to implement circuitry within the FOMAU in an application-dependent manner provided the FOMDI and AUI are satisfied. (The provision of the physical and mechanical implementation of the AUI is optional.)

9.9.1.4 Relationship to AUI

A close relationship exists between this subclause and Clause 7. This subclause specifies all of the physical medium parameters, all of the FOPMA logical functions residing in the FOMAU, and references the AUI defined in Clause 7 with the exception of the *signal_quality_error* message Test of 7.2.1.2.3(3), which shall not be implemented, that is, shall not be enabled when connected to a repeater unit.

NOTE—The specification of a FOMAU component requires the use of both this subclause and Clause 7 for the AUI specifications.

9.9.1.5 Mode of operation

The FOMAU functions as a direct connection between the optical fiber cable link segment and the repeater unit. During collision-free operation, data from the repeater unit is transmitted into the FOMAU's transmit optical fiber, and all data in the FOMAU's receive optical fiber is transmitted to the repeater unit.

9.9.2 FOMAU functional specifications

The FOMAU component provides the means by which signals on the three AUI signal circuits are coupled:

a) From the repeater unit into the FOMAU's transmit optical fiber, and
b) From the FOMAU's receive optical fiber to the repeater unit.

To achieve this basic objective, the FOMAU component contains the following functional capabilities to handle message flow between the repeater unit and the optical fiber cable link segment:

a) *Transmit function*: The ability to receive serial bit streams from the attached repeater unit and transmit them into the FOMAU's optical fiber.

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b) *Receive function*: The ability to receive serial data bit streams from the FOMAU's receive optical fiber and transmit them to the attached repeater unit.

c) *Collision Presence function*: The ability to detect, and report to the attached repeater unit, an FOIRL collision.

d) *Jabber function*: The ability to automatically interrupt the Transmit function and inhibit an abnormally long output data stream.

e) *Low Light Level Detection function*: The ability to automatically interrupt the Receive function and Inhibit the reception of signals from the FOMAU's receive optical fiber which could result in abnormally high BERs.

9.9.2.1 Transmit function requirements

At the start of a packet transmission into the FOMAU's transmit optical fiber, no more than two bits (two full bit cells) of information may be received from the DO circuit and not transmitted into the FOMAU's transmit optical fiber. In addition, it is permissible for the first bit sent to contain encoded phase violations or invalid data. All successive bits of the packet shall be transmitted into the FOMAU's transmit optical fiber and shall exhibit the following:

a) No more edge jitter than that given by the sum of the worst-case edge jitter components specified in 7.4.3.6, 7.5.2.1, and 9.9.4.1.7, and
b) The levels and waveforms specified in 9.9.4.1.

The FOMAU DO circuit shall comply with the AUI specification for receivers given in 7.4.2. The FOMAU's DI circuit driver shall comply with the AUI specification for drivers given in 7.4.1.

The steady-state propagation delay between the DO circuit receiver input and the FOMAU's transmit optical fiber input shall not exceed one-half a bit cell. It is recommended that the designer provide an implementation in which a minimum threshold level is required on the DO circuit to establish a transmit bit stream.

The higher optical power level transmitted into the FOMAU's transmit optical fiber shall be defined as the low (LO) logic state on the optical fiber link segment. There shall be no logical signal inversions between the DO circuit and the FOMAU's transmit optical fiber, as specified in 9.9.4.1.5.

The difference in the start-up delay (bit loss plus invalid bits plus steady-state propagation delay), as distinct from the absolute start-up delays, between any two packets that are separated by 9.6 µs or less shall not exceed 2 bit cells.

The FOMAU shall loop back a packet received from the DO circuit into the DI circuit. At the start of a packet transmission, no more than five bits of information may be received from the DO circuit and not transmitted into the DI circuit. It is permissible for the first bit sent to contain encoded phase violations or invalid data. All successive bits of the packet shall be transmitted into the DI circuit and shall exhibit no more edge jitter than that specified for signals transmitted into the DI circuit by the Receive function, as specified in 9.9.2.2. The steady-state propagation delay between the DO circuit receiver input and the DI circuit driver output for such signals shall not exceed one bit cell. There shall be no logical signal inversions between the DO circuit and the DI circuit during collision-free transmission.

When the DO circuit has gone idle after a packet has been transmitted into the FOMAU's transmit optical fiber, the FOMAU shall not activate the Collision Presence function so as not to send the *signal_quality_error* message Test of 7.2.1.2.3(3) to the repeater unit.

During the idle state of the DO circuit, the Transmit function shall output into the transmit optical fiber an optical idle signal as specified in 9.9.4.1.4. The transmitted optical signals shall exhibit the optical power levels specified in 9.9.4.1.8. At the end of a packet transmission, the first optical idle signal pulse transition

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to the higher optical power level must occur no sooner than 400 ns and no later than 2100 ns after the packet's last transition to the lower optical power level. This first optical pulse must meet the timing requirements of 9.9.4.1.4.

The FOMAU shall not introduce extraneous optical signals into the transmit optical fiber under normal operating conditions, including powering-up or powering-down of the FOMAU.

9.9.2.2 Receive function requirements

At the start of a packet reception from the FOMAU's receive optical fiber, no more than two bits (two full bit cells) of information may be received from the FOMAU's receive optical fiber and not transmitted into the DI circuit. It is permissible for the first bit transmitted into the DI circuit to contain encoded phase violations or invalid data. All successive bits of the packet shall be transmitted into the DI circuit and shall exhibit the following:

a) The levels and waveforms specified in 7.4.1, and
b) No more edge jitter than that given by the sum of the worst-case edge jitter components specified in 7.4.3.6, 7.5.2.1, 9.9.4.1.7, 9.9.4.2.2, and 9.9.5.1.

The steady-state propagation delay between the output of the FOMAU's receive optical fiber and the output of the DI circuit driver shall not exceed one-half a bit cell. There shall be no logical signal inversions between the FOMAU's receive optical fiber and the DI circuit during collision-free operation, as specified in 9.9.4.2.3.

The difference in the start-up delay (bit loss plus invalid bits plus steady-state propagation delay), as distinct from the absolute start-up delays, between any two packets that are separated by 9.6 µs or less shall not exceed 2 bit cells.

The FOMAU shall not introduce extraneous signals into the DI circuit under normal operating conditions, including powering-up or powering-down of the FOMAU.

9.9.2.3 Collision Presence function requirements

The signal presented to the CI circuit in the absence of an SQE signal shall be the IDL signal.

The signal presented to the CI circuit during the presence of a collision shall be the CS0 signal, a periodic pulse waveform of frequency 10 MHz +25% –15% with pulse transitions that are no less than 35 ns and no greater than 70 ns apart at the zero crossing points. This signal shall be presented to the CI circuit no more than 3.5 bit times after the simultaneous appearance of signals at both the input of the FOMAU's transmit optical fiber and the output of the FOMAU's receive optical fiber. This signal shall be de-asserted no earlier than 4.5 bit times and no later than 7 bit times after the above defined collision condition ceases to exist.

During a collision, if a packet is received at the DO circuit before a packet is received at the FOMAU's receive optical fiber, then only the packet received at the DO circuit shall be transmitted into the DI circuit, as specified in 9.9.2.1. Conversely, if during a collision a packet is received at the FOMAU's receive optical fiber before a packet is received at the DO circuit, then only the packet received at the FOMAU's receive optical fiber shall be transmitted into the DI circuit, as specified in 9.9.2.2. In the event of both packets being received at their respective ports within 3.5 bit times of each other, then either one, but only one, of the packets shall be selected to be transmitted into the DI circuit.

The Collision function shall not introduce extraneous signals into the CI circuit under normal operating conditions, including powering-up or powering-down of the FOMAU.

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9.9.2.4 Jabber function requirements

The FOMAU shall have the capability, as defined in Figure 9–9, to interrupt a transmission from the repeater unit that exceeds a time duration determined by the FOMAU. This time duration shall not be less than 20 ms nor more than 150 ms. If the packet being transmitted is still being transmitted after the specified time duration, the FOMAU shall activate the Jabber function by the following:

a) First inhibiting the transmission of bits from its DO circuit into its transmit optical fiber,
b) Then transmitting into its transmit optical fiber the optical idle signal specified in 9.9.4.1.4, and
c) Presenting the CS0 signal to the CI circuit.

Once the error condition has been cleared, the FOMAU shall reset the Jabber function and present the IDL signal to the CI circuit:

a) On power reset, and
b) Optionally, automatically after a continuous period of 0.5 s ± 50% of inactivity on the DO circuit.

The FOMAU shall not activate its Jabber function when operated under the worst-case Jabber Lockup Protection condition specified in 9.6.5.

When both the Jabber function and the Low Light Level Detection function (see 9.9.2.5) have been activated, the Jabber function shall override the Low Light Level Detection function.

9.9.2.5 Low Light Level Detection function requirements

The FOMAU shall have a low light level detection capability, as defined in Figure 9–10, whereby it shall interrupt the reception of both the optical idle signal and packets from the FOMAU's receive optical fiber when reliable reception can no longer be assured. This error condition shall not be activated if the peak optical power level at the output of the FOMAU's receive optical fiber exceeds –27 dBm. It shall be activated before the peak optical power level at the output of the FOMAU's receive optical fiber has fallen to a level that is lower than the peak optical power level that corresponds to a BER = 10^{-10} for the FOMAU under consideration. Once this error condition has been activated, the FOMAU shall, no earlier than 30 bit times and no later than 200 bit times

a) Disable its Receive function so that the transmission of bits from its receive optical fiber to the DI circuit is inhibited.
b) Assure that only the optical idle signal is transmitted into its transmit optical fiber, irrespective of the state of the DO circuit.
c) Disable its Transmit function during the period of time that the FOMAU recognizes the presence of a packet on the DO circuit such that the transmission of the packet from the DO circuit into the DI circuit is inhibited.

Once this error condition has been cleared, the FOMAU shall return automatically to its normal mode of operation within 40 bit times once the DO circuit is in the idle state.

When both the Jabber function (see 9.9.2.4) and the Low Light Level Detection function have been activated, the Jabber function shall override the Low Light Level Detection function.

NOTE—It is recommended that, for diagnostic purposes, the status of the Low Light Level Detection function be indicated on the exterior of the FOMAU package.

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9.9.2.6 Repeater Unit to FOMAU Physical Layer messages

The following messages can be received by the FOMAU Physical Layer entities from the repeater unit:

Message	Circuit	Signal	Meaning
output	DO	CD1, CD0	Output information
output_idle	DO	IDL	No data to be output

9.9.2.7 FOMAU Physical Layer to repeater unit messages

The following messages can be sent by the FOMAU Physical Layer entities to the repeater unit:

Message	Circuit	Signal	Meaning
input	**DI**	**CD1, CD0**	**Input information**
input_idle	DI	IDL	No information to be input
fomau_available	CI	IDL	FOMAU is available for output
signal_quality_error	CI	CS0	Collision or error detected by FOMAU

9.9.2.7.1 *input* message

The FOMAU Physical Layer sends an *input* message to the repeater unit when the FOMAU has a bit of data to send to the repeater unit. The physical realization of the *input* message is a CD0 or CD1 sent by the FOMAU to the repeater unit on the DI circuit. The FOMAU sends CD0 if the input bit is a zero, or CD1 if the input bit is a one. No retiming of the CD1 or CD0 signals takes place within the FOMAU.

9.9.2.7.2 *input_idle* message

The FOMAU Physical Layer sends an *input_idle* message to the repeater unit when the FOMAU does not have data to send to the repeater unit. The physical realization of the *input_idle* message is the IDL signal sent by the FOMAU to the repeater unit on the DI circuit.

9.9.2.7.3 *fomau_available* message

The FOMAU Physical Layer sends the *fomau_available* message to the repeater unit when the FOMAU is available for output, and when the FOMAU has activated the Low Light Level Detection function in accordance with the Low Light Level Detection function requirements of 9.9.2.5 and Figure 9–10. The *fomau_available* message shall be sent by a FOMAU that is prepared to output data. The physical realization of the *fomau_available* message is an IDL signal sent by the FOMAU to the repeater unit on the CI circuit.

9.9.2.7.4 *signal_quality_error* message

The *signal_quality_error* message shall be implemented in the following fashion:

a) When the FOMAU has completed the transmission of a packet into its transmit optical fiber, it shall not send any *signal_quality_error* message Test sequence.

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b) The simultaneous appearance of packets at both the input of a FOMAU's transmit optical fiber and the output of its receive optical fiber shall cause the *signal_quality_error* message to be sent by the FOMAU to the repeater unit.
c) When the FOMAU has activated the Jabber function, it shall send the *signal_quality_error* message in accordance with the Jabber function requirements of 9.9.2.4 and Figure 9–9.

The physical realization of the *signal_quality_error* message is the CS0 signal sent by the FOMAU to the repeater unit on the CI circuit.

The FOMAU is required to assert the *signal_quality_error* message at the appropriate times whenever the FOMAU is powered and not just when the repeater unit is providing output data.

9.9.2.8 FOMAU state diagrams

The state diagrams, Figure 9–8, Figure 9–9, and Figure 9–10, depict the full set of allowed FOMAU state functions relative to the control circuits of the repeater unit/FOMAU interface for FOMAUs. Messages used in these state diagrams are explained as follows:

NOTE—Figures 9–8, 9–9, and 9–10 must all be considered together.

a) *enable_opt_driver* : Activates the path employed during normal operation to cause the FOMAU transmitter to impress the packet data received from the DO circuit into the FOMAU's transmit optical fiber.
b) *disable_opt_driver* : Deactivates the path employed during normal operation to cause the FOMAU transmitter to impress the packet data received from the DO circuit into the FOMAU's transmit optical fiber.
c) *enable_opt_idle_driver* : Causes the FOMAU transmitter to impress the optical idle signal into the FOMAU's transmit optical fiber.
d) *disable_opt_idle_driver* : Causes the FOMAU to stop transmitting the optical idle signal into the FOMAU's transmit optical fiber.
e) *enable_loop_back* : Activates the path employed during normal operation to cause the FOMAU Transmit function to impress the packet data received from the DO circuit into the DI circuit.
f) *disable_loop_back* : Deactivates the path employed during normal operation to cause the FOMAU Transmit function to impress the packet data received from the DO circuit into the DI circuit.
g) *enable_opt_receiver* : Activates the path employed during normal operation to cause the FOMAU to impress the packet data received from the FOMAU's receive optical fiber into the DI circuit.
h) *disable_opt_receiver* : Deactivates the path employed during normal operation to cause the FOMAU to impress the packet data received from the FOMAU's receive optical fiber into the DI circuit.
i) [*start_packet_timer*] : Starts a timing function which is used to monitor the amount of time the FOMAU is transmitting a packet into the transmit optical fiber. The timing function is maintained as long as *output* is true and is stopped on the transition to *output_idle true.* The term *packet_timer_done* is satisfied when the timing function has run to expiration (see 9.9.2.4).
j) [*start_unjab_timer*] : Starts a timing function that is used to monitor the amount of time that the Jabber error condition has been clear. The timing function is maintained as long as *output_idle* is true and is stopped on the transition to *output true*. The term *unjab_timer_done* is satisfied when the timing function has run to expiration (see 9.9.2.4).

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k) *opt_input* : Signifies that a packet is present at the FOMAU's receive optical fiber.

l) *opt_input_idle* : Signifies that a packet is no longer present at the FOMAU's receive optical fiber.

m) *opt_input_coll_select* : Signifies that, during a collision, a packet has been received at the DO circuit within 3.5 bit times of a packet being received at the FOMAU's receive optical fiber, and that only the packet received at the FOMAU's receive optical fiber is to be transmitted into the DI circuit.

n) *output_coll_select* : Signifies that, during a collision, a packet has been received at the DO circuit within 3.5 bit times of the packet being received at the FOMAU's receive optical fiber, and that only the packet received at the DO circuit is to be transmitted into the DI circuit.

The following abbreviations have been used in Figure 9–8, Figure 9–9, and Figure 9–10:

— LLP = Low Light Level Condition Present
— LLNP = Low Light Level Condition Not Present
— p_t_d = *packet_timer_done*
— p_t_n_d = *packet_timer_not_done*
— * = logical AND operator

9.9.3 FOMAU electrical characteristics

9.9.3.1 Electrical isolation

Electrical isolation shall be provided between FOMAUs attached to the FOIRL by the optical fiber cable link segment. There shall be no conducting path between the optical medium connector plug and any conducting element within the optical fiber cable link segment. This isolation shall withstand at least one of the following electrical strength tests:

a) 1500 V rms at 50–60 Hz for 60 s, applied as specified in 5.3.2 of IEC 60950: 1991.
b) 2250 V dc for 60 s, applied as specified in 5.3.2 of IEC 60950: 1991.
c) A sequence of ten 2400 V impulses of alternating polarity, applied at intervals of not less than 1 s. The shape of the impulses shall be 1.2/50 μs (1.2 μs virtual front time, 50 μs virtual time of half value), as defined IEC 60060.

There shall be no isolation breakdown, as defined in 5.3.2 of IEC 60950: 1991, during the test. The resistance after the test shall be at least 2 MΩ, measured at 500 V dc.

NOTE—Although isolation is provided by the optical fiber cable link segment, it is recommended that the normal noise immunity provided by common-mode isolation on the AUI be retained.

9.9.3.2 Power consumption

The current drawn by the FOMAU shall not exceed 0.5 A when powered by the AUI source. The FOMAU shall be capable of operating from all possible voltage sources as supplied by the repeater unit (7.5.2.5 and 7.5.2.6) through the resistance of all permissible AUI cables. The surge current drawn by the FOMAU on power-up shall not exceed 5 A peak for a period of 10 ms. In addition, the FOMAU shall be capable of powering-up from 0.5 A current limited sources.

It is permissible as an option to provide a separate power source for the FOMAU. If a separate power source is implemented, provision will be made to assure that power shall under no circumstances be sourced on pin 13 (Circuit VP) of the AUI.

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The FOMAU shall be labeled externally to identify the maximum value of power supply current required by the device when the AUI mechanical connection is implemented.

The FOMAU shall not introduce into the FOMAU's transmit optical fiber or onto the DI or CI circuits of the AUI any extraneous signal on routine power-up or power-down under normal operating conditions.

The FOMAU shall be fully functional no later than 0.5 s after power is applied to it.

9.9.3.3 Reliability

The FOMAU shall be designed to provide a MTBF of at least 200 000 hours of operation without causing a communication failure amongst DTEs attached to the network. The FOMAU electronics shall be designed to minimize the probability of component failures within the FOMAU that prevent communication amongst other MAUs on the 10BASE5 and 10BASE2 segments. Connectors and other passive means of connection shall be designed to minimize the probability of total network failure.

9.9.3.4 FOMAU/Repeater unit electrical characteristics

The electrical characteristics of the driver and receiver components connected to the AUI cable shall be identical to those specified in Clause 7.

9.9.3.5 FOMAU/Repeater unit mechanical connection

The FOMAU, if it implements the AUI mechanical connection, shall be provided with a 15-pin male connector, as specified in the AUI specification of Clause 7.

9.9.4 FOMAU/Optical medium interface

9.9.4.1 Transmit optical parameters

9.9.4.1.1 Wavelength

The center wavelength of the optical source emission shall be between 790 nm and 860 nm. See 15.2.1.1.

9.9.4.1.2 Spectral width

The spectral width of the optical source shall be less than 75 nm full width half maximum (FWHM).

9.9.4.1.3 Optical modulation

The optical modulation during packet transmission shall be on-off keying of the optical source power. The minimum extinction ratio shall be 13 dB.

9.9.4.1.4 Optical idle signal

During the idle state of the DO circuit, the Transmit function shall input into the FOMAU's transmit optical fiber an optical idle signal. This signal shall consist of a periodic pulse waveform of frequency 1 MHz +25% –15% with a duty cycle ratio between 45/55 and 55/45.

9.9.4.1.5 Transmit optical logic polarity

The higher optical power level transmitted into the FOMAU's transmit optical fiber shall correspond to the low (LO) logic state (see 7.4.2.1) of the AUI DO circuit.

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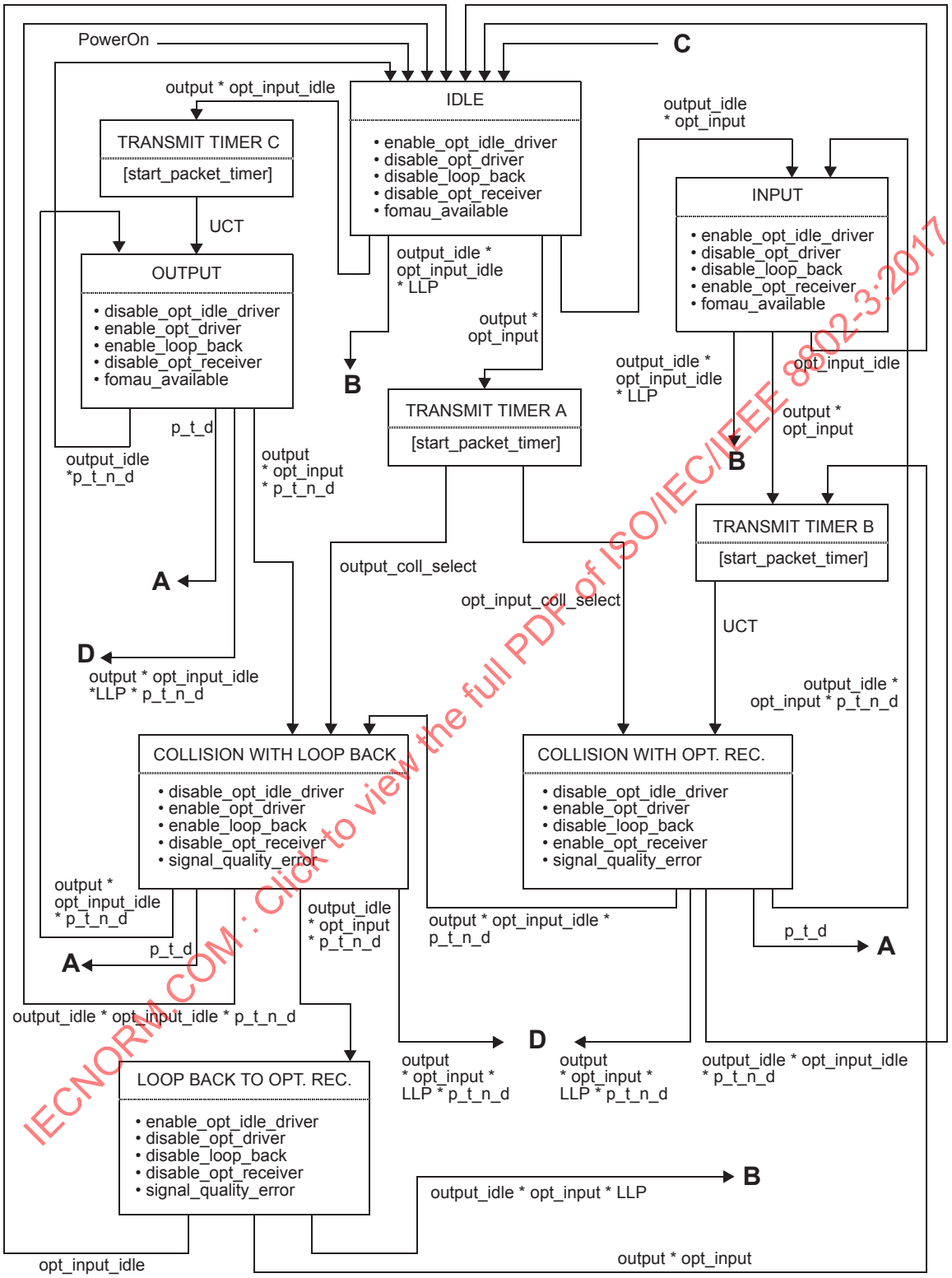

Figure 9–8—FOMAU Transmit, Receive, and Collision functions state diagram

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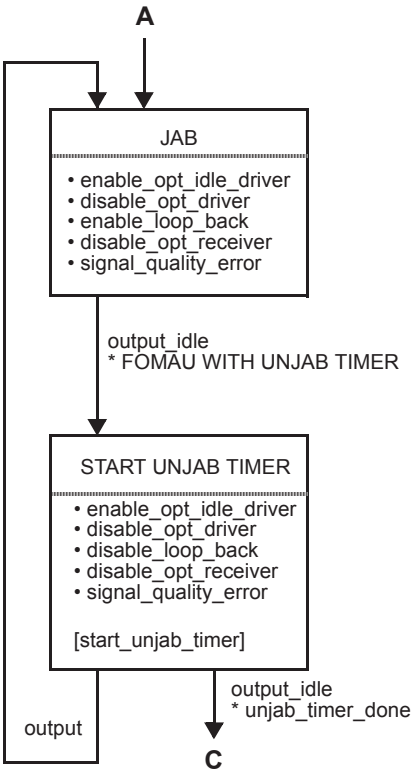

Figure 9–9—
FOMAU Jabber function state diagram

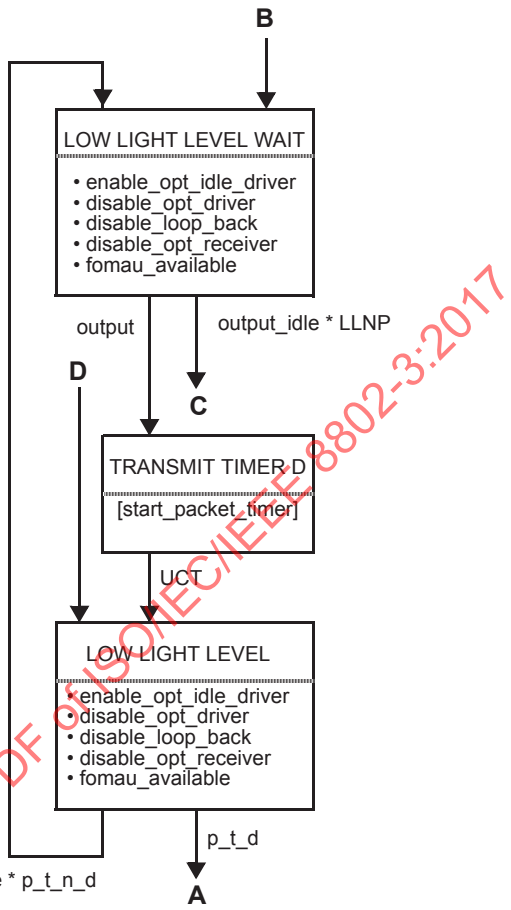

Figure 9–10—
Low Light Level Detection function state diagram

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9.9.4.1.6 Optical rise and fall times

The optical rise and fall times of the FOMAU shall be no more than 10 ns from the 10% to the 90% levels. There shall be no more than 3 ns difference between the rise and fall times.

9.9.4.1.7 Transmit optical pulse edge jitter

The additional edge jitter introduced by the FOMAU from the input of the DO circuit receiver to the output of the electro-optic source shall be no more than 2 ns. The jitter measured at the input of the DO circuit receiver shall be measured at the zero crossing points, as determined from the previous 16 or more transitions in any valid bit stream. The jitter measured at the output of the electro-optic source shall be measured at the power level median of the optical waveform's upper and lower power levels, as determined from the previous 16 or more transitions in any valid optical bit stream.

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9.9.4.1.8 Peak coupled optical power

At the beginning of the FOMAU's lifetime, the peak optical power coupled into the FOMAU's transmit optical fiber, when terminated with an optical connector as specified in 9.9.5.2, shall be –12 dBm ± 2 dB, when measured with a graded index optical fiber of nominal dimension of 62.5 µm core diameter and 0.275 nominal numerical aperture. The actual optical power, which will be coupled into other fiber sizes listed in 9.9.5.1, may differ from the above value. The peak optical power shall be measured in the steady state, and the measurement shall be independent of optical pulse ringing effects. Peak optical overshoot shall not exceed 10%.

NOTE 1—The source is allocated an aging margin of 3 dB over its operating lifetime. Thus, with respect to an optical fiber of nominal dimension of 62.5 µm core diameter and 0.275 nominal numerical aperture, the minimum launch peak power at the end of life is –17 dBm and the maximum initial launch peak power is –10 dBm. The variation in the peak coupled optical power into any of the optical fibers specified in 9.9.5.1 is ±1 dB with respect to the above-mentioned nominal optical fiber. Hence, with respect to any of the optical fibers specified in 9.9.5.1, the minimum possible launch peak power at the end of life is –18 dBm and the maximum possible initial launch peak power is –9 dBm. The start of life minimum possible launch peak power is then –15 dBm.

NOTE 2—The transmit optical power range specified above is the power coupled into the core of the optical fiber. Typical current fibers require 1 m to 5 m to remove optical power from the cladding. For links under 5 m in length, it may be necessary to use techniques such as attenuators or mode-stripping filters to attenuate optical power coupled into the cladding in order to meet the requirements of 9.9.4.2.1.

9.9.4.2 Receive optical parameters

9.9.4.2.1 Receive peak optical power range

The BER shall be $< 10^{-10}$ for peak optical powers at the output of the FOMAU's receive optical fiber between –27 dBm and –9 dBm.

9.9.4.2.2 Receive optical pulse edge jitter

The additional edge jitter introduced by the FOMAU from the input of the opto-electric detector to the output of the DI circuit driver shall be no more than 4 ns. The jitter measured at the input of the opto-electric receiver shall be measured at the power level median of the optical waveform's upper and lower power levels as determined from the previous 16 or more transitions in any valid optical bit stream. The jitter measured at the output of the DI circuit driver shall be measured at the zero crossing points as determined from the previous 16 or more transitions in any valid bit stream. This requirement shall apply when the optical receive peak power level is in the range –27 to –9 dBm.

9.9.4.2.3 Receive optical logic polarity

The low (LO) logic state (see 7.4.2.1) on the DI circuit shall correspond to the presence of the higher optical power level at the output of the FOMAU's receive optical fiber.

9.9.5 Characteristics of the optical fiber cable link segment

The optical fiber cable link segment is a length of optical fiber cable (IEC 60794-1: 1993 and IEC 60794-2: 1989) containing two optical fibers, as specified in 9.9.5.1, and comprising one or more optical fiber cable sections and their means of interconnection. Each optical fiber is terminated at each end in the optical connector plug specified in 9.9.5.2. The two optical fibers correspond to the FOMAU's transmit and receive optical fibers.

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9.9.5.1 Optical fiber medium

The FOMAU can operate with a variety of optical fiber sizes, e.g., 50/125 µm, 62.5/125 µm, 85/125 µm, 100/140 µm.

Interoperability of FOMAUs that originate from different manufacturers, using any of these fiber sizes, is assured provided that the received peak optical power is between –27 dBm and –9 dBm and the optical fiber cable link segment bandwidth is greater than or equal to 150 MHz.

In order to satisfy the above attenuation and bandwidth criteria for all allowable FOIRL lengths, and assuming up to 4 dB of connection losses within the optical fiber cable link segment, it is recommended that the cabled optical fiber have an attenuation ≤ 4 dB/km and a bandwidth of ≥ 150 MHz referred to 1 km at a wavelength of 850 nm.

The total incremental optical pulse edge jitter introduced by the optical fiber cable link segment shall be less than 1 ns when driven by an optical transmitter as specified in 9.9.4.1. The pulse delay introduced by the optical fiber cable shall not exceed 50 bit times for a 1 km length.

In the specific case of 62.5/125 µm fiber, to ensure interoperability of FOMAUs that originate from different manufacturers:

a) The two cabled optical fibers contained in the optical fiber cable link segment shall satisfy the optical fiber parameters specified in IEC 60793-2: 1992 type A1b (62.5/125 µm), and
b) The optical fiber cable link segment shall have an attenuation less than or equal to 8 dB and a bandwidth greater than or equal to 150 MHz.

NOTE—For newer fiber installations, it is recommended that the requirements of 15.3 be used.

9.9.5.2 Optical medium connector plug and socket

The two optical fibers contained in the optical fiber cable link segment shall be terminated at each end in an optical connector plug as specified in IEC 60874-1: 1993 and 60874-2: 1993.

The corresponding mating connector socket shall conform with the specifications given in IEC 60874-1: 1993 and 60874-2: 1993. This document specifies the mechanical mating face dimensions to ensure mechanical intermateability without physical damage, of all F-SMA connectors covered by the document. In addition, the optical insertion loss when interconnecting two optical connector plugs shall not exceed 2.5 dB (measured using a socket adaptor conforming to the mechanical specifications given in IEC 60874-1: 1993 and 60874-2: 1993 and also using two identical fibers, as specified in 9.9.5.1, assuming uniform mode distribution launch conditions).

9.9.6 System requirements

9.9.6.1 Optical transmission system considerations

Subclause 9.9.4.2.1 specifies that the BER shall be $<10^{-10}$ for peak optical powers at the output of the FOMAU's receive optical fiber between –27 dBm and –9 dBm. The value of –9 dBm corresponds to the maximum allowable peak optical power that can be coupled into the worst-case optical fiber specified in 9.9.5.1 at the beginning of the FOMAU's lifetime (see 9.9.4.1.8), and assumes zero optical loss between the optical source output and the optical detector input.

The value of –27 dBm is calculated by subtracting the FOIRL flux budget from the minimum allowable peak optical power that can be coupled into the FOMAU's transmit optical fiber at the beginning of the FOMAU's lifetime (see 9.9.4.1.8). The flux budget is the maximum loss allowed within the FOIRL to guar-

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antee a BER < 10^{-10} assuming worst-case link components. A portion of the flux budget has been allocated as a design margin to allow for degradation and tolerance effects in the optical source. This is noted in the table below as the optical source lifetime degradation. The remaining flux budget of 9 dB assumes a system margin allowance for the optical fiber cable link segment over its lifetime, and may be allocated to the optical fiber cable link segment loss at the discretion of the network planner/installer. The following summarizes the allocated optical flux budgets for the example graded index optical fiber of worst-case dimensions 62.5 µm – 3 µm (i.e., 59.5 µm) core diameter and 0.275 – 0.015 (i.e., 0.260) numerical aperture:

Start of life minimum peak coupled optical power (9.9.4.1.8) : –15 dBm

Optical source lifetime degradation : 3 dB

Maximum optical fiber cable link segment loss including system margin allowance : 9 dB

Resultant required receive peak optical power : –27 dBm

9.9.6.2 Timing considerations

Table 9–4 summarizes the maximum allowable timing budget contributions to the system timing budget for the FOIRL. The last bit in to last bit out delay shall equal the Steady-State Propagation Delay.

Table 9–4—Maximum allowable timing budget contributions to the FOIRL system timing budget

Symbol	Function	Bit loss (bit times)	Invalid bits (bit times)	Steady-state propagation delay (bit times)	Start-up delay (bit times)
I1	OPTICAL DATA IN ASSERT→INPUT	2.0	1.0	0.5	3.5
I2	OUTPUT→OPTICAL DATA OUT ASSERT	2.0	1.0	0.5	3.5
LOOP BACK	DO CIRCUIT ASSERT →DI CIRCUIT ASSERT	5.0	1.0	1.0	7.0
I3	OPTICAL COLLISION →SQE ASSERT	—	—	—	3.5
I4	COLLISION DE-ASSERT →SQE DE-ASSERT	—	—	—	7.0[a]
A1	AUI propagation	—	—	2.57	2.57
F1	Optical fiber propagation per kilometer	—	—	50	50

[a]Minimum start-up delay for I4 is 4.5 bit times.

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9.9.7 Environmental specifications

9.9.7.1 Safety requirements

9.9.7.1.1 Electrical safety

A major application for the vendor-independent FOIRL is interconnecting electrically conductive cable segments located within different buildings. The level of isolation provided by the optical fiber cable link segment shall be consistent with this application and provide adequate personnel and equipment safety from earth faults and lightning strike hazards.

9.9.7.1.2 Optical source safety

The recommendations of IEC 60825: 1993, if applicable, shall be adhered to in determining the optical source safety and user warning requirements.

9.9.7.2 Electromagnetic environment

9.9.7.2.1 Susceptibility levels

Sources of interference from the environment include electromagnetic fields, electrostatic discharge, and transient voltages between earth connections. Several sources of interference contribute to voltage between the optical fiber cable link segment (either a metallic strength member in the cable, a metallic optical connector plug, or the outermost conducting element of the FOMAU for the case of no metallic strength member) and the earth connection of a DTE.

For information on limits and methods of measurements of radio interference characteristics of information technology equipment, see 1.3 in CISPR 22: 1993.

The physical channel hardware shall meet its specifications when operating in both of the following conditions:

a) Ambient plane wave field of 2 V/m from 10 kHz through 30 MHz and 5 V/m from 30 MHz through 1 GHz.

NOTE—These are the levels typically found 1 km from radio broadcast stations.

b) Interference source voltage of 15.8 V peak sine wave of frequency 10 MHz in series with a 50 Ω source resistance applied between the optical fiber cable link segment (either a metallic strength member in the cable, a metallic optical connector plug, or the outermost conducting element of the FOMAU for the case of no metallic strength member) and the earth connection of a DTE.

NOTE—The optical fiber link segment is capable of withstanding higher levels of electromagnetic interference. The above specifications are the minimum requirements for the environment in which the FOMAU is required to operate.

9.9.7.2.2 Emission levels

The FOMAU and optical fiber cable link segment shall comply with CISPR 22: 1993.

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9.9.7.3 Temperature and humidity

The FOMAU and associated connector/cable systems are expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling such as shock and vibration. Specific requirements and values for these parameters are beyond the scope of this standard. Manufacturers should indicate in the literature associated with the FOMAU (and on the FOMAU if possible) the operating environment specifications to facilitate selection, installation, and maintenance of these components. It is further recommended that such specifications be stated in standard terms, as specified in IEC 60068, IEC 60793-1: 1992, IEC 60794-1: 1993, and IEC 60874-1: 1993.

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10. Medium attachment unit and baseband medium specifications, type 10BASE2

NOTE—This MAU is not recommended for new installations. Since September 2011, maintenance changes are no longer being considered for this clause.

10.1 Scope

10.1.1 Overview

This standard defines the functional, electrical, and mechanical characteristics of the Medium Attachment Unit (MAU) and one specific medium for use with LANs. The relationship of this specification to the OSI Reference Model is shown in Figure 10–1.

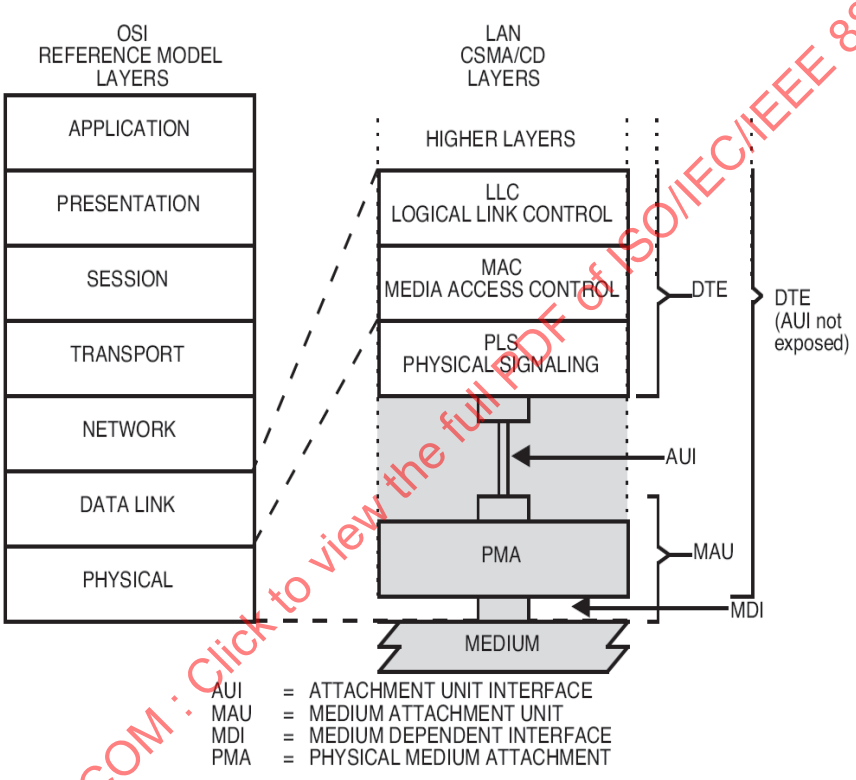

Figure 10–1—Physical Layer partitioning, relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model

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The purpose of the MAU is to provide a simple, inexpensive, and flexible means of attaching devices to the LAN medium. This standard defines a means of incorporating the MAU function within the DTE and bringing the trunk coaxial cable directly to the DTE. Interconnection of DTE units is easily achieved by the use of industry standard coaxial cables and BNC connectors.

This MAU and medium specification is aimed primarily at applications where there are a relatively small number of devices located in a work area. Installation and reconfiguration simplicity is achieved by the type of cable and connectors used. An inexpensive implementation is achieved by eliminating the MAU and Attachment Unit Interface (AUI) as separate components and using widely available interconnection components.

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10.1.1.1 Medium attachment unit (normally contained within the data terminal equipment [DTE])

The MAU has the following general characteristics:

a) Enables coupling the PLS to the explicit baseband coaxial transmission system defined in this clause of the standard.
b) Supports message traffic at a data rate of 10 megabits per second (Mb/s).
c) Provides for driving up to 185 m coaxial trunk cable segment without a repeater.
d) Permits the DTE to test the MAU and the medium itself.
e) Supports system configurations using the CSMA/CD access mechanism defined in IEEE 802.3.
f) Supports a bus topology interconnection means.
g) Supports low-cost capability by incorporating the MAU function within the physical bounds of the DTE, thereby eliminating the need for a separate AU connector and cable but containing the remaining AU interface functionality.

10.1.1.2 Repeater unit

The Repeater Unit is used to extend the physical system topology and provides for coupling two or more coaxial trunk cable segments. Multiple Repeater Units are permitted within a single system to provide the maximum trunk cable connection path specified in 10.7. The repeater is not a DTE and therefore has slightly different attachment requirements.

10.1.2 Definitions

See 1.4.

10.1.3 Application perspective: MAU and medium objectives

This subclause states the broad objectives and assumptions underlying the specifications defined throughout Clause 10 of the standard.

10.1.3.1 Object

a) Provide the physical means for communication between local network Data Link entities.

NOTE—This specification covers a portion of the Physical Layer as defined in the OSI Reference Model and, in addition, the physical medium itself, which is beyond the scope of the OSI Reference Model.

b) Define a physical interface that can be implemented independently among different manufacturers of hardware and achieves the intended level of compatibility when interconnected in a common local network.
c) Provide a communication channel capable of high bandwidth and low bit error ratio performance. The resultant mean bit error ratio, at the Physical Layer service interface, should be less than one part in 10^7 (on the order of one part in 10^8 at the link level).
d) Provide for ease of installation and service.
e) Provide for high network availability (ability of a station to gain access to the medium and enable the Data Link connection in a timely fashion).
f) Enable low-cost implementations.

NOTE—The figures and numerous textual references throughout this clause refer to terminology associated with the AUI (that is, DO, DI, CI). Since the normal embodiment of the type 10BASE2 configuration does not require an AUI, actual existence of the DO, DI, CI circuit may not be required. Use of this terminology, however, is retained throughout Clause 10 for purposes of clarity and consistency.

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10.1.3.2 Compatibility considerations

All implementations of this baseband coaxial system shall be compatible at the Medium Dependent Interface (MDI).

This standard provides one explicit trunk cable medium specification for the interconnection of all MAU devices. The medium itself, and the functional capability of the MAU, are defined to provide the highest possible level of compatibility among devices designed by different manufacturers. Designers are free to implement circuitry within the MAU in an application-dependent manner provided the MDI specifications are satisfied.

10.1.3.3 Relationship to PLS and AUI

This clause defines the Primary Physical Layer for the LAN, a layer comprised of both the physical medium and the rudimentary circuitry necessary to couple a station's message path directly to/from the medium. The complete Logical Physical Layer of the LAN resides within the DTE. Therefore, a close relationship exists between this subclause and Clause 7. This subclause specifies the physical medium parameters, the PMA logical functions residing in the MAU, and references the signal circuits associated with the AUI as defined in Clause 7.

The design of a MAU component requires the use of both this clause and parts of the PLS and AUI specifications contained in Clause 7.

10.1.3.4 Mode of operation

The MAU functions as a direct connection between the baseband medium and the DTE. Data from the DTE is output to the coaxial trunk medium and all data on the coaxial trunk medium is input to the DTE.

10.2 References

References to such local or national standards that may be useful resource material for the reader are identified and located in Annex A.

10.3 MAU functional specifications

The MAU component provides the means by which signals on the three AUI signal circuits to/from the DTE and their associated interlayer messages are coupled to the single coaxial cable baseband signal line. To achieve this basic objective, the MAU component contains the following functional capabilities to handle message flow between the DTE and the baseband medium:

a) *Transmit function.* The ability to transmit serial data bit streams on the baseband medium from the local DTE entity to one or more remote DTE entities on the same network.
b) *Receive function.* The ability to receive serial data bit streams over the baseband medium.
c) *Collision Presence function.* The ability to detect the presence of two or more stations' concurrent transmissions.
d) *Jabber function.* The ability to automatically interrupt the Transmit function and inhibit an abnormally long output data stream.

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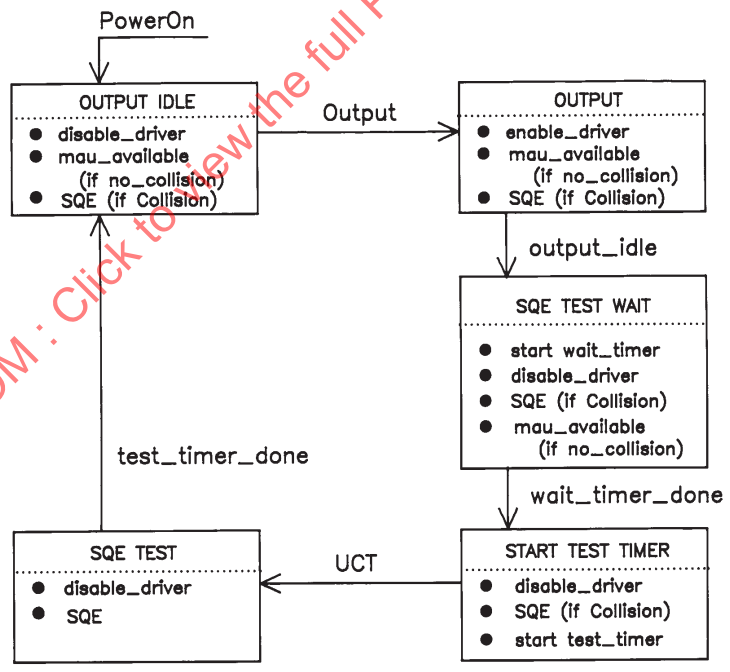
10.3.1 MAU Physical Layer functional requirements

10.3.1.1 Transmit function requirements

At the start of a frame transmission on the coaxial cable, no more than 2 bits (2 full bit cells) of information may be received from the DO circuit and not transmitted onto the coaxial medium. In addition, it is permissible for the first bit sent to contain invalid data or timing; however, all successive bits of the frame shall be reproduced with no more than the specified amount of jitter. The 4th bit cell shall be carried from the DO signal line and transmitted onto the coaxial trunk cable medium with the correct timing and signal levels. The steady-state propagation delay between the DO circuit receiver input and the coaxial cable output shall not exceed 1/2 bit cell. There shall be no logical signal inversions between the branch cable DO circuit and the coaxial trunk cable (for example, a "high" logic level input to the MAU shall result in the less negative current flow value on the trunk coaxial medium). A positive signal on the A signal lead of the DO circuit shall result in a more positive voltage level on the trunk coaxial medium. It is assumed that the AUI shall provide adequate protection against noise. It is recommended that the designer provide an implementation in which a minimum threshold signal is required to establish a transmit bit stream.

The Transmit function shall output a signal on the trunk coaxial medium whose levels and waveform comply with 10.4.1.3.

In addition, when the DO circuit has gone idle after a frame is output, the MAU shall then activate the Collision Presence Function as close to the trunk coaxial cable as possible without introducing an extraneous signal on the trunk coaxial medium. The MAU shall initiate the Collision Presence state within 0.6 µs to 1.6 µs after the Output Idle signal (Wait_Timer_Done in Figure 10–2) and shall maintain an active Collision Presence state for a time equivalent to 10 bit cells ± 5 bit cells.



(UCT = unconditional transition)
(Wait_Timer_Done is specified in 10.3.1.1)

Figure 10–2—MAU Interface function

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10.3.1.2 Receive function requirements

The signal from the coaxial trunk cable shall be AC-coupled before reaching the receive DI circuit. The Receive Function shall output a signal onto the DI circuit that complies with the specification for drivers in MAUs (7.5).

At the start of a frame reception from the coaxial cable, no more than 5 bits (5 full bit cells) of information may be received from the coaxial cable and not transmitted onto the receive DI circuit. In addition, it is permissible for the first bit sent over the receive circuit to contain invalid data or timing; however, all successive bits of the frame shall reproduce the incoming signal with no more than the amount of jitter specified below. This implies that the 7th bit cell presents valid data to the PLS. The steady-state propagation delay between the coaxial cable and the receive DI circuit output shall not exceed 1/2 bit cell. There are no logical signal inversions between the coaxial (trunk) cable and the MAU receive circuit.

A MAU meeting this specification shall exhibit edge jitter into the DI pair when terminated in the appropriate test load specified in 7.4.1.1, of no more than 7.0 ns in either direction when it is installed on the distant end of all lengths up to 185 m of the cable specified in 10.5.1.1 through 10.5.2.1.5 terminated at both ends with terminators meeting the impedance requirements of 10.6.2 and driven at one end with pseudorandom Manchester encoded binary data from a data generator that exhibits no more than 1.0 ns of edge jitter in either direction on half bit cells of exactly 1/2 BT and whose output meets the specifications of 10.4.1.3 except that the rise time of the signal shall be 30 ns + 0, – 2 ns. The combination of coaxial cable and MAU receiver introduce no more than 6 ns of edge jitter into the system.

The local Transmit and Receive functions shall operate simultaneously while connected to the medium.

10.3.1.3 Collision Presence function requirements

The signal presented to the CI circuit in the absence of a collision shall be the IDL signal.

The signal presented to the CI circuit during the presence of a collision shall be the CS0 signal encoded as specified in 7.3.1.2. Under no conditions shall the Collision Presence function generate an output when only one MAU is transmitting. Table 10–1 summarizes the allowable conditions under which collisions shall be detected.

a) Collision Assertion
   1) In the case where the MAU has been transmitting for at least 20 bit times, the CS0 signal shall be presented to the CI circuit no more than 17 bit times after the arrival at the MAU on the coaxial cable of a transmission from another MAU. Arrival at the MAU shall be considered to be the time when the transmission of the other MAU causes the dc level on the coaxial cable to become more negative.
   2) In all other cases where the MAU is transmitting, the CS0 signal shall be presented to the CI circuit no more than 29 bit times after the later of start of transmission by the MAU and the arrival of a transmission from another MAU.

b) Collision De-assertion
   1) In the case where a collision has occurred between the MAU and one other MAU, the IDL signal shall be presented to the CI circuit no more than 17 bit times after either the end of transmission by the MAU or the arrival of the end of transmission from the other MAU, whichever occurs earlier. The arrival of the end of transmission from the other MAU shall be the time when the cessation of transmission causes the dc level on the coaxial cable to become less negative.
   2) In the case where a collision has occurred between more than two MAUs, the IDL signal shall be presented to the CI circuit no more than 29 bit times after the arrival of the end of transmission from all but one MAU.

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These timing conditions shall be met for all data bit patterns and combinations of MDI, MAU transmit levels, and MAU locations on the segment.

The Collision Presence function may, in some implementations, be able to sense an abnormal (for example, open) medium.

Table 10–1—Generation of collision presence signal

MAU	Numbers of transmitters		
	<2	=2	>2
Transmitting	N	Y	Y
Not transmitting	N	Y	Y
Y = shall generate SQE message N = shall not generate SQE message			

10.3.1.4 Jabber functional requirements

The MAU shall contain the capability as defined in Figure 10–3 to interrupt a transmission from a DO circuit that exceeds a time duration determined by the MAU. This time duration shall not be less than 20 ms nor more than 150 ms. If the frame being transmitted continues longer than the specified time duration, the MAU shall inhibit transmission and assume its not-transmitting state on the coaxial cable.

When the Transmit function has been positively disabled, the MAU shall then activate the Collision Presence function without introducing an extraneous signal on the trunk coaxial medium. A MAU may reset the Jabber and Collision Presence functions on power reset once the error condition has been cleared. Alternately, a MAU may reset these functions automatically after a period of 0.5 s ± 50%.

10.3.2 MAU interface messages

10.3.2.1 DTE to MAU messages

The following messages can be sent by the DTE Physical Layer (PLS Sublayer) Entities to the MAU Entities:

Message	Circuit	Signal	Meaning
output	DO	CD1, CD0	Output information
output_IDL	DO	IDL	No data to be output

10.3.2.2 MAU to DTE messages

The following messages can be sent by the MAU Physical Layer Entities to the DTE Physical Layer Entities:

Message	Circuit	Signal	Meaning
input	DI	CD1, CD0[a]	Input information
input_idle	DI	IDL	No information to be input
mau_available	CI	IDL	MAU is available for output
SQE	CI	CS0	Error detected by MAU

[a]It is assumed that no retiming of these clocked data signals takes place within the MAU.

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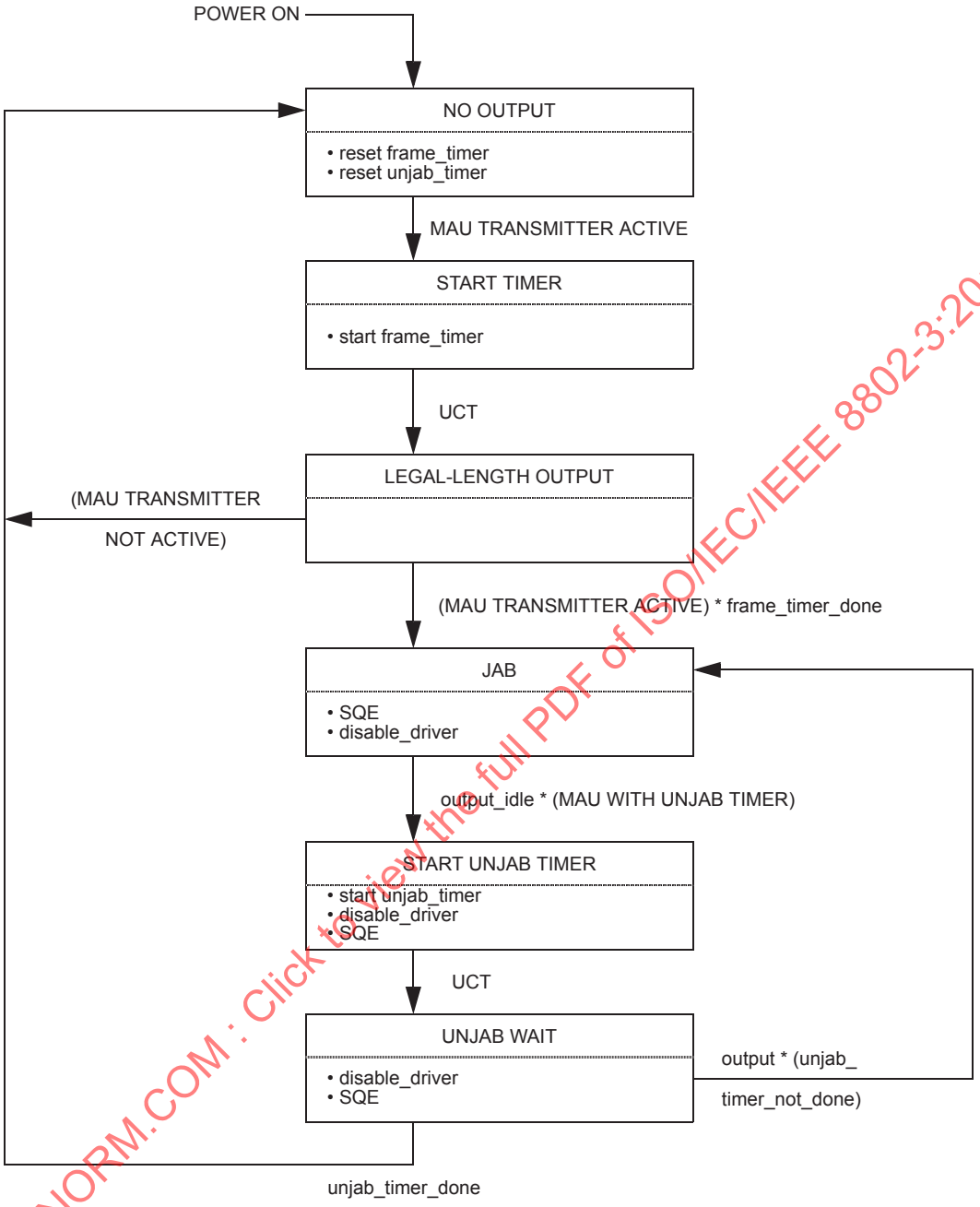

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(Figure 10–3 outputs override those in Figure 10–2.
Optional states: START UNJAB TIMER, UNJAB WAIT.)

Figure 10–3—Jabber function state diagram

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10.3.2.2.1 *input* message

The MAU sends an input message to the DTE Physical Layer when the MAU has a bit of data to send to the DTE. The physical realization of the input message is a CD0 or CD1 sent by the MAU to the DTE on the Data In circuit. The MAU sends CD0 if the input bit is a zero or CD1 if the input bit is a one. No retiming of the CD1 or CD0 signals takes place within the MAU.

10.3.2.2.2 *input_idle* message

The MAU sends an *input_idle* message to the DTE Physical Layer when the MAU does not have data to send to the DTE. The physical realization of the *input_idle* message is the IDL signal sent by the MAU to the DTE on the Data In circuit.

10.3.2.2.3 *mau_available* message

The MAU sends the *mau_available* message to the DTE Physical Layer when the MAU is available for output. The *mau_available* message is always sent by a MAU that is always prepared to output data unless the SQE message should be sent instead. Such a MAU does not require *mau_request* to prepare itself for data output. The physical realization of the *mau_available* message is an IDL signal sent by the MAU to the DTE on the Control In circuit.

10.3.2.2.4 *signal_quality_error* (SQE) message

The SQE message shall be implemented in the following fashion:

a) The SQE message shall not be sent by the MAU if no or only one MAU is transmitting on the trunk coaxial medium.
b) If two or more remote MAUs are transmitting on the trunk coaxial medium, but the MAU connected to the local DTE is not transmitting, then the local MAU shall send the SQE message.
c) When the local MAU is transmitting on the trunk coaxial medium, all occurrences of one or more additional MAUs transmitting shall cause the SQE to be sent by the local MAU to its DTE.
d) When the MAU has completed each output frame it shall perform an SQE test sequence. Note that MAUs associated with repeaters shall not generate the SQE test sequence.
e) When the MAU has inhibited the Transmit function, it shall send the SQE message in accordance with the Jabber function requirements of 10.3.1.4 and Figure 10–3.

The physical realization of the SQE message is the CS0 signal sent by the MAU to the DTE Physical Layers on the Control In circuit.

NOTE—The MAU is required to assert the SQE at the appropriate times whenever the MAU is powered and not just when the DTE Physical Layer is providing data output.

10.3.3 MAU state diagrams

The state diagrams, Figure 10–2 and Figure 10–3, depict the full set of allowed MAU state functions relative to the control circuits of the DTE-MAU interface for MAUs without conditioning requirements. Messages used in these state diagrams are explained as follows:

enable_driver. Activates the path employed during normal operation to cause the MAU transmitter to impress data onto the trunk coaxial medium.

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disable_driver. Deactivates the path employed during normal operation to cause the MAU transmitter to impress data onto the trunk coaxial medium.

no_collision. Signifies that the condition of multiple transmitters simultaneously active on the trunk coaxial medium does not exist.

collision. Signifies that the condition of multiple transmitters simultaneously active on the trunk coaxial medium does exist.

frame_timer. Measures the time the MAU transmits on the trunk coaxial cable.

test_timer. Measures the length of the SQE Test.

unjab_timer. Measures the amount of time the MAU has been in Jab mode.

wait_timer. Measures the time between output idle and the start of the SQE Test.

10.4 MAU–medium electrical characteristics

10.4.1 MAU-to-coaxial cable interface

The following subclauses describe the interface between the MAU and the coaxial cable. Negative current is defined as current into the MAU (out of the center conductor of the cable).

10.4.1.1 Input impedance

The shunt capacitance presented to the coaxial cable by the MAU circuitry (not including the means of attachment to the coaxial cable) is recommended to be not greater than 6 pF. The magnitude of the reflection from a MAU plus the cable connection specified in 10.6.3 shall not be more than that produced by an 8 pF capacitance when measured by both a 25 ns rise time and 25 ns fall time waveform. The resistance presented to the coaxial cable shall be greater than 100 kΩ.

These conditions shall be met in both the power-off and power-on, not-transmitting states.

10.4.1.2 Bias current

The MAU must draw (from the cable) between +2 μA and –25 μA in the power-off and the power-on, not-transmitting states.

10.4.1.3 Coaxial cable signaling levels

The signal on the coaxial cable due to a single MAU as measured at the MAU's transmitter output is composed of an ac component and an offset component. Expressed in terms of current immediately adjacent to the MAU connection (just prior to splitting the current flow in each direction), the signal has an offset component (average dc current including the effects of timing distortion) of from –37 mA min to –45 mA max and an ac component from ± 28 mA up to the offset value.

The current drive limit shall be met even in the presence of one other MAU transmitter. The MAU shall be capable of generating at least 2.2 V of average dc level on the coaxial cable in the presence of two or more other MAUs transmitting concurrently. The MAU shall, in addition, sink no more than ± 250 μA when the voltage on the center conductor of the cable drops to –10 V when the MAU is transmitting.

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The actual current measured at a given point on the cable is a function of the transmitted current and the cable loss to the point of measurement. Negative current is defined as current out of the center conductor of the cable (into the MAU). The 10 – 90% rise/fall times shall be 25 ns ± 5 ns at 10 Mb/s. The rise and fall times must match within 2 ns. Figure 10–4 shows typical waveforms present on the cable. Harmonic content generated from the 10 MHz fundamental periodic input shall meet the following requirements:

Second and Third Harmonics: At least 20 dB below fundamental
Fourth and Fifth Harmonics: At least 30 dB below fundamental
Sixth and Seventh Harmonics: At least 40 dB below fundamental
All Higher Harmonics: At least 50 dB below fundamental

NOTE—Even harmonics are typically much lower.

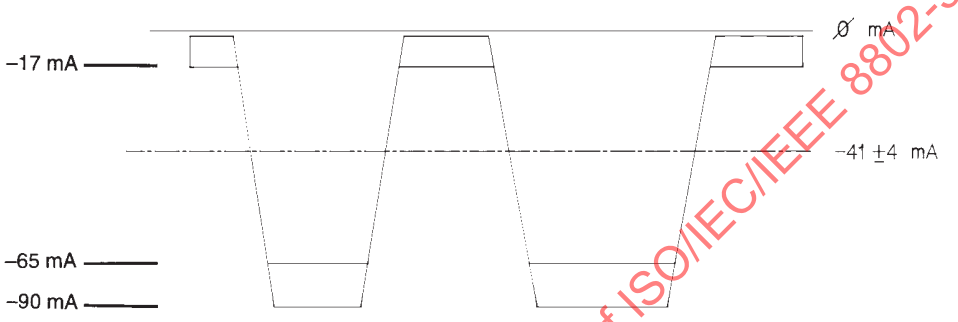
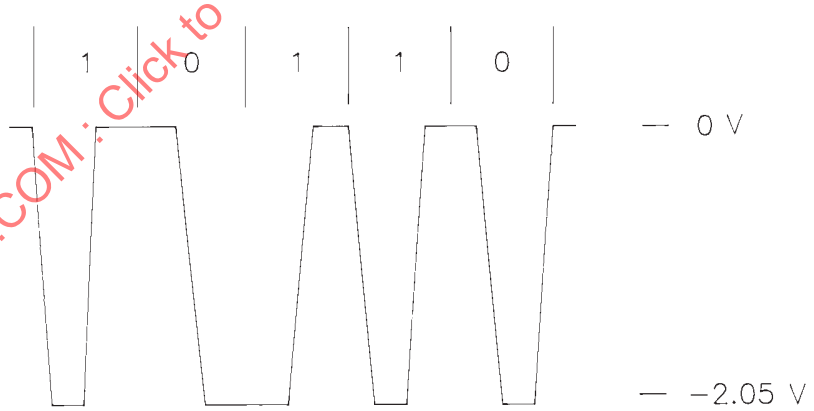


Figure 10–4—Driver current signal levels

The above specifications concerning harmonics cannot be satisfied by a square wave with a single-pole filter, nor can they be satisfied by an output waveform generator employing linear ramps without additional waveshaping. The signals, as generated from the encoder within PLS, shall appear on the coaxial cable without any inversions (see Figure 10–5).



NOTE: (1) Voltages given are nominal, for a single transmitter.
(2) Rise time is 25 ns nominal at 10 Mb/s rate.
(3) Voltages are measured on terminated coaxial cable adjacent to transmitting MAU.
(4) Manchester coding.

Figure 10–5—Coaxial trunk cable signal waveform

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10.4.1.4 Transmit output levels symmetry

Signals received from the DO circuit must be transmitted onto the coaxial cable with the characteristics specified in 10.4.1.3. Since the coaxial cable proceeds in two directions from the MAU, the current into the MAU is nominally twice the current measured on the coaxial cable.

The output signal of a MAU meeting this specification shall exhibit edge jitter of no more than 2.5 ns into a 25 Ω ± 1% resistor substituted for the connection to the coaxial cable when the DO circuit into the MAU is driven with pseudo-random Manchester encoded binary data from a data generator that exhibits no more than 0.5 ns of edge jitter on half bit cells of exactly 1/2 BT, whose output meets the specifications of 7.4.1.1 through 7.4.1.5. The above specified component shall not introduce more than 2 ns of edge jitter into the system.

The MAU shall not transmit a negative going edge after cessation of the CD output data stream or before the first valid edge of the next frame.

10.4.1.5 Collision detect thresholds

For receive mode collision detection the MAU shall have its collision detection threshold set in the range –1404 mV and –1581 mV. These limits take account of up to 8% collision detect filter impulse response. If a specific filter implementation has a higher value of impulse response, the lower threshold limit of –1404 mV is required to be replaced by –1300 mV × [1 + impulse response].

Receive mode collision detection indicates that a nontransmitting MAU has the capability to detect collisions when two or more MAUs are transmitting simultaneously.

All MAUs are required to implement receive mode collision detection.

NOTE—The above threshold limits are measured at the coaxial cable center conductor with respect to the shield at the MAU connector. The MAU designer must take into account circuit offsets, low-frequency noise (for example, 50 Hz, 60 Hz), and 5 MHz ripple at the filter output in determining the actual internal threshold value and its tolerance.

10.4.2 MAU electrical characteristics

10.4.2.1 Electrical isolation

The MAU must provide isolation between the DTE Physical Layer circuits and the coaxial trunk cable. The isolation impedance measured between any conductor in the DTE Physical Layer circuitry and either the center conductor or shield of the coaxial cable shall be greater than 250 kΩ at 50 Hz, 60 Hz. In addition, the isolation impedance between the DTE ground and the coaxial cable shield shall be less than 15 Ω between 3 MHz and 30 MHz. The isolation means provided shall withstand 500 V ac, rms for one minute.

10.4.2.2 Power consumption

The current drawn by the MAU shall not exceed 0.5 A if powered by the AUI source. The MAU shall be capable of operating from all permissible voltage sources as supplied by the DTE through the resistance of all permissible AUI cables. The MAU shall not disrupt the trunk coaxial medium should the DTE power source fall below the minimum operational level under abnormal MAU load conditions.

The MAU shall be labeled externally to identify the maximum value of current required by the device. This requirement only applies to MAUs that are external to DTEs.

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10.4.2.3 Reliability

The MAU shall be designed to provide an MTBF of at least 100 000 hours of continuous operation without causing communication failure among other stations attached to the local network medium. Component failures within the MAU electronics should not impede the communication among other MAUs on the coaxial cable. Connectors and other passive components comprising the means of connecting the MAU to the coaxial cable shall be designed to minimize the probability of total network failure.

It should be noted that a fault condition that causes a MAU to draw in excess of 2 mA from the coaxial cable may cause communication failure among other stations.

10.4.3 MAU–DTE electrical characteristics

If the AUI is exposed, the electrical characteristics for the driver and receiver components connected between the DTE Physical Layer circuitry and the MAU shall be identical with those as specified in Clause 7 of this standard.

10.5 Characteristics of coaxial cable system

The trunk cable is of constant impedance, coaxial construction. It is terminated at each of the two ends by a terminator (see 10.6.2), and provides the transmission path for connection of MAU devices. Coaxial cable connectors are used to make the connection from the cable to the terminators and between cable sections. The cable has various electrical and mechanical requirements that shall be met to ensure proper operation.

10.5.1 Coaxial cable electrical parameters

The parameters specified in 10.5.1 are met by cable types RG 58 A/U or RG 58 C/U.

10.5.1.1 Characteristic impedance

The average characteristic cable impedance shall be 50 ± 2 Ω. Periodic variations in impedance along a single piece of cable may be up to ±3 Ω sinusoidal, centered around the average value, with a period of less than 2 m.

10.5.1.2 Attenuation

The attenuation of a 185 m cable segment shall not exceed 8.5 dB measured at 10 MHz, or 6.0 dB measured at 5 MHz.

10.5.1.3 Velocity of propagation

The minimum required velocity of propagation is 0.65 c.

10.5.1.4 Edge jitter; entire segment without DTEs attached

A coaxial cable segment meeting this specification shall exhibit edge jitter of no more than 8.0 ns in either direction at the receiving end when 185 m of the cable is terminated at both ends with terminators meeting the impedance requirements of 10.6.2 and is driven at one end with pseudorandom Manchester encoded binary data from a data generator that exhibits no more than 1.0 ns of edge jitter in either direction on half bit cells of exactly $^1/_2$ BT and whose output meets the specifications of 10.4.1.3, except that the rise time of the signal must be 30 ns + 0, – 2 ns, and no offset component in the output current is required. This test shall be conducted in a noise-free environment. The above specified component is not to introduce more than 7 ns of edge jitter into the system.

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10.5.1.5 Transfer impedance

The coaxial cable medium shall provide sufficient shielding capability to minimize its susceptibility to external noise and also to minimize the generation of interference by the medium and related signals. While the cable construction is not mandated, it is necessary to indicate a measure of performance expected from the cable component. A cable's EMC performance is determined, to a large extent, by the transfer impedance value of the cable.

The transfer impedance of the cable shall not exceed the values shown in Figure 10–6 as a function of frequency.

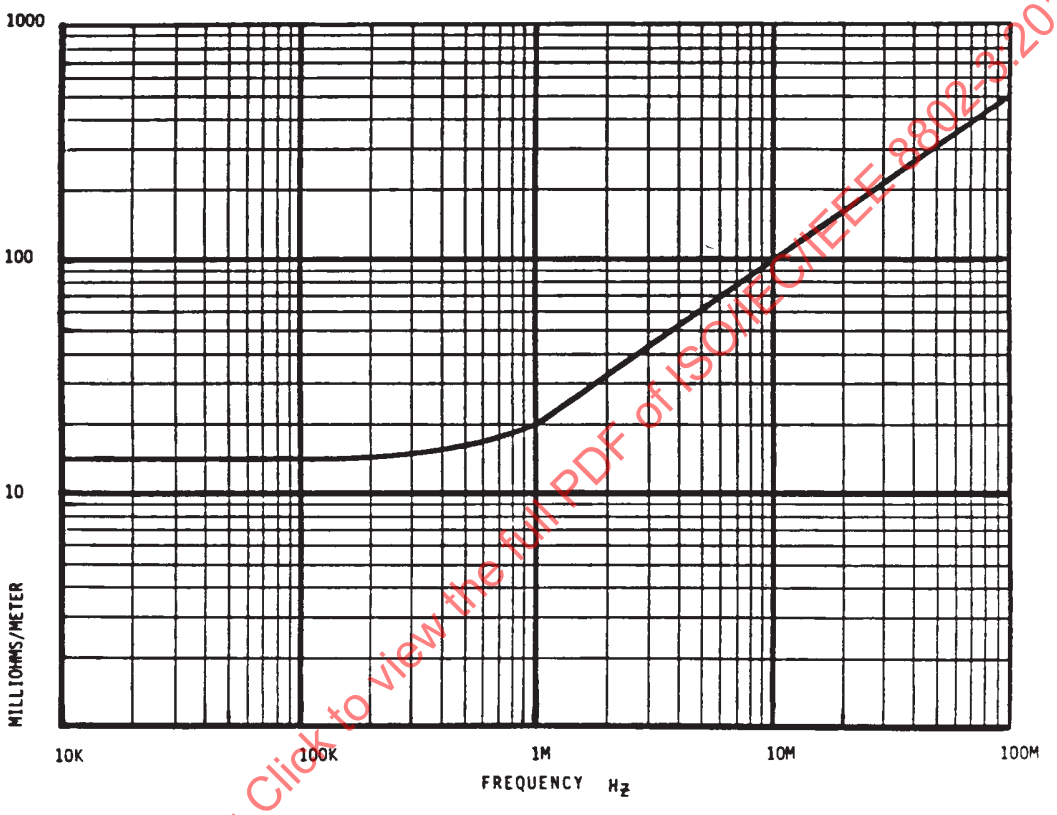

Figure 10–6—Maximum coaxial cable transfer impedance

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10.5.1.6 Cable dc loop resistance

The sum of the center conductor resistance plus the shield resistance measured at 20 °C shall not exceed 50 mΩ/m.

10.5.2 Coaxial cable physical parameters

10.5.2.1 Mechanical requirements

The cable used should be suitable for routing in various environments, including but not limited to, dropped ceilings, raised floors, and cable troughs as well as throughout open floor space. The jacket shall provide insulation between the cable sheath and any building structural metal. Also, the cable shall be capable of accepting coaxial cable connectors, described in 10.6. The cable shall conform to the following requirements.

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10.5.2.1.1 General construction

a) The coaxial cable shall consist of a center conductor, dielectric, shield system, and overall insulating jacket.
b) The coaxial cable shall be sufficiently flexible to support a bend radius of 5 cm.

10.5.2.1.2 Center conductor

The center conductor shall be stranded, tinned copper with an overall diameter of 0.89 mm ± 0.05 mm.

10.5.2.1.3 Dielectric material

The dielectric may be of any type, provided that the conditions of 10.5.1.2 and 10.5.1.3 are met; however, a solid dielectric is preferred.

10.5.2.1.4 Shielding system

The shielding system may contain both braid and foil elements sufficient to meet the transfer impedance of 10.5.1.5 and the EMC specifications of 10.8.2.

The inside diameter of the shielding system shall be 2.95 mm ± 0.15 mm.

The shielding system shall be greater than 95% coverage. The use of tinned copper braid is recommended to meet the contact resistance and shielding requirements.

10.5.2.1.5 Overall jacket

a) Any one of several jacket materials shall be used provided the specifications of 10.5.1 and 10.5.2 are met.
b) Either of two jacket dimensions may be used for the two broad classes of materials provided the specification of 10.5.2.1.1 are met:
    1) Polyvinyl chloride (for example, PVC) or equivalent having an OD of 4.9 mm ± 0.3 mm.
    2) Fluoropolymer (for example, FEP, ECTFE) or equivalent having an OD of 4.8 mm ± 0.3 mm.

The cable shall meet applicable flammability and smoke criteria to meet the local and national codes for the installed environment (see 10.8.3).

Different types of cable sections (for example, polyvinyl chloride and fluoropolymer dielectric) may be interconnected, while meeting the sectioning requirements of 10.7.2.1.

10.5.2.2 Jacket marking

It is recommended that the cable jacket be marked with manufacturer and type at a nominal frequency of at least once per meter along the cable.

10.5.3 Total segment dc loop resistance

The sum of the center conductor, connectors, and shield resistance shall not exceed 10 Ω total per segment. Each in-line connector pair or MAU shall contribute no more than 10 mΩ.

As a trunk coaxial cable segment consists of several cable sections, all connectors and internal resistance of the shield and center conductor shall be included in the loop resistance measurement.

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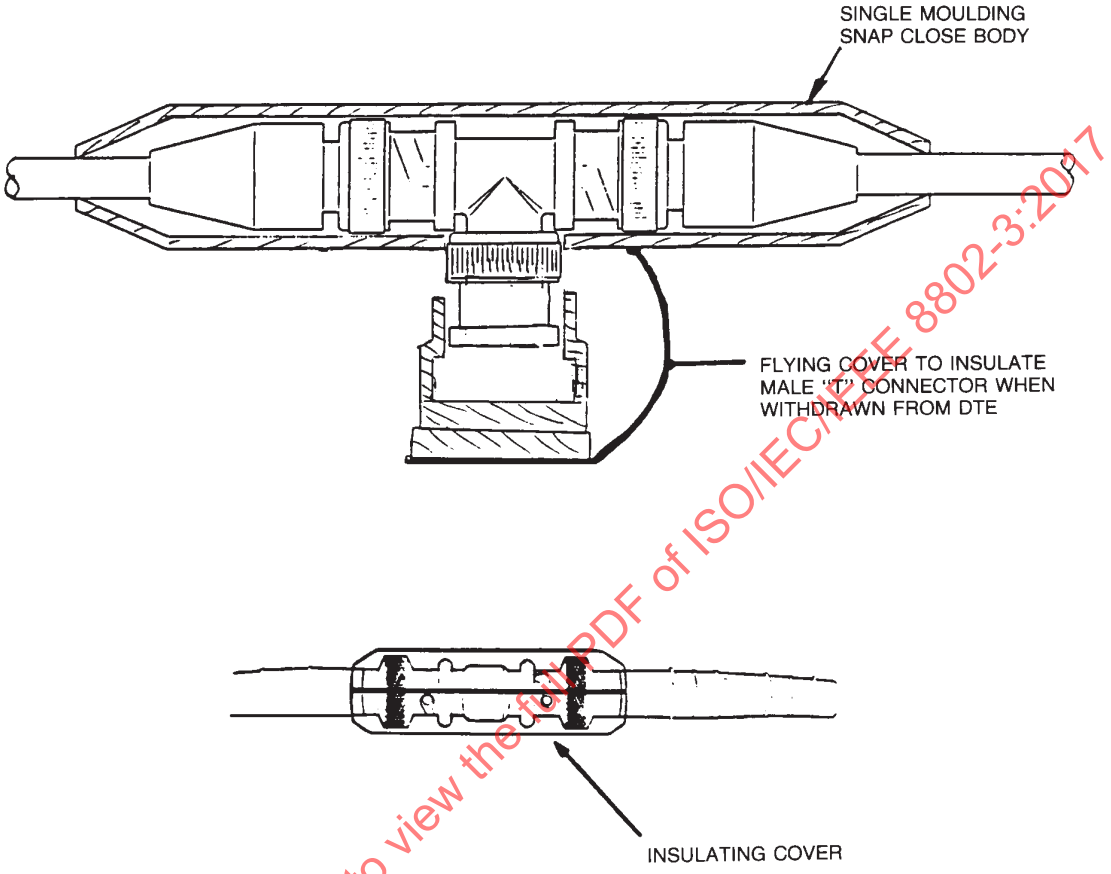
10.6 Coaxial trunk cable connectors

The trunk coaxial medium requires termination and is partitioned into sections. Devices to be attached to the medium require a means of connection to the medium. This means is provided by a BNC "T" adapter, as shown in Figure 10–7.



(Tutorial only and not part of the standard.)

Figure 10–7—Examples of insulated connector cover

The BNC connectors shall be of the 50 Ω constant impedance type. High-quality versions of these connectors (per IEC 169-8) are recommended in order to meet dc loop resistance and reliability considerations. All of the coaxial connectors shall follow the requirements as defined in 10.6.3.

10.6.1 In-line coaxial extension connector

All coaxial cables shall be terminated with BNC plug connectors. A means shall be provided to ensure that the connector shell (which connects to the cable sheath) does not make contact with any building metal (at ground potential) or other unintended conductor.

An insulating sleeve or boot slipped over the connector at installation time is suitable.

In-line coaxial extensions shall be made with BNC receptacle-to-receptacle connectors joined together to form one "barrel." An insulating sleeve or boot shall also be provided with each barrel assembly.

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10.6.2 Coaxial cable terminator

Coaxial cable terminators are used to provide a termination impedance for the cable equal in value to its characteristic impedance, thereby minimizing reflection from the ends of the cables. Terminators shall be packaged within a male or female connector. The termination impedance shall be 50 Ω ± 1% measured from 0 MHz to 20 MHz, with the magnitude of the phase angle of the impedance not to exceed 5°. The terminator power rating shall be 0.5 W or greater. A means of insulation shall be provided with each terminator.

10.6.3 MAU-to-coaxial cable connection

A BNC "T" (plug, receptacle, plug) adaptor provides a means of attaching a MAU to the coaxial cable. The connection shall not disturb the transmission line characteristics of the cable significantly; it shall present a low shunt capacitance, and therefore a negligibly short stub length. This is facilitated by the MAU being located as close to its cable connection as possible; the MAU and connector are normally considered to be one assembly. Long (greater than 4 cm) connections between the coaxial cable and the input of the MAU jeopardize this objective.

Overall system performance is dependent largely on the MAU-to-coaxial cable connection being of low shunt capacitance.

The design of the connection shall meet the electrical requirements contained in 10.4.1.1 and the reliability specified in 10.4.2.3. The use of BNC "T" adaptors and connectors satisfies these requirements. Figure 10–7 shows a MAU-to-coaxial cable attachment.

A means shall be provided to ensure that the connector assembly (that is, BNC "T" plus male connectors) does not make contact with any building metalwork (at ground potential) or any other unintended conductors. An insulating cover should therefore be applied after connection. A possible design is depicted in Figure 10–7. The insulating cover should have these characteristics:

a) It should guard against accidental grounding of the connector assembly.
b) It should allow ease of attachment and detachment of an assembled "T" connector to the MAU without necessitating the removal of section cable connectors (that is, segment integrity is maintained).
c) It should be a simple moulding that attaches firmly to a connector assembly.

10.7 System considerations

10.7.1 Transmission system model

The maximum configuration for the physical transmission system is as follows:

a) A trunk coaxial cable, terminated in its characteristic impedance at each end, constitutes a coaxial cable segment. A coaxial cable segment may contain a maximum of 185 m of coaxial cable and a maximum of 30 MAUs. The propagation velocity of the coaxial cable is assumed to be 0.65 c minimum ($c = 3 \times 10^8$ m/s). The maximum end-to-end propagation delay for a coaxial cable segment is 950 ns.
b) The maximum transmission path permitted between any two MAUs is limited by the number of repeater sets that can be connected in series.

NOTE—Care should be taken to ensure that the safety requirements are met when extending the trunk cable by the use of repeaters (see 10.7.2.4.1).

c) The repeater unit specified in Clause 9 provides the means for connecting 10 Mb/s baseband segments into a CSMA/CD network. The proper operation of a CSMA/CD network requires network

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size to be limited to control round-trip propagation delay to meet the requirements of 4.2.3.2.3 and 4.4.2, and the number of repeaters between any two DTEs to be limited in order to limit the shrinkage of the interpacket gap as it travels through the network. Configuration rules, which ensure that these limits are not exceeded, are given in Clause 13.

NOTE—Care should be taken to ensure that the safety requirements are met when extending the trunk cable by the use of repeaters (see 10.7.2.4.1)

Figure 10–8 and Figure 10–9 show minimal single segment and repeatered transmission systems. For specifications on the boundary conditions on topologies, see Clause 13.

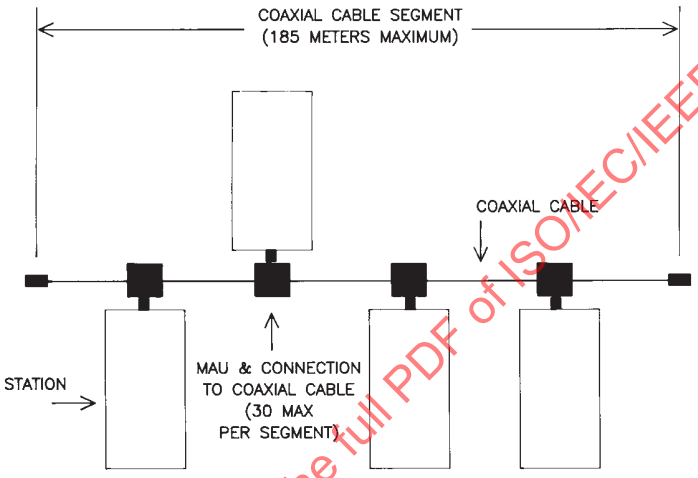

Figure 10–8—The minimum system configuration

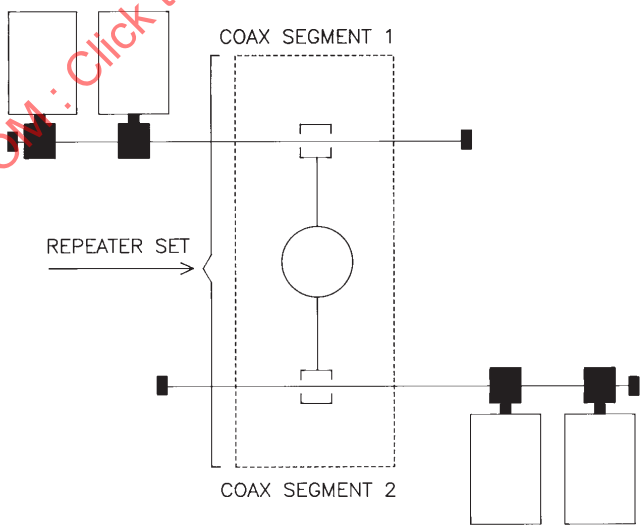

Figure 10–9—The minimum system configuration requiring a repeater set

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10.7.2 Transmission system requirements

10.7.2.1 Cable sectioning

The 185 m maximum length coaxial cable segment will be made from a number of cable sections. As the variation on cable characteristic impedance is ±2 Ω on 50 Ω, a possible worst-case reflection of 4% may result from the mismatch between two adjacent cable sections. The MAU will add to this reflection by the introduction of its noninfinite bridging impedance.

The accumulation of this reflection can be minimized by observing a minimum distance between MAUs (and between cable sections). In order to maintain reflections at an acceptable level, the minimum length cable section shall be 0.5 m.

10.7.2.2 MAU placement

MAU components and their associated connections to the cable cause signal reflections due to their noninfinite bridging impedance. While this impedance must be implemented as specified in 10.6, the placement of MAUs along the coaxial cable must also be controlled to ensure that reflections from the MAU do not accumulate to a significant degree.

Coaxial cable sections as specified in 10.7.2.1 shall be used to connect MAUs. This guarantees a minimum spacing between MAUs of 0.5 m.

The total number of MAUs on a cable segment shall not exceed 30.

10.7.2.3 Trunk cable system earthing

The shield conductor of each coaxial cable segment may make electrical contact with an effective earth reference[34] at one point and shall not make electrical contact with earth elsewhere on such objects as building structural metal, ducting, plumbing fixture, or other unintended conductor. Insulators should be used to cover any coaxial connectors used to join cable sections and terminators, to ensure that this requirement is met. A sleeve or boot attached at installation time is acceptable. (See 10.6.3.)

10.7.2.4 Static discharge path

A static discharge path shall be provided. The shield of the trunk coaxial cable is required to be connected to each DTE earth (within the DTE) via a 1 MΩ, 0.25 W resistor that has a voltage rating of at least 750 V dc.

10.7.2.4.1 Installation environment

This specification is intended for networks in use within a single building and within an area served by a single low-voltage power distribution system. Applications requiring interplant connections via external (outdoors) means may require special considerations. Repeaters and nonconducting IRL components may provide the means to satisfy these isolation requirements.

NOTE—The reader is advised that devices should not be operated at significantly different frame potentials. The 10BASE2 connection system may not be capable of handling excessive earth currents.

[34]See local or national regulations for guidance on these matters and reference [B53].

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10.8 Environmental specifications

10.8.1 Safety requirements

The designer should consult relevant local and national safety regulations to assure compliance with the appropriate standards (for example, see Annex A for reference material).

10.8.1.1 Installations

If the trunk coaxial cable is to be installed in close proximity to electrical power cables, then installation practice according to local and national code shall be followed (see Annex A for resource material).

10.8.1.2 Earthing

Where earthing is mandated by locally or nationally prescribed codes of practice, the shield of the trunk coaxial cable shall be effectively earthed at only one point along the length of the cable. Effectively earthed means permanently connected to earth through an earth connection of sufficiently low impedance and having sufficient ampacity to prevent the building up of voltages that may result in undue hazard to connected equipment or to persons.

10.8.2 Electromagnetic environment

10.8.2.1 Susceptibility levels

Sources of interference from the environment include electromagnetic fields, electrostatic discharge, transient voltages between earth connections, etc.

Several sources of interference will contribute to voltage buildup between the coaxial cable and the earth connection of a DTE.

The physical channel hardware shall meet its specifications when operating in either of the following conditions:

a) Ambient plane wave field of 1 V/m from 10 kHz through 1 GHz.

   NOTE—Levels typically >1 km from broadcast stations.

b) Interference source voltage of 15.10 V peak 10 MHz sine wave with a 50 Ω source resistance applied between the coaxial cable shield and the DTE ground connection.

MAUs meeting this standard should provide adequate RF ground return (coaxial cable shield to DTE ground) to satisfy the referenced EMC specifications.

10.8.2.2 Emission levels

The physical MAU and trunk cable system shall comply with local and national regulations (see Annex A for resource material).

10.8.3 Regulatory requirements

The MAU and medium should consider IEC 60950 in addition to local and national regulations. See IEC 60950 and [B53].

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11. Broadband medium attachment unit and broadband medium specifications, type 10BROAD36

NOTE—This MAU is not recommended for new installations. Since September 2003, maintenance changes are no longer being considered for this clause.

11.1 Scope

11.1.1 Overview

This clause defines the functional, electrical, and mechanical characteristics of the Broadband Medium Attachment Unit (MAU) and the specific single- and dual-cable broadband media for use with LANs. The headend frequency translator for single-cable broadband systems is also defined. The relationship of this clause to all of the ISO/IEC LAN International Standards is shown in Figure 11–1. Repeaters as defined in Clause 9 are not relevant for 10BROAD36.

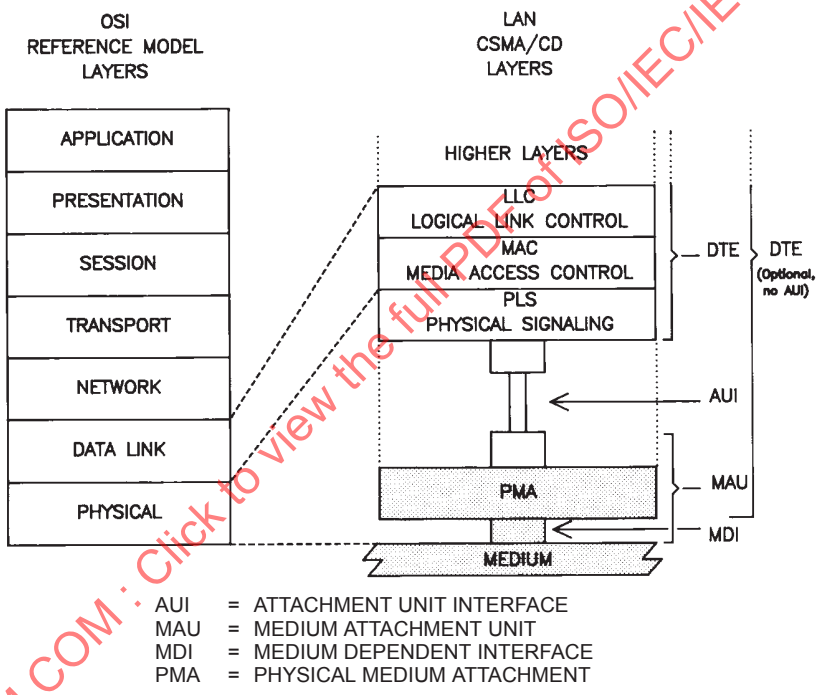

Figure 11–1—Physical Layer partitioning, relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model

The purpose of the MAU is to provide a means of attaching devices to a broadband local network medium. The medium comprises CATV-type cable, taps, connectors, and amplifiers. A coaxial broadband system permits the assignment of different frequency bands to multiple applications. For example, a band in the spectrum can be utilized by LANs while other bands are used by point-to-point or multidrop links, television, or audio signals.

The physical tap is a passive directional device such that the MAU transmission is directed toward the headend location (reverse direction). On a single-cable system the transmission from the MAU is at a carrier fre-

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quency f1. A frequency translator (or remodulator) located at the headend up-converts to a carrier frequency f2, which is sent in the forward direction to the taps (receiver inputs). On a dual-cable system the transmit and receive carrier frequencies are identical (both f1) and the MAU connects to the medium via two taps, one on the receive cable and the other on the transmit cable. The transmit and receive cables are connected to each other at the headend location. Figure 11–2 shows broadband single- and dual-cable systems.

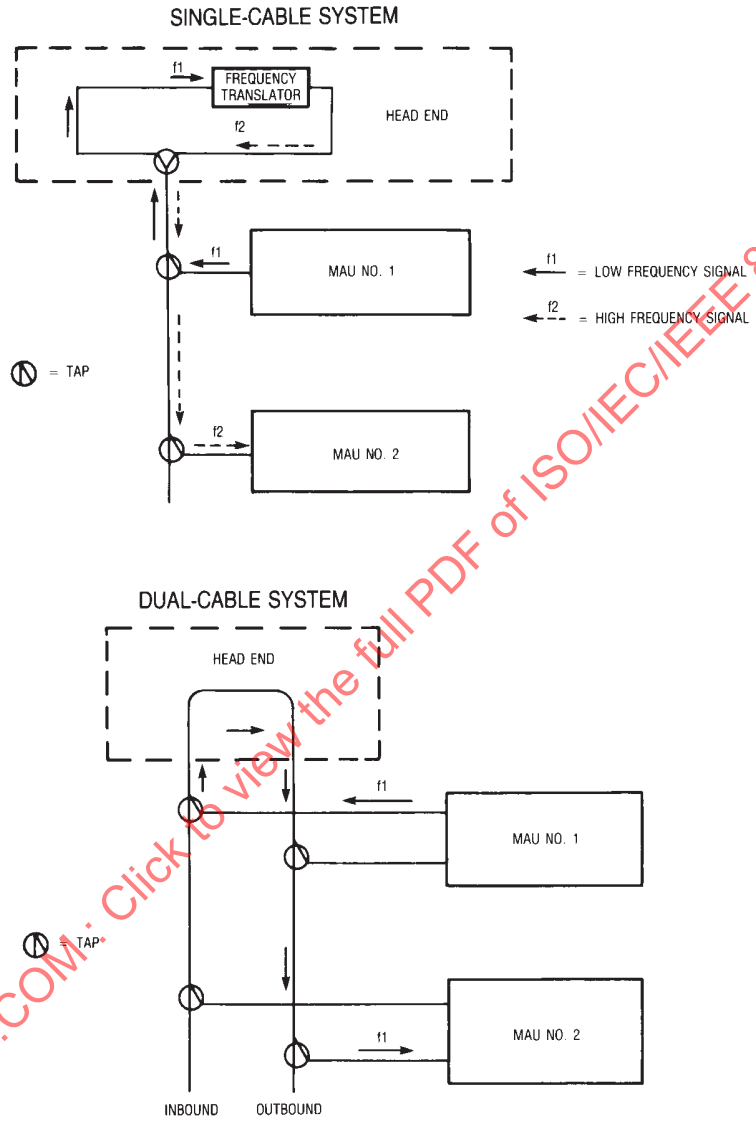

Figure 11–2—Broadband cable systems

The broadband MAU operates by accepting data from the attached Data Termination Equipment (DTE) and transmitting a modulated radio frequency (RF) data signal in a data band on the broadband coaxial cable system. All MAUs attached to the cable system receive and demodulate this RF signal and recover the DTE data. The broadband MAU emulates a baseband MAU except for delay between transmission and reception, which is inherent in the broadband cable system.

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A transmitting MAU logically compares the beginning of the received data with the data transmitted. Any difference between them, which may be due to errors caused by colliding transmissions, or reception of an earlier transmission from another MAU, or a bit error on the channel, is interpreted as a collision.

When a collision is recognized, the MAU stops transmission in the data band and begins transmission of an RF collision enforcement (CE) signal in a separate CE band adjacent to the data band. The CE signal is detected by all MAUs and informs them that a collision has occurred. All MAUs signal to their attached Medium Access Controllers (MACs) the presence of the collision. The transmitting MACs then begin the collision handling process.

Collision enforcement is necessary because RF data signals from different MAUs on the broadband cable system may be received at different power levels. During a collision between RF data signals at different levels, the MAU with the higher received power level may see no errors in the detected data stream. However, the MAU with the lower RF signal will see a difference between transmitted and received data; this MAU transmits the CE signal to force recognition of the collision by all transmitting MAUs.

11.1.2 Definitions

See 1.4.

11.1.3 MAU and medium objectives

This subclause states the broad objectives and assumptions underlying the specifications defined throughout this clause of the standard.

a) Provide the physical means for communication among local network Data Link Entities using a broadband coaxial medium.
b) Provide a broadband Medium Attachment Unit (MAU) that is compatible at the Attachment Unit Interface (AUI) with DTEs used on a baseband medium.
c) Provide a broadband MAU that emulates the baseband MAU except for the signal delay from Circuit DO to Circuit DI.
d) Provide a broadband MAU that detects collisions within the timing constraints specified in the baseband case.
e) Provide a broadband network diameter no less than 2800 m.
f) Provide a broadband Physical Layer that ensures that no MAU is allowed to capture the medium during a collision due to signal level advantage (that is, ensures fairness of the Physical Layer).
g) Provide a broadband MAU that detects collisions in both receive and transmit modes.
h) Provide a broadband MAU that requires a transmission bandwidth no wider than 18 MHz.
i) Define a physical interface that can be implemented independently among different manufacturers of hardware and achieve the intended level of compatibility when interconnected in a common broadband LAN.
j) Provide a communication channel capable of high bandwidth and low bit error ratio performance. The resultant mean bit error ratio at the Physical Layer service interface should be less than one part in 10^8 (on the order of one part in 10^9 at the link level) in a worst-case signal-to-noise ratio of 26 dB.
k) Provide a broadband medium Physical Layer that allows for implementation in both dual- and single-cable systems.
l) Provide for ease of installation and service.
m) Provide a communication channel that coexists with other channels on the same physical medium.

It is not an objective of this broadband MAU to allow its use with the baseband repeater defined in Clause 9 of this standard.

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11.1.4 Compatibility considerations

All implementations of the broadband coaxial system shall be compatible at the Medium Dependent Interface (MDI). This standard provides medium specifications for the interconnection of all MAU devices. The medium itself, the functional capability of the MAU and the AU Interface are defined to provide the highest possible level of compatibility among devices designed by different manufacturers. Designers are free to implement circuitry within the MAU in an application-dependent manner provided the MDI and AUI specifications are satisfied. Subsystems based on this specification may be implemented in several different ways provided compatibility at the medium is maintained. It is possible, for example, to design an integrated station where the MAU is contained within a physical DTE system component, thereby eliminating the AUI cable.

11.1.5 Relationship to PLS and AUI

The broadband MAU and cable system specifications are closely related to Clause 7 (Physical Signaling and Attachment Unit Interface Specifications). The design of a physical MAU component requires the use of both this clause and the PLS and AUI specifications in Clause 7.

11.1.6 Mode of operation

In its normal mode of operation, the MAU functions as a direct connection between the DTE and the broadband medium. Data from the DTE are transmitted onto the broadband coaxial system and all inband data on the coaxial cable system is received by the DTE. This mode is the mode of operation for the intended message traffic between stations. Other operating modes, such as a loopback mode or a monitor mode, may be provided but are not defined by this standard.

11.2 MAU functional specifications

11.2.1 MAU functional requirements

The MAU component provides the means by which signals on the physically separate AUI signal circuits to and from the DTE and their associated interlayer messages are coupled to the broadband coaxial medium. To achieve this basic objective, the MAU component contains the following capabilities to handle message flow between the DTE and the broadband medium:

a) *Transmit function.* The ability to transmit serial data bit streams originating at the local DTE in a band-limited modulated RF carrier form, to one or more remote DTEs on the same network.
b) *Receive function.* The ability to receive a modulated RF data signal in the band of interest from the broadband coaxial medium and demodulate it into a serial bit stream.
c) *Collision Presence function.* The ability to detect the presence of two or more stations' concurrent transmissions.
d) *Jabber function.* The ability of the MAU itself to interrupt the Transmit function and inhibit an abnormally long output data stream.

11.2.1.1 Transmit function requirements

The Transmit function shall include the following capabilities:

a) Receive Manchester encoded data sent by the local DTE to the attached MAU on Circuit DO (transmit data pair).
b) Decode the Manchester encoded data received on Circuit DO to produce NRZ (Non-Return to Zero) data and a recovered clock signal.

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c) Scramble the NRZ data using a CCITT V.29-type scrambler with seed changed on each transmitted packet.
d) Transform the incoming bits (prior to modulation) to provide an unscrambled alternating zero-one pattern terminated by an Unscrambled Mode Delimiter (UMD); scramble the remainder of the incoming preamble, Start Frame Delimiter (SFD), and data frame; and append an unscrambled postamble (Broadband End of Frame Delimiter [BEOFD]).
e) Differentially encode the packet generated above.
f) Produce a bandlimited, double sideband suppressed carrier, binary PSK modulated RF signal representing the above generated differentially encoded packet.
g) Drive the coaxial cable with the modulated RF signal.

Figure 11–3 functionally represents these capabilities. The order of the functional blocks may be altered, provided that the result is the same.

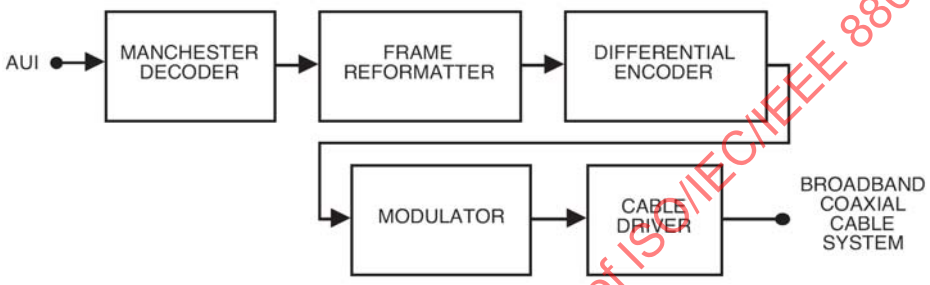

Figure 11–3—Transmit function requirements

11.2.1.2 Receive function requirements

The receive function shall include the following:

a) Receive the differentially encoded binary PSK modulated RF signal from the broadband coaxial medium.
b) Receive the data band RF signals and reject signals in bands other than the data band (rejection of signals in the adjacent collision enforcement band is optional).
c) Demodulate and differentially decode the incoming RF data signal from the coaxial medium to provide a receive bit stream that represents the scrambled bit stream at the transmitter.
d) Descramble the receive bit stream using a self-synchronizing descrambler.
e) Manchester encode the descrambled bit stream.
f) Send to the DTE, using Circuit DI (receive data pair), an additional, locally-generated, Manchester encoded preamble equal to the number of preamble bits lost in the receive data path (plus or minus one bit), followed by the Manchester encoded bit stream. No more than 6 preamble bits may be lost from the preamble presented to Circuit DO at the transmitting MAU.
g) Detect end of frame, using the postamble (BEOFD), and ensure that no extraneous bits are sent to the DTE on Circuit DI.
h) Receive signals in the collision enforcement band and reject signals in the data band and all other bands on the broadband medium.

11.2.1.3 Collision Detection function requirements

The MAU shall perform the following functions to meet the collision detection requirements:

a) Store the scrambled bits (not differentially encoded) in the transmit section through to the last bit in the source address.

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b) Detect the UMD in the transmit and receive paths.
c) Compare received scrambled bits after the received UMD with transmitted scrambled bits after the transmit UMD through to the last bit in the source address.
d) A Receive UMD Timer function shall be performed by the MAU. The timer shall be as long as the time required from initial detection of RF data signal presence to detection of a UMD in a normally received (no collision) packet.
e) Enter a LOCAL COLLISION DETection state if one of the following occurs:
   1) A bit error is found in the bit compare process through the last bit in the source address.
   2) The Receive UMD Timer expires before a UMD is detected in the received bit stream.
   3) The MAU receives the *output* (that is, transmit) signal from the AUI AFTER having received an RF signal from the coaxial cable.
f) Upon entering the LOCAL COLLISION DET state, cease transmission in the data band and commence transmission in the collision enforcement band for as long as the DTE continues to send data to the MAU.
g) Upon entering the LOCAL COLLISION DET state send the *signal_quality_error* (SQE) message on Circuit CI (collision presence pair) using the CS0 signal for as long as RF signals are detected on the broadband coaxial medium in either the data or collision enforcement bands.
h) Detect power in the collision enforcement band and send the SQE message on Circuit CI using the CS0 signal. Send the SQE message for as long as energy is detected in the collision enforcement band.
i) Ensure that during collisions, due to phase cancellations of the colliding carriers, Circuit DI does not become inactive before Circuit CI becomes active.
j) Test the collision detection circuitry following every transmission that does not encounter a collision. This test consists of transmitting a burst of collision enforcement RF signal after the end of the postamble transmission and detecting this burst on the receive side. If the burst is detected, the CS0 (BR) signal is sent on Circuit CI of the transmitting MAU.

11.2.1.3.1 Collision enforcement transmitter requirements

The MAU shall provide a collision enforcement (CE) transmitter that generates a constant amplitude RF signal in the CE band at the same power level as the data signal postamble.

11.2.1.3.2 Collision enforcement detection requirements

The MAU shall detect energy in the CE band that is within the specified range of receive levels, irrespective of the signal power level in the data band.

11.2.1.4 Jabber function requirements

The MAU shall have a Jabber function that inhibits transmission onto the coaxial cable interface if the MAU attempts to transmit an RF signal longer than 150 ms. The MAU shall provide an MTBF of at least 1 million hours of continuous operation without rendering the transmission medium unusable by other transceivers. Transmissions of less then 20 ms shall not be affected. When the jabber circuit is activated, *signal_quality_error* shall be sent on Circuit CI.

Circuit DO shall also be monitored for transmissions in excess of the maximum packet length. If the packet is longer than 20 ms, an attempt shall be made to deactivate the transmitter before the jabber circuit is activated, to avoid locking up the unit due to a non-MAU failure.

State diagrams defining the Jabber function may be found in 11.2.3.

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11.2.2 DTE PLS to MAU and MAU to DTE PLS messages

11.2.2.1 DTE Physical Layer to MAU Physical Layer messages

The following messages can be sent by the DTE Physical Layer entities to the MAU Physical Layer entities (refer to 7.3 of this standard for the definitions of the signals):

Message	Circuit	Signal	Meaning
output	DO	CD1, CD0	Output information
output_idle	DO	IDL	No data to be output

11.2.2.2 MAU Physical Layer to DTE Physical Layer messages

The following messages can be sent by the MAU Physical Layer entities to the DTE Physical Layer entities:

Message	Circuit	Signal	Meaning
input	DI	CD1, CD0	Input information
input_idle	DI	IDL	No input information
mau_available	CI	IDL	MAU is available for output
signal_quality_error	CI	CS0 (BR)	Error detected by MAU

11.2.2.2.1 *input* message

The MAU Physical Layer sends an *input* message to the DTE Physical Layer when the MAU has a bit of data to send to the DTE. The physical realization of the *input* message is a CD0 or CD1 sent by the MAU to the DTE on Circuit DI. The MAU sends CD0 if the input bit is a zero or CD1 if the input bit is a one. The jitter and asymmetry on CD0 and CD1 shall be no more than that specified in 7.5.2.1.

11.2.2.2.2 *input_idle* message

The MAU Physical Layer sends an *input_idle* message to the DTE Physical Layer when the MAU does not have data to send to the DTE. The physical realization of the *input_idle* message is the IDL signal sent by the MAU to the DTE on Circuit DI.

11.2.2.2.3 *mau_available* message

The MAU Physical Layer sends a *mau_available* message to the DTE Physical Layer when the MAU is available for output. The *mau_available* message is always sent by an MAU that is prepared to output data. The physical realization of the *mau_available* message is an IDL signal sent by the MAU to the DTE on Circuit CI.

11.2.2.3 *signal_quality_error* message

The *signal_quality_error* message shall be implemented in the following fashion:

a) The *signal_quality_error* (SQE) message shall not be sent by the MAU if no or only one MAU is transmitting a legal length packet (as specified in this standard) on the coaxial medium, except as a part of the SQE self test.

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b) If the MAU connected to the local node is not transmitting, then the local MAU shall send the *signal_quality_error* message in every instance when it detects power in the collision enforcement band earlier than the time equivalent for reception of a 512 bit data frame plus preamble and SFD.
c) When the local MAU is transmitting on the coaxial medium, all occurrences of one or more additional MAUs transmitting shall cause the *signal_quality_error* message to be sent by the local MAU to the attached DTE.
d) When the MAU has completed a successful transmission of a packet it shall perform an SQE Test sequence. In this instance, the collision enforcement RF signal is interpreted as an SQE Test signal.

11.2.3 MAU state diagrams

The operation of the MAU during normal transmission and reception can be described by a state diagram that relates the functions of transmission, reception, collision detection, and collision detection testing. Figure 11–4, at the end of this subclause, shows the state transitions for normal operation. Abnormal conditions are implementation-specific.

The state diagram in Figure 11–4 does not describe the operation of the MAU in detail. This is found in 11.2 and 11.3.

The operation of the Jabber function is described by the state diagram of Figure 11–5. When the MAU Jabber state machine is in the INTERRUPT or JAB state, outputs of the MAU Jabber state machine shall override those of the MAU state machine.

11.2.3.1 MAU state diagram messages

The following messages are used in the state diagram:

a) disable_data_driver. Deactivates the mechanism by which the RF data signal is impressed onto the coaxial cable.
b) enable_data_driver. Activates the mechanism by which the RF data signal is impressed onto the coaxial cable.
c) disable_CE_driver. Deactivates the mechanism by which collision enforcement RF signals are impressed onto the coaxial cable.
d) enable_CE_driver. Activates the mechanism by which collision enforcement RF signals are impressed onto the coaxial cable.
e) *mau_available*. Signifies that the MAU is available for transmission (that is, there is no SQE active).
f) *signal_quality_error* (SQE). Signifies that the MAU has detected a collision, it has successfully completed the SQE Test sequence, or the jabber circuit is active.
g) start_SQE_test_timer. Causes a timer to begin counting so that the SQE Test signal may be sent to the coaxial cable interface.
h) positive_disable. Prevents any RF signal from being sent onto the coaxial cable.

11.2.3.2 MAU state diagram signal names

The signal names used in the state diagram are as follows:

a) PowerOn. This signal signifies that power has been applied to the unit.
b) rx_energy. When this signal is active, an RF signal on the coaxial cable has been detected either in the data band or in the collision enforcement band or in both. The delay in asserting or de-asserting this signal is sufficiently short that the delays specified in 11.3.4.5 are met.
c) output. Signifies that data from the DTE is being presented for transmission at the AUI.
d) tx_umd (Transmit Unscrambled Mode Delimiter). When the Unscrambled Mode Delimiter has been detected in the transmit data sequence, this signal is asserted.

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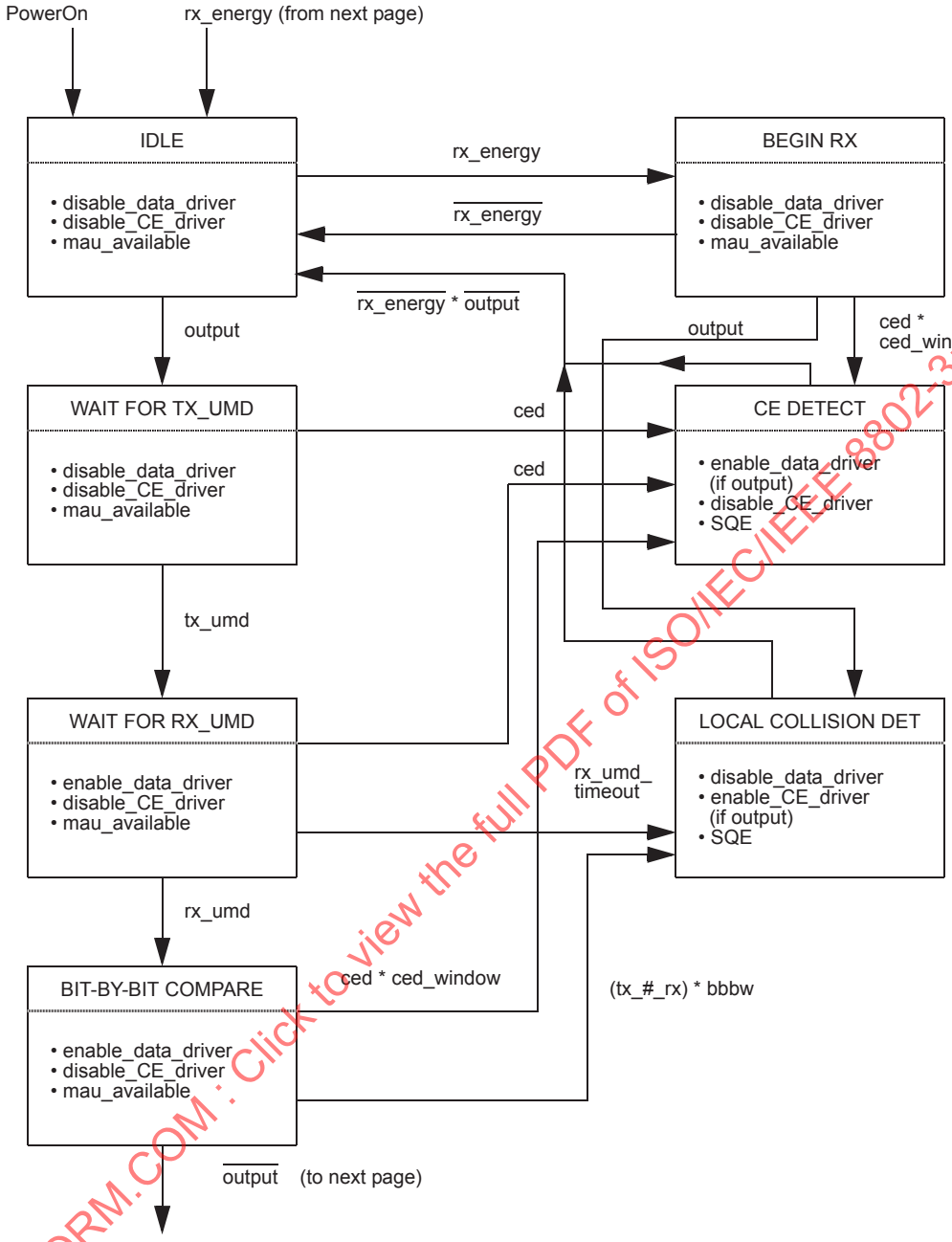

Figure 11–4—MAU state diagram

e) rx_umd (Receive Unscrambled Mode Delimiter). When the Unscrambled Mode Delimiter has been detected in the receive data sequence as it is conveyed from the coaxial cable interface, this signal is asserted.

f) SQE_test_timer. This signal is on during the time that the SQE Test Timer is engaged. At the end of the time, this signal is de-asserted.

g) rx (Receive). As long as data is being presented by the MAU to Circuit DI of the AUI, this signal is active. When the last bit of the receive data has been presented to the AUI, this signal is de-asserted.

h) ced (Collision Enforcement Detection). RF signal power in the collision enforcement band causes this signal to be asserted.

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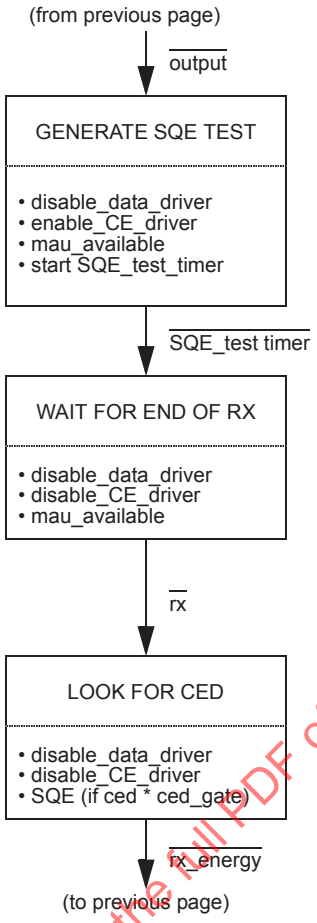

Figure 11-4—MAU state diagram *(continued)*

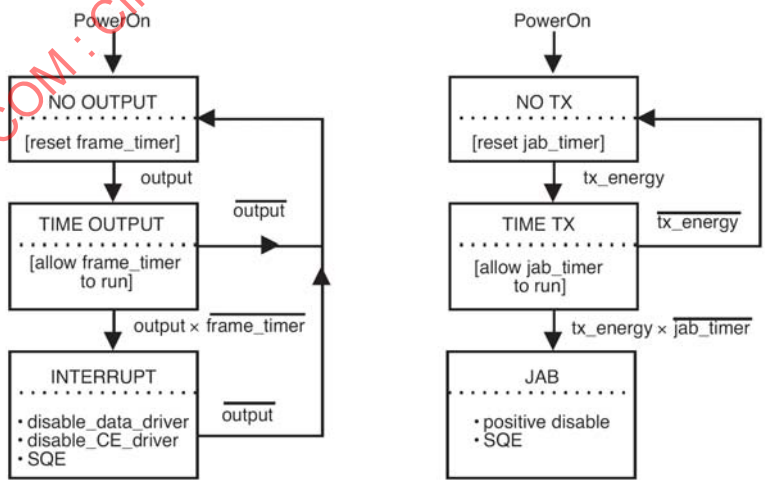

Figure 11–5—MAU jabber state diagram

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i) ced_window (Collision Enforcement Detection Window). This signal defines a period of time (a "window") during which collisions may occur. Its purpose is to distinguish collision enforcements from SQE Test sequences on the coaxial cable. The window opens when rx_energy goes active and closes a minimum of 365 bit times later. The maximum time the window may be open is the minimum frame length, plus preamble and SFD: 576 bits.

j) rx_umd_timeout (Receive Unscrambled Mode Delimiter Timeout). It is possible that the Receive Unscrambled Mode Delimiter may be corrupted by a collision such that the bit-by-bit comparison may not begin. This signal forces detection of a collision due to failure to detect the rx_umd within a maximum time. The timeout begins upon receipt of RF signal in the data band and expires 32 bit times later.

k) tx_#_rx (Transmit Not Equal to Receive). Assertion of this signal occurs when a difference is detected between the received data stream and the transmitted data stream.

l) bbbw (Bit-by-Bit Window). Bit-by-bit comparison shall be performed only for a time long enough to guarantee that the last bit of the source address has been examined. This signal is asserted after the UMD is received and throughout the bit-by-bit comparison process. To place a bound on the location of the source address relative to the UMD, the maximum preamble length permitted for operation with the broadband MAU is 62 bits. This places the last bit of the source address no later than 143 bits after the UMD.

m) ced_gate. This signal is a gating function that serves to shape the timing of ced during an SQE Test. It becomes true a minimum of 6 and a maximum of 16 bit times after the last bit has been presented to Circuit DI and stays active 10 bit times ± 5 bit times.

n) tx_energy. This signal signifies that the MAU is attempting to transmit an RF signal onto the coaxial cable.

o) frame_timer. This signal is on from the beginning of output until it is reset or until it has been on continuously for timeout1 s. The value of timeout1 shall be greater than 20 ms and less than timeout2.

p) jab_timer. This signal turns on when tx energy turns on and lasts until it is reset or until it has been on continuously for timeout2 s. The value of timeout2 shall be greater than timeout1 and less than 150 ms.

11.3 MAU characteristics

11.3.1 MAU-to-coaxial cable interface

The following subclauses describe the interface between the MAU and the broadband coaxial medium. The medium is a 75 Ω CATV-type broadband cable installation employing a single bidirectional cable with band-split amplifiers and filters, or dual unidirectional cables with line amplifiers.

11.3.1.1 Receive interface

11.3.1.1.1 Receive input impedance

The nominal input impedance at the receive port shall be 75 Ω. The return loss within the data and collision enforcement frequency bands shall be at least 14 dB with power applied to the MAU.

11.3.1.1.2 Receiver squelch requirements

There shall be a receiver squelch that inhibits reception of RF signals that are too low in level. This squelch shall permit reception of RF data or collision enforcement signals that are greater than or equal to –7 dBmV rms as measured by the method of 11.3.1.2.5. RF signals (data, collision enforcement, noise, or other signals) of levels lower than –15 dBmV rms shall be ignored.

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The receive squelch for CE signals shall be derived from a power detector with noise bandwidth greater than or equal to 1.5 MHz centered at the CE center frequency.

11.3.1.1.3 Receive level requirements

The receiver shall operate with RF data and CE signals having levels from –4 dBmV to +16 dBmV rms. The nominal receive level shall be +6 dBmV rms.

11.3.1.1.4 Receiver selectivity and linearity requirements

The MAU shall operate in the presence of single frequency (CW) signals adjacent to the receive band of the MAU and offset from the band edges, received at the following levels:

a) 0 dBmV rms at 0.25 MHz below and above the band
b) 10 dBmV rms at 1.25 MHz below and above the band

The receiver shall be capable of operating in a cable environment loaded with TV signals (for example, every 6 MHz in the USA). The TV signals shall be no higher than +10 dBmV peak video at the receiver coaxial cable interface.

11.3.1.1.5 Receive input mechanical requirements

The receiver mechanical interface shall be a 75 Ω female F-series coaxial connector. The connection to the broadband medium shall be through a coaxial drop cable with a mating male F-series connector. For single-cable configurations, the same connector may be used for receive and transmit.

11.3.1.2 Transmit interface

11.3.1.2.1 Transmit output impedance

The nominal output impedance at the transmit port shall be 75 Ω. The return loss within the data and collision enforcement frequency bands shall be at least 14 dB with power applied.

11.3.1.2.2 Transmitted RF packet format

Figure 11–6 shows the transmitted RF packet format.

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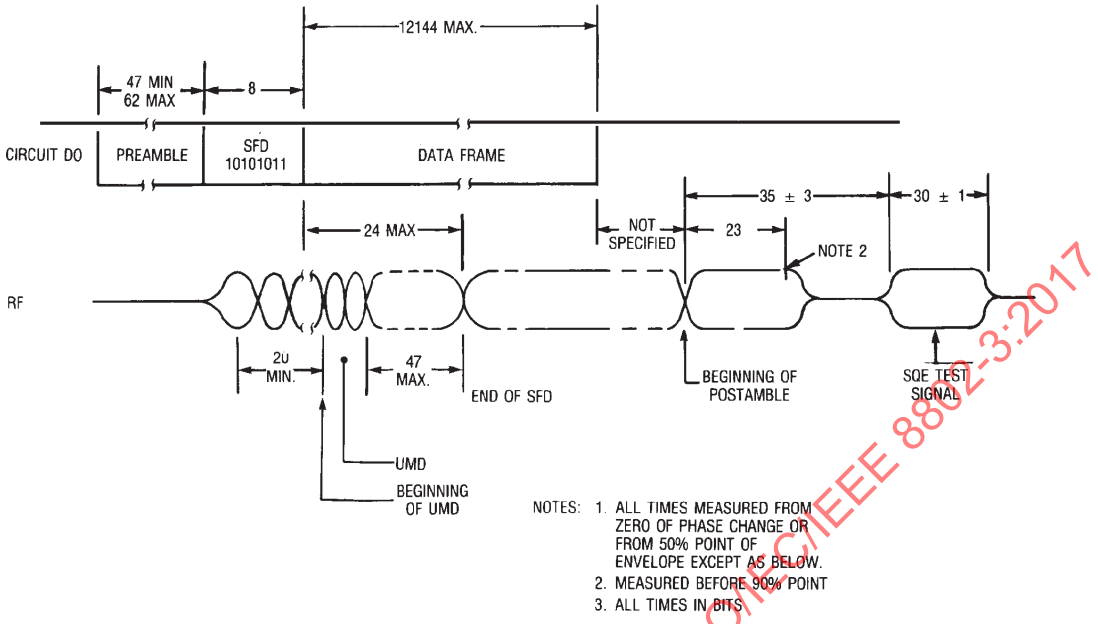

Figure 11–6—Packet format and timing diagram (AUI to coaxial cable interface)

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11.3.1.2.3 Transmit spectrum and group delay characteristics

The transmit RF data signal shall be binary phase-shift-keyed (PSK) modulated and shall have a frequency spectrum equivalent to baseband raised-cosine Nyquist filtering with a rolloff factor (a) of 0.4, and within the limits of Figure 11–7. For rectangular pulses, the filter characteristic is

$$H(jw) = \begin{cases} \dfrac{w(T/2)}{\sin\left(w\dfrac{T}{2}\right)}; & \left[0 <= w < \dfrac{\pi}{T}(1-a)\right] \\ \dfrac{w(T/2)}{\sin(wT/2)} \quad ;\cos^2\left(\dfrac{T}{4a}\left[w - \dfrac{\pi(1-a)}{T}\right]\right); & \\ & \left[\dfrac{\pi}{t}(1-a) <= w < \dfrac{\pi}{T}(1+a)\right] \\ 0; & \left[w >= \dfrac{\pi}{T}(1+a)\right] \end{cases}$$

where T = one symbol time (100 ns for 10 Mb/s) and a = 0.4, and the first term accounts for the sin x/x spectrum of NRZ random data.

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The total variation in group delay from Circuit DO to the RF coaxial medium interface shall not exceed 20 ns in the frequency band from the carrier frequency to ± 5 MHz, and 32 ns to ± 5.5 MHz.

The collision enforcement (CE) signal shall be a constant amplitude pulse with controlled turn-on and turn-off times. Random modulation may be added to reduce the probability of cancellation when more than one CE signal is received simultaneously. The modulated signal shall have an instantaneous frequency within 0.75 MHz of the CE band center frequency and shall conform to the spectrum mask specified in 11.3.1.2.4. The random modulation may be derived from the transmit NRZ data stream.
The CE signal rise and fall times shall approximate a Gaussian shape of the form

$$f(t) = \exp\left(-\frac{1}{2}\left[\frac{t}{T}\right]^2\right)$$

where T = one symbol time and $t < 0$ for the rise time and $t > 0$ for the fall time.

The CE and data RF signals shall not be transmitted simultaneously.

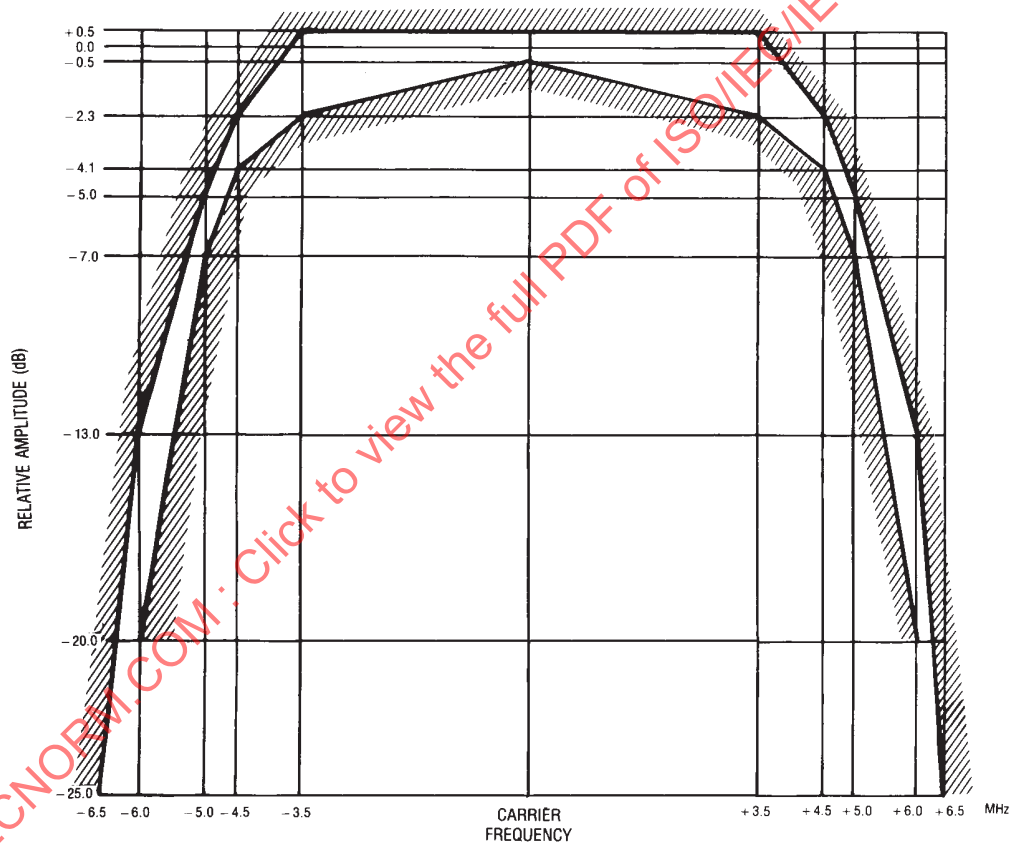

Figure 11–7—Spectrum mask for RF data signal

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11.3.1.2.4 Transmit out-of-band spectrum

The transmitted power outside the specified band shall meet or exceed the relative attenuation (RA) specified below, under the following conditions:

a) Transmitted packet length is 256 bits with a 25.6 μs interval between packets, for 50% duty cycle on the cable.
b) Reference level is an unmodulated carrier, equivalent to the postamble transmitted level.
c) *RA* is the attenuation in decibels relative to the reference level outside the specified band, measured in a 30 kHz noise bandwidth with a video filter of 300 Hz bandwidth or less.
d) *B* is 18 MHz, the width of data plus collision enforcement bands.
e) *MF* is the measurement frequency in MHz.
f) *NCEF* is the frequency of the nearest edge of the band, in MHz.

$$RA = \min (63, 55 + 30 \times | (MF - NCEF) / B|)$$

Figure 11–8 graphically shows the attenuation requirement for out-of-band power.

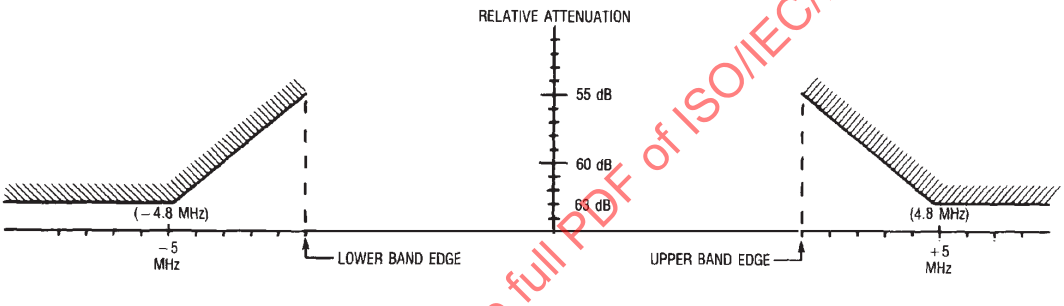

Figure 11–8—Transmit out-of-band power attenuation

11.3.1.2.5 Transmit level requirements

The transmitter output power during the postamble and during the SQE Test of the collision enforcement signal shall be 1000 mV peak-to-peak into a 75 Ω load (51 dBmV rms). Truncation loss due to the specified data filtering is 1 dB; transmitted RF data signal power is 50 dBmV rms. Transmit output power variations shall not exceed ± 2 dB.

11.3.1.2.6 Nontransmitting signal leakage requirement

The RF data signal and collision enforcement signal leakage to the coaxial cable interface while the MAU is not in its transmission mode shall be less than –20 dBmV rms.

11.3.1.2.7 Transmit spurious output requirement

All spurious signals from the transmitter (inband and out-of-band) while not transmitting shall be less than –20 dBmV rms. All spurious signals from the transmitter while transmitting data or collision enforcement shall be below the spectrum mask specified in 11.3.1.2.4.

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11.3.1.2.8 Collision enforcement signal leakage requirement

The collision enforcement RF signal leakage to the coaxial cable during data transmission and while the MAU is not enforcing collisions shall be less than 5 dBmV rms. Leakage shall be less than –20 dBmV rms when the MAU is not in the transmission mode.

11.3.1.2.9 Transmit output mechanical requirements

The transmit mechanical interface shall be a 75 Ω female F-series coaxial connector. The connection to the broadband medium shall be through a coaxial drop cable with a mating male F-series connector. For single cable installations, the same connector may be used for transmit and receive.

11.3.2 MAU frequency allocations

The broadband MAU uses a data band 14 MHz wide and an adjacent collision enforcement band 4 MHz wide. A single cable midsplit configuration with a frequency offset of 156.25 MHz or 192.25 MHz between forward and reverse channels is recommended. Other configurations, including dual-cable, where forward and reverse channels are on separate unidirectional cables, also are permitted.[35] The preferred pairing for the usual North American 6 MHz channels is specified in Table 11–1 and Table 11–2. The tables also specify the data carrier or collision enforcement center frequency for each band, and for single-cable systems, the frequency translation and the headend local oscillator frequency.

11.3.2.1 Single-cable systems frequency allocations

Table 11–1 lists the permissible frequency band allocations for single-cable systems. The 192.25 MHz translation is recommended for all new designs. The 156.25 MHz translation is allowed for compatibility with some existing systems. The 156.25 MHz translation results in a reversal of the data and collision enforcement bands, as the lower sideband is used.

Table 11–1—Single-cable frequency allocations (frequencies in MHz)

TRANSMITTER					RECEIVER	
Data carrier	Coll enf center freq	Transmit band	Translation 156.25 MHz		Translation 192.25 MHz	
			Headend local osc	Receive band	Headend local osc	Receive band
43	52	35.75–53.75	245.75	192-210	192.25	228-246
49	58	41.75–59.75	257.75	198-216	192.25	234-252
55	64	47.75–65.75	269.75	204-222	192.25	240-258
+61	70	53.75–71.75	281.75	210-228	192.25	246-264
67	76	59.75–77.75	293.75	216-234	192.25	252-270
73	82	65.75-83.75	305.75	222-240	192.25	258-276

NOTE 1—Some of these optional bands are overlapping.
NOTE 2—Frequency tolerance of the data carrier and headend local oscillator shall each be ± 25 kHz.
NOTE 3—+ denotes the preferred frequency allocation.

[35] The remainder of 11.3.2 and all of 11.3.2.1 and 11.3.2.2 are not part of the ISO/IEC International Standard. Frequency allocations are a subject for national standardization.

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11.3.2.2 Dual-cable systems frequency allocations[36]

In nontranslated dual-cable systems transmit and receive frequencies are identical. Table 11–2 lists the permissible frequency band allocations. In some instances translated dual-cable systems are installed. In such cases the single-cable frequency allocations may be used.

Table 11–2—Dual-cable frequency allocations (frequencies in MHz)

Data carrier	Coll enf center freq	Data band	Coll enf band
43	52	36–50	50–54
49	58	42–56	56–60
55	64	48–62	62–66
+61	70	54–68	68–72
67	76	60–74	74–78
73	82	66–80	80–84
235.25	244.25	228–242	242–246
241.25	250.25	234–248	248–252
247.25	256.25	240–254	254–258
253.25	262.25	246–260	260–264
259.25	268.25	252–266	266–270
265.25	274.25	258–272	272–276

NOTE 1— Some of these optional bands are overlapping.
NOTE 2—Frequency tolerance of the data carrier shall be ± 25 kHz.
NOTE 3— + denotes the preferred frequency allocations.

11.3.3 AUI electrical characteristics

11.3.3.1 Electrical isolation requirements

The MAU must provide isolation between the AUI cable and the broadband coaxial medium. The isolation impedance shall be greater than 250 kΩ at 60 Hz, measured between any conductor (including shield) of the AU Interface cable and either the center conductor or shield of the coaxial cable. The isolation means provided shall be able to withstand 500 Vac rms for one minute.

The MAU power supply, if provided, shall meet the appropriate national requirements. See IEC 950: 1991 for guidance.

11.3.3.2 Current consumption

The MAU may have its own power supply but is also allowed to use the power supplied by the DTE through the AUI cable. When drawing current from the AUI, the current shall not exceed 0.5 A as provided by the AUI source. The MAU shall be capable of operating from all possible voltage sources as supplied by the DTE through the resistance of all permissible AUI cables. The MAU shall not disrupt the broadband coaxial medium should the DTE power source fall below the minimum operational level under abnormal MAU load conditions. The MAU shall be labeled externally to identify the nominal value of current required by the device at the AUI.

[36] See Footnote 35.

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11.3.3.3 Driver and receiver requirements

The requirements for AUI cable driver and receiver components within the MAU are identical with those specified in Clause 7 of this standard. The drivers shall provide signals that meet the symmetry and jitter requirements of Circuit DI defined in Clause 7 and the receivers shall accept signals that have traversed the worst-case lengths of AUI cable.

11.3.3.4 AUI mechanical connection

The MAU shall be provided with a 15-pin male connector as specified in detail in the PLS/AUI specifications, in 7.6 of this standard.

11.3.4 MAU transfer characteristics

Signals presented on Circuit DO are transformed into signals at the coaxial cable interface by delaying them and by reformatting them. Signals at the coaxial cable interface are transformed into signals on Circuit DI and Circuit CI by a different framing change and by additional delay.

11.3.4.1 AUI to coaxial cable framing characteristics.

Data presented on Circuit DO shall first be received differentially, then Manchester decoded into an NRZ data stream. The framing of the data shall then be transformed into a new packet for presentation to the RF modulator in the following way (see Figure 11–6 and Figure 11–9):

a) Up to 5 bits of the incoming data stream may be dropped for detection and Manchester decoding purposes.
b) Beginning with the first zero, 20 bits of zero-one pattern shall be sent for receiver synchronization and clock recovery.

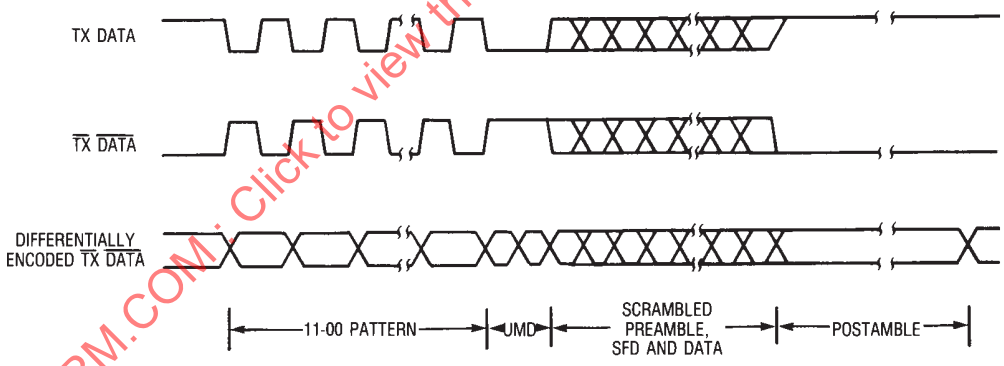

Figure 11–9—Packet format at modulator input

c) The next two bits (zero-one in the incoming pattern) shall both be set to zero and form the Unscrambled Mode Delimiter (UMD). The UMD shall take the place of the zero-one in the incoming pattern; it shall not be inserted into the data stream.
d) All remaining bits in the preamble, SFD, and data fields shall be scrambled (using a CCITT V.29 scrambler plus a differential encoder per 11.3.4.1).
e) A postamble (BEOFD) consisting of a zero followed by 22 ones shall be added immediately after the last scrambled data bit (the postamble is not scrambled). The postamble may be extended to allow controlled turnoff of the transmitted signal, as shown in Figure 11–6.

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f) All bits (unmodified preamble; UMD; scrambled preamble, SFD, and data; and postamble) are inverted.
g) All bits sent to the RF modulator are differentially encoded. Figure 11–9 shows the appearance of the data before and after the differential encoder.
h) The SQE Test sequence shall be generated after a successful data transmission by transmitting a collision enforcement RF signal with the timing shown in Figure 11–6.

Because the preamble of the incoming data on Circuit DO is modified, it is assumed that DTEs generate a minimum length preamble of 47 bits. The maximum preamble length is allowed to be 62 bits, as shown in Figure 11–6.

11.3.4.1.1 Scrambler and differential encoding requirements

The NRZ data shall be scrambled (using a CCITT V.29-type scrambler). A new seed shall be used by the scrambler for every new packet presented by the DTE to the MAU. Figure 11–10 is a diagram of a typical scrambler implementation.

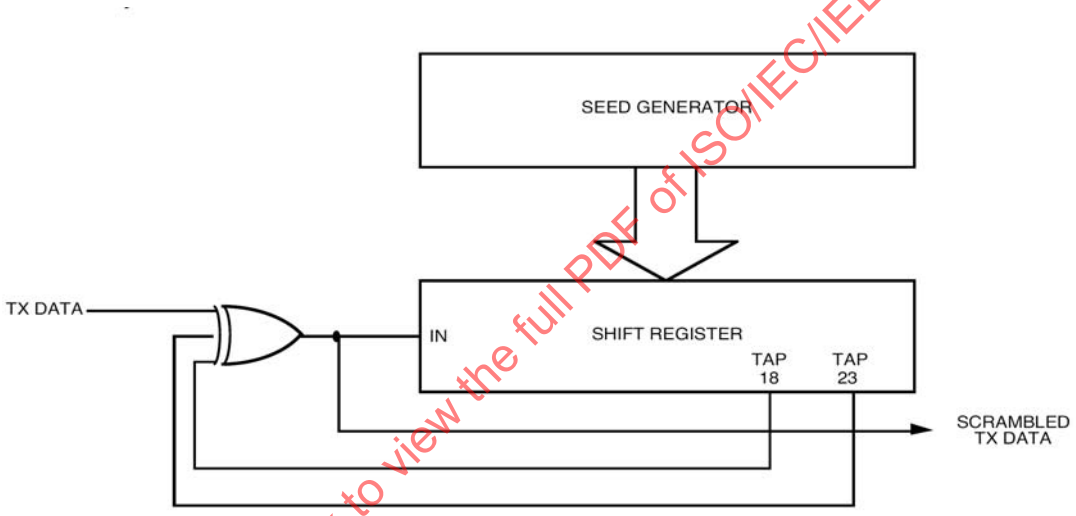

Figure 11–10—Scrambler

The scrambled NRZ data shall be differentially encoded (see Figure 11–11 for a typical implementation).

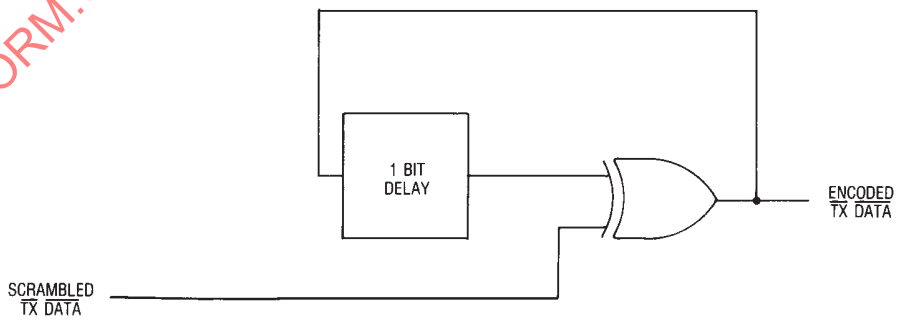

Figure 11–11—Differential encoder

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The entire encoding process comprising the scrambling and differential encoding is essentially equivalent to a division of the polynomial representing the data to be transmitted by the following polynomial:

$$G(x) = 1 + x^{-1} + x^{-18} + x^{-19} + x^{-23} + x^{-24}$$

11.3.4.2 Coaxial cable to AUI framing characteristics

The MAU shall demodulate, differentially decode, and invert the received RF data signal to recover the scrambled and inverted data stream. Clock shall be recovered and a replica of the unfiltered and noninverted transmitted data stream shall be created. The restored data shall be forced to a logic "one" state whenever no RF data signal is detected. This prevents false UMD detection and forces postamble detection when no carrier is present.

The framing information contained in the RF data stream shall be used to reconstruct the received data so that no more than 6 bits are lost and no more than one bit added to the preamble field, and no bits are added to or lost from the end of the transmit data. Detection of the UMD in the receive data shall initiate, after a fixed delay, a locally generated preamble sequence of zero-one pattern. This pattern "fills in" the preamble bits altered due to the framing information at the beginning of the packet: the zero-one synchronization and clock recovery sequence, the UMD, and the descrambler synchronization sequence.

The MAU shall descramble the received data using a self-synchronizing (CCITT V.29-type) descrambler. No prior knowledge of the seed used by the scrambler shall be assumed by the descrambler circuit. The descrambler shall have valid output no later than 23 bit intervals after the UMD is detected by the receiver. An example of a descrambler is shown in Figure 11–12. The differential decoding performed by the demodulator and the descrambling function are essentially equivalent to multiplying the received polynomial by G(x) as defined in the scrambling and differential encoding requirements subclause above.

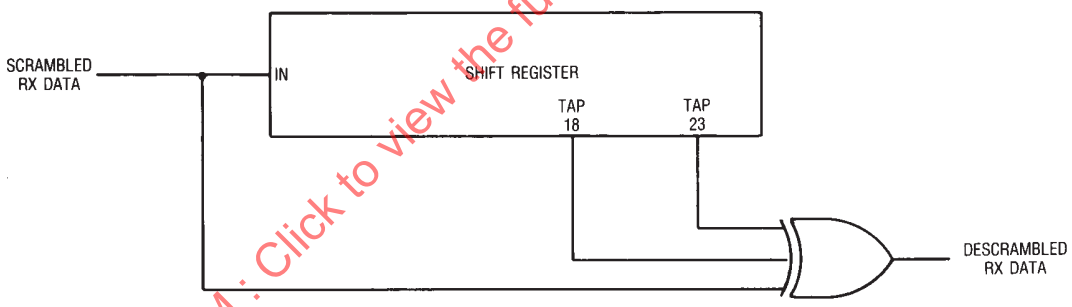

Figure 11–12—Descrambler

After the descrambler is synchronized, 23 bits after the UMD, the correctly descrambled receive data, starting with the 24th bit after the UMD, shall be transferred to the Manchester encoder and therefrom to the AUI. The delay from the detection of the UMD to the beginning of the locally generated zero-one pattern shall be chosen so that no more than 6 bits of preamble are lost, and no more than one bit added, in transmission from Circuit DO to Circuit DI.

The MAU shall detect the "zero" followed by 22 "ones" (the postamble pattern) and, in conjunction with the loss of carrier detection in the data band or the presence of a collision enforcement detection signal, shall ensure that the packet presented to the local DTE has no extraneous bits added by the MAU to the end of the packet.

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The SQE Test signal shall be detected on the RF interface and the SQE signal shall be presented to Circuit CI of the transmitting MAU, subject to the timing restrictions of 11.3.4.5.4. If the signal is not observed at the RF interface due to failure of any element in the transmitter or receiver, no SQE signal may be presented to the AUI. In the event of a collision enforcement, energy will appear in the collision enforcement band within the ced_window time after energy first appears in the data band. Circuit CI shall be asserted when collision enforcement is first detected and shall continue to be active until after the RF signal on the RF port has subsided. Note that an SQE Test signal appended to a packet whose length is less than the ced_window time (less than the minimum allowed packet length) will be indistinguishable from a collision enforcement, except by the MAU transmitting. The transmitting MAU shall take this into account and shall not interpret energy in the collision enforcement band to be a collision when the length of the transmitted packet is less than the ced_window time and the SQE Test sequence has been transmitted. See the discussion in 11.4.2 for more information on ced_window.

11.3.4.3 Circuit DO to circuit DI framing characteristics

In the absence of a collision, the packet format of the receive data at the AUI is identical to that of the transmit data, except that there may be one more preamble bit than was sent at the transmit port and up to 6 bits of the preamble lost. In the presence of a collision, the receive data is undefined, but shall still be properly Manchester encoded.

11.3.4.4 AUI to coaxial cable delay characteristics

The timing and delays associated with the transmitter of the MAU are identified below. To ensure compatibility with all MAUs the delays identified below cannot be exceeded nor traded off with other delays in the system.

11.3.4.4.1 Circuit DO to RF data signal delay

The delay from a transition on Circuit DO at the end of a bit to the corresponding phase change of the RF data signal (such bit chosen so that an RF burst phase change does exist) shall be no more than 24 bit times. The delay from the first transition on Circuit DO to the first appearance of RF energy, however, is not specified except as it is determined by other timing constraints.

11.3.4.4.2 Circuit DO to CE RF output delay

In the event that the MAU begins receiving energy on the coaxial medium just before the DTE presents data to the AUI, a collision shall be detected locally, as described in Figure 11–4. The delay from the first bit at Circuit DO of the AUI to the presentation of collision enforcement at the coaxial cable interface in this circumstance shall be 32 bit times maximum.

11.3.4.4.3 Transmit postamble to SQE test signal delay

The delay from the initial transition of the first bit of the postamble (Broadband End of Frame Delimiter) measured at the RF port to the 50% point of the rising edge of the SQE Test signal shall be 35 bit times ± 3 bit times.

11.3.4.4.4 SQE test signal length

The SQE Test signal length shall be 30 bit times ± 1 bit time as measured at the 50% points of the RF signal.

11.3.4.5 Coaxial cable to AUI delay characteristics

The MAU receiver timing and delays described below shall not be exceeded or traded off against any other delays in the system.

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11.3.4.5.1 Received RF to circuit DI delay

When there is no collision in progress, the delay from the end of the SFD in the received RF data signal at the coaxial cable interface to the end of the SFD on Circuit DI, shall be a maximum of 75 bit times (see Figure 11–13). The minimum is not specified, nor is the delay specified at other locations in the packet. The end of the SFD in the received RF data signal (at the coaxial cable interface) is defined as the time at which the envelope of the carrier would pass through the midpoint if the first bit following the SFD was a zero and the scrambler disabled.

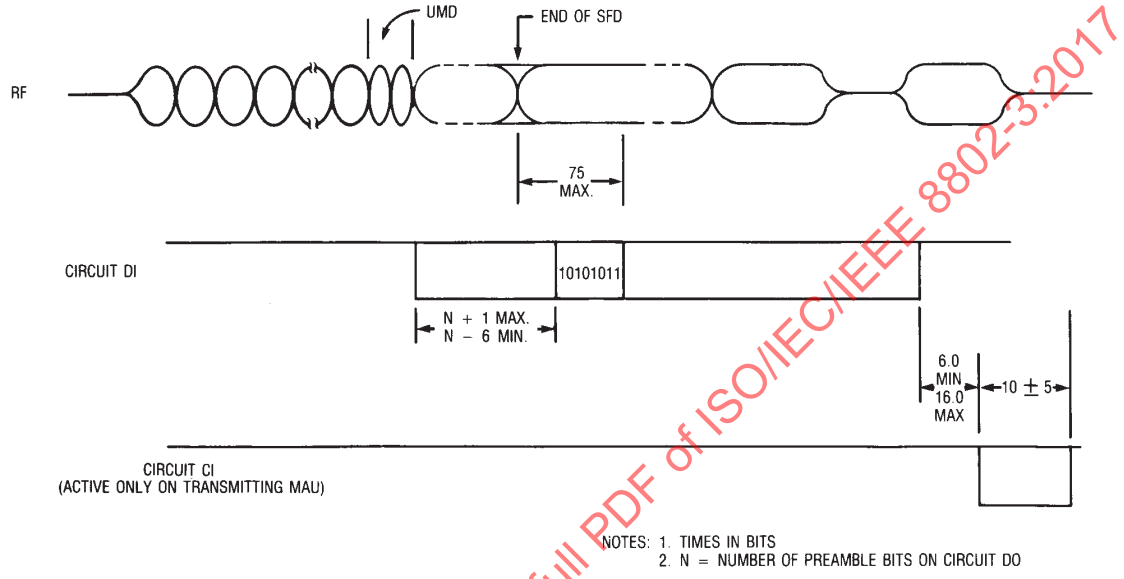

Figure 11–13—No collision timing diagram (coax to AUI)

11.3.4.5.2 Received RF to CE RF output and circuit CI delay

In the event that a collision is detected via the bit-by-bit comparison, the delay from the end of the bit in which the collision was detected, as represented by the RF signal, to the 50% point on the rising edge of the collision enforcement signal shall not exceed 34 bit times. The delay from the same point to the first transition of Circuit CI shall not exceed 27 bit times. Circuit CI shall cease activity no more than 31 bit times after activity on the RF interface (in both data channel and collision enforcement channel) ceases. See Figure 11–14 and Figure 11–15.

11.3.4.5.3 Collision enforcement to circuit CI delay

In the event of a collision enforcement by another MAU, the delay from the 50% point on the rising edge of the RF collision enforcement signal to the first transition of Circuit CI shall be no more than 31 bit times. Circuit CI shall be active for a minimum of 5 bit times and shall become inactive within 31 bit times of the cessation of activity on the RF coaxial cable interface, as shown in Figure 11–15.

11.3.4.5.4 Receive data to SQE test delay

If a collision enforcement signal is received after the ced_window signal becomes inactive [see item i) in 11.2.3.2], or if the MAU has transmitted an SQE Test sequence, the MAU is to interpret the collision enforcement signal as an SQE Test signal. If the SQE Test sequence is correctly detected (that is, the test passes), then the delay from the last transition of Circuit DI to the first transition of Circuit CI shall be at

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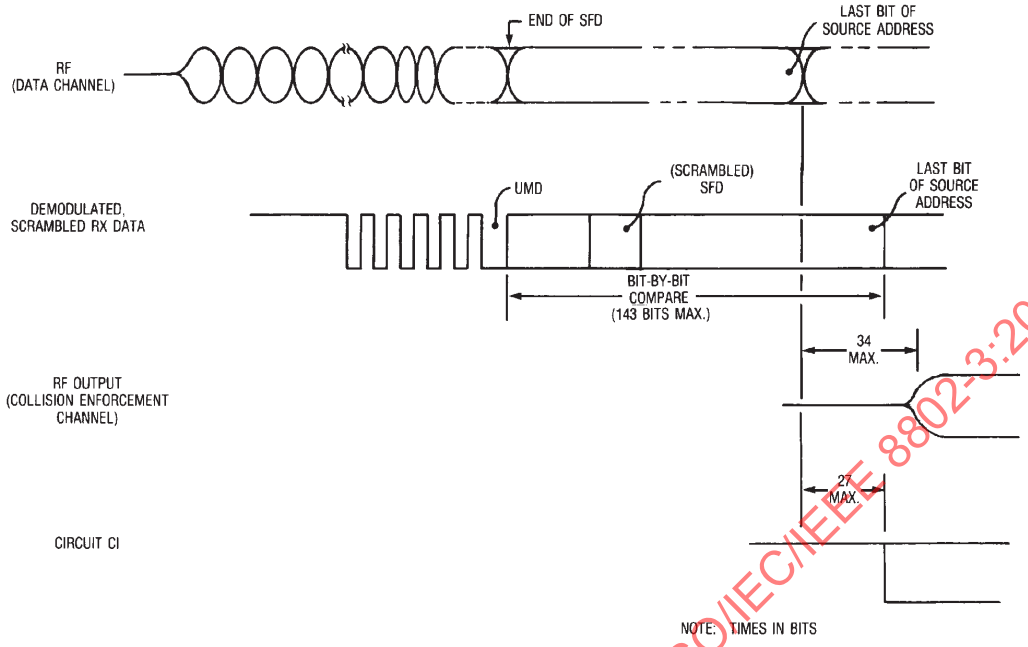

Figure 11–14—Collision timing diagram (RF data to RF collision enforcement)

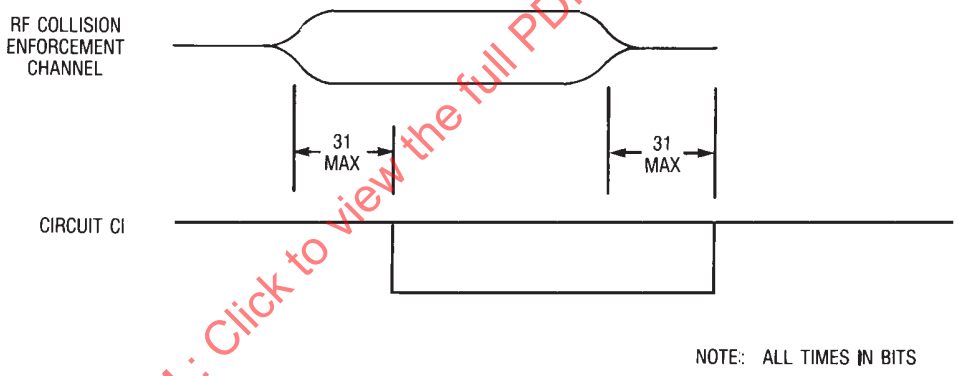

Figure 11–15—Collision timing diagram (coaxial cable interface to AUI circuit)

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least 6 but not more than 16 bit times. Circuit CI shall remain active for 10 bit times ± 5 bit times. Only the transmitting MAU shall assert its Circuit CI as a result of successful completion of the SQE Test sequence.

If a collision enforcement signal is received before the ced_window signal becomes inactive, the MAU shall interpret it as a collision enforcement and the timing of 11.3.4.5.3 shall apply.

11.3.4.6 Delay from circuit DO to circuit DI

The time delay from a bit on Circuit DO at the AU Interface to the corresponding bit on Circuit DI at the AU Interface is equal to the round trip delay of the MAU connected back-to-back with itself (that is, in RF loop-back) plus the round trip delay through the cable system at the location of the MAU. Therefore, the delay is a function of the location of the MAU on the cable system. It is never less than the transmitter delay plus the postamble length plus the time to detect loss of carrier or presence of the SQE Test signal. See Figure 11–16 for the timing relationship when the cable has zero length.

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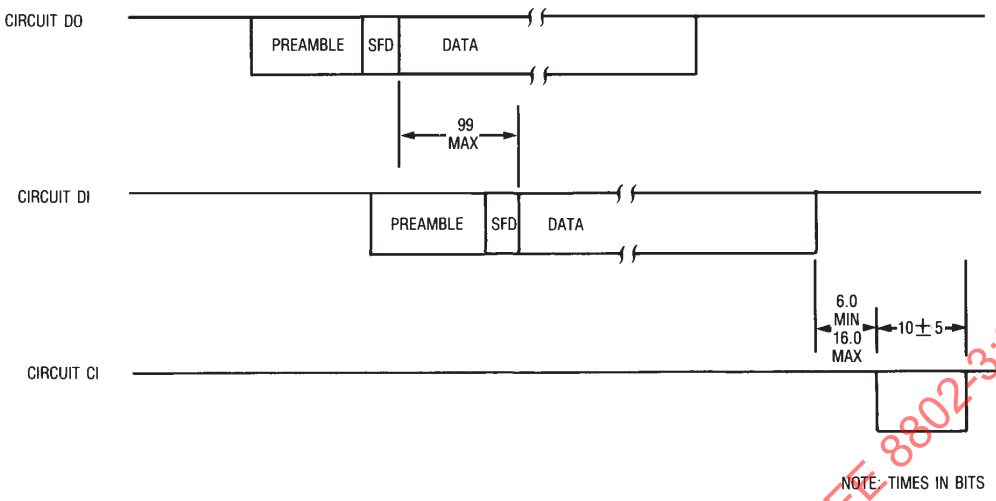

Figure 11–16—Timing at AUI for zero-length coax

When the MAU is transmitting a short packet (less than 576 bits), the timing for Circuit CI during the SQE Test sequence shall be the same as it is for normal length packets. If the MAU transmits a short packet (less than 576 bits) that encounters a collision and if the SQE Test sequence has not been transmitted when the collision is detected by the MAU, then the timing for Circuit CI shall be the same as it is for any normal collision.

11.3.4.7 Interpacket gap requirement

The MAU shall be able and ready to transmit data presented to it by the DTE no later than 90 bit times after the last bit of a received packet was presented by the MAU at its AUI.

11.3.4.8 Bit error ratio

The MAU shall have a Bit Error Ratio (BER) as measured at the AUI lower than one error in 10^8 in a "zero-length coax" test environment (that is, a coaxial cable connection sufficiently short to have negligible delay and transmission impairments). It shall have this BER for receive signal levels in the range specified in 11.3.1.1.3 and in the presence of –28.3 dBmV rms/14 MHz white Gaussian noise. This represents a 24.3 dB signal-to-noise ratio for the specified minimum signal level, –4 dBmV rms. For the same BER in a "system" environment (as opposed to zero-length coax), a 26 dB signal-to-noise ratio is required.

The MAU shall meet the BER requirements specified above when receiving strings of up to 33 consecutive identical bits.

11.3.5 Reliability

Component failures within the MAU electronics should not impede communication among other MAUs on the broadband coaxial cable. Connectors and other passive components comprising the means of connecting the MAU to the coaxial cable shall be designed to minimize the probability of total network failure. The MAU shall be designed to provide an MTBF of at least 1 000 000 hours without causing communication failure among other stations attached to the broadband local network medium.

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11.4 System considerations

11.4.1 Delay budget and network diameter

The delay budget for the broadband MAU and rest of the Physical Layer is tabulated in Table 11–3. This table includes allocations for trunk cables (the backbone cables in the system), drop cables (a length of 25 m is assumed), etc. The velocities of propagation assumed are included in the table; use of other types of cables will alter the system diameter accordingly. The types of cables, including the mix of drop and trunk cable lengths, can be altered as long as the total propagation delay from the most distant MAU to the headend does not exceed 70 bit times. The total delay budget of 576 bit times includes allowance for the preamble and SFD (64 bits).

Table 11–3 tabulates delay allocations for a dual-cable system with no headend delay. In translated single-cable systems, the headend translator delay reduces the maximum trunk cable distance by $[D/(2 \times CV)]$, where D is the delay in nanoseconds, and CV is the cable velocity in nanoseconds per meter. For 3.83 ns/m velocity trunk cable, this reduction is [Delay (ns) / 7.66] m.

Table 11–3—Broadband dual-cable systems—Physical Layer delay budget

Delay element	Maximum allowed value (bits)
DTE1 starts to put out first bit	0.00
First bit from DTE1 at AUI	3.00
AUI cable (50 m at 5.13 ns/m)	2.57
Circuit DO to Tx RF out	24.00
Tx drop cable (25 m at 4.27 ns/m)	1.05
Tx trunk cable (1800 m at 3.83 ns/m)	68.95
Rx trunk cable (25 m at 4.27 ns/m)	68.95
Rx drop cable (25 m at 4.27 ns/m)	1.05
End of bit comparison (last bit of source address)	160.00
Rx RF to collision enforcement RF out (from RX bit that is found to be in error to collision enforcement out)	34.00
Tx drop cable (25 m at 4.27 ns/m)	1.05
Tx trunk cable (1800 m at 3.83 ns/m)	68.95
Rx trunk cable (1800 m at 3.83 ns/m)	68.95
Rx drop cable (25 m at 4.27 ns/m)	1.05
Rx collision enforcement to circuit Ci	31.00
AUI cable (50 m at 5.13 ns/m)	2.57
DTE1 detects collision presence	3.00
DTE1 jams channel	32.00
Allowance for traps, splitters, amplifiers, and margin	3.86
Total	576.00

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11.4.2 MAU operation with packets shorter than 512 bits

The MAU transmits an SQE Test sequence onto the RF medium after every transmitted packet. If the frame plus preamble and SFD is less than the ced_window in length, a receiving MAU cannot distinguish the SQE

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Test signal from a collision enforcement signal due to a collision. Therefore, operation of the MAU with data frames shorter than 512 bits may cause all other receiving MAUs to see a collision. The transmitting MAU, however, recognizes the SQE Test because that MAU was the one that transmitted the test. An MAU transmitting a short packet that encounters a collision can distinguish the resulting collision enforcement from an SQE Test signal by the fact that the transmitting MAU will not have transmitted the SQE Test sequence unless the packet is shorter than the round trip delay on the cable plant. In the latter instance, the transmitting MAU may not detect a collision enforcement.

11.5 Characteristics of the coaxial cable system

The cable system upon which the broadband MAU operates shall meet the following electrical and mechanical requirements.

11.5.1 Electrical requirements

The electrical requirements of the cable system are listed in Table 11–4. Each parameter is applicable over the frequency range to be used by the broadband MAU.

Table 11–4—Cable system electrical requirements

Impedance	75 Ω
Return loss	14 dB min
Transmit level	+50 dBmV ±2 dB
Receive level	+6 dBmV ±10 dB
Maximum receive noise level	–30 dBmV/14 MHz
Loss variation[a] (per 18 MHz band)	2 dB min, 52 dB max
Path loss (between any transmit port and receive port, including loss variation)	36 dB min, 52 dB max
Group delay variation —around data carrier —over 18 MHz band	 20 ns/10 MHz max 34 ns max

[a]Not including headend.

Adjacent channel signal levels shall be consistent with the requirements of 11.3.1.1.4.

11.5.2 Mechanical requirements

The connection of the cable system to the broadband MAU is via a standard F-series screw-on male connector. For the dual-cable case, two such connectors are required: one for transmit and the other for receive.

11.5.3 Delay requirements

The maximum length of the cable system is constrained by the allowable round trip delay from the farthest transmitting MAU to the farthest receiving MAU. Table 11–3 allows 140 bit times round trip delay in the cable system. For trunk cable propagation velocity of 3.83 ns/m, this allows 3600 m of trunk cable (round trip; 1800 m from the farthest point to the headend), and 25 m of 4.27 ns/m velocity drop cable at each MAU. In addition, 50 m of AUI cable is allowed on each MAU, therefore allowing, in this case, a maximum

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of 3750 m DTE to DTE separation. These lengths will be different if cables of different propagation velocity are used. This is acceptable so long as the maximum delay is not exceeded.

For single-cable systems, the maximum delay of 140 bit times includes the delay through the headend. The maximum cable system length must be reduced appropriately, as described in 11.4.1.

11.6 Frequency translator requirements for the single-cable version

11.6.1 Electrical requirements

The headend frequency translator performance is included in the cable system characteristics specified in 11.5, except as defined in Table 11–5.

Table 11–5—Frequency translator requirements

Group delay variation —around data carrier frequency —between data carrier and CE center frequency	 20 ns/10 MHz max 50 ns max
Amplitude variation (from 6 MHz below the input data carrier frequency to 1 MHz above the CE center frequency)	2 dB max
Translation frequency	per Table 11–1

The frequency translator contributes to total cable system delay and shall be labeled by the vendor with the input-to-output delay in the band of operation. The effect on network length can then be computed per 11.4.1.

11.6.2 Mechanical requirements

The input and output mechanical interface shall be 75 Ω female F-series coaxial connectors. The connection to the broadband medium shall be through a coaxial cable with a mating male F-series connector.

11.7 Environmental specifications

11.7.1 Safety requirements

This subclause sets forth a number of recommendations and guidelines related to safety concerns. This list is neither complete nor does it address all possible safety issues. The designer is urged to consult the relevant local, national, and international safety regulations to assure compliance with the appropriate standards.

LAN cable systems, as described in this clause, are subject to at least four direct electrical safety hazards during their use, and designers of connecting equipment should be aware of these hazards. The hazards are as follows:

a) Direct contact between local network components and power or lighting circuits
b) Static charge buildup on local network cables and components
c) High-energy transients coupled onto the local network cabling system
d) Potential differences between safety grounds to which various network components are connected

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These electrical safety hazards, to which all similar cabling systems are subject, should be alleviated for a local network to perform properly. In addition to provisions for properly handling these faults in an operational system, special measures shall be taken to ensure that the intended safety features are not negated when attaching or detaching equipment from the LAN medium of an existing network.

Sound installation practice, as defined in applicable national and local codes and regulations, shall be followed in every instance in which such practice is applicable.

11.7.2 Electromagnetic environment

11.7.2.1 Susceptibility levels

Sources of interference from the environment include electromagnetic fields, electrostatic discharge, transient voltages between earth connections, etc.

The physical MAU hardware shall meet its specifications when operating in an ambient plane wave field of:

a) 2 V/m from 10 kHz through 30 MHz
b) 5 V/m from 30 MHz through 1 GHz

MAUs meeting this clause should provide adequate RF ground return to satisfy the EMC specification.

11.7.2.2 Emission levels

The physical MAU hardware shall comply with the applicable national and local regulations for emission levels.

11.7.3 Temperature and humidity

The MAU and associated cable system are expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling such as shock and vibration. Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

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12. Physical signaling, medium attachment, and baseband medium specifications, type 1BASE5

NOTE—This MAU is not recommended for new installations. Since September 2003, maintenance changes are no longer being considered for this clause.

12.1 Introduction

12.1.1 Overview

1BASE5 is a 1 Mb/s CSMA/CD network based on twisted-pair wiring. Each DTE (Data Terminal Equipment) is star-connected to a shared hub through two pairs that function as transmit and receive channels. Hubs can be cascaded, and DTEs can be connected to any hub. Packets transmitted by a DTE are propagated by the hub to a higher-level hub if one exists; otherwise the hub broadcasts the packet back down to all DTEs and lower-level hubs. Packets received by a hub from a higher-level hub are retransmitted to all attached DTEs and lower-level hubs. If two or more DTEs or lower-level hubs transmit concurrently, the hub generates a collision-presence signal that the DTEs detect as a collision. Hubs between a transmitting DTE and the header (highest level) hub propagate data or the collision-presence signal to the header hub; this hub in turn broadcasts the packet or collision signal to all DTEs and lower-level hubs.

12.1.2 Scope

The 1BASE5 specification builds upon the first six major clauses of this standard; the remaining major clauses (other than this one, of course) do not apply to 1BASE5. That is, the Media Access Control (MAC) and Physical Signaling (PLS) Service Specifications are used in common with the other implementations of this standard, but the Physical Medium Attachment (PMA) sublayer, transmission medium, and hub functions for type 1BASE5 are specified in this clause. The relationship of the 1BASE5 specification to the OSI reference model and the IEEE 802.3 CSMA/CD LAN model is shown in Figure 12–1.

12.1.3 Definitions

See 1.4.

12.1.4 General characteristics

Type 1BASE5 has the following general characteristics:

a) 1 Mb/s signaling rate, Manchester encoded
b) Twisted-pair wiring
c) Point-to-point interconnection of DTEs to hubs, with one twisted-pair serving as the upward link, the other as the downward link
d) Data pairs can coexist in the same telephone cable bundles as voice pairs
e) When a hub receives signals from a DTE or lower-level hub, it propagates them to a higher-level hub if one exists; otherwise, the hub broadcasts the signals back down to the DTEs and lower-level hubs
f) When a hub receives signals concurrently from two or more DTEs or lower-level hubs, it generates a unique collision presence signal, and distributes it as in item e) above
g) DTE-to-hub and hub-to-hub interfaces are electrically isolated at both ends
h) Up to five hub levels are allowed
i) Hubs serve as repeaters
j) Maximum DTE-to-hub and hub-to-hub distance is approximately 250 m for telephone wiring (cable-type dependent; see 12.7)

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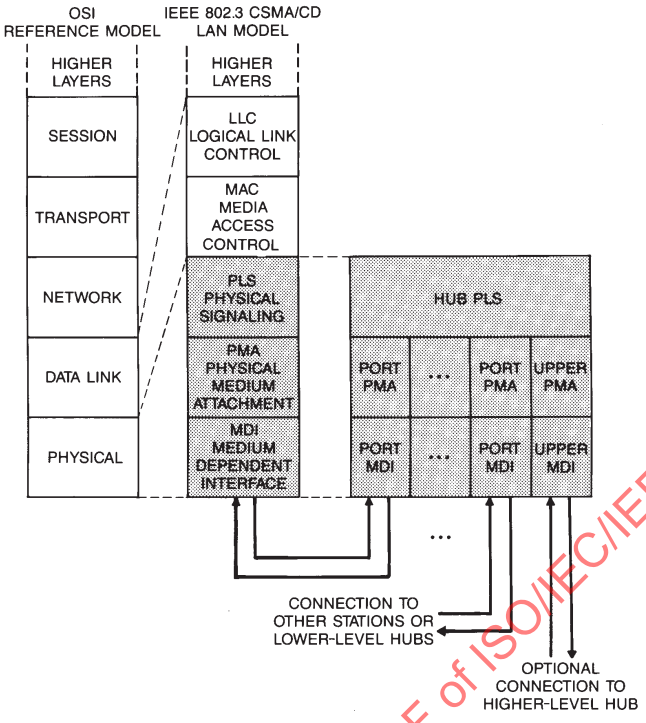

Figure 12–1—1BASE5 relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

k) Special links may be used to extend some DTE-to-hub or hub-to-hub distances to 4 km

12.1.5 Compatibility

This specification calls out one principal compatibility interface, namely PMA-to-Medium. It is intended that different implementations of DTEs and hubs be able to interoperate in 1BASE5 networks.

12.1.6 Objectives of type 1BASE5 specification

a) Provide for low-cost networks, as related to both equipment and cabling
b) Make it possible to use telephone-type building wiring, and in particular spare wiring when available
c) Provide for easy installability, reconfigurability, and service
d) Ensure interconnectability of independently developed DTEs and hubs
e) Ensure fairness of DTE access
f) Provide a communication channel with a resultant mean bit error ratio, at the Physical Layer service interface, of less than one part in 10^8 (on the order of one part in 10^9 at the link level)

12.2 Architecture

12.2.1 Major concepts

Type 1BASE5 is a 1 Mb/s CSMA/CD network. DTEs are connected to hubs (and hubs to other hubs) by point-to-point wiring, resulting in a star topology network. Data transmissions are Manchester encoded.

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An elementary configuration is illustrated in Figure 12–2. In this instance, each DTE is connected to the hub via separate transmit and receive channels (normally two twisted pairs). The hub serves as the point of concentration and performs two major functions: signal regeneration/retiming (repeating) and collision detection. When only one DTE transmits, the hub repeats the signals, compensating for amplitude and phase distortion, and broadcasts to all DTEs. When a hub detects two or more DTEs transmitting concurrently, the hub generates a unique Collision Presence (CP) signal, which it broadcasts instead of the originally transmitted signals. The hub continues to send CP until it receives IDL from all lower-level DTEs. CP has the property that it can be detected by DTEs as a Manchester code violation.

The interconnection architecture does not imply any minimum, typical, or maximum number of DTEs to be connected to a given hub; this is an implementation or installation detail.

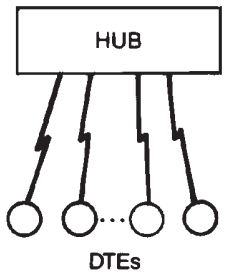

Figure 12–2—Single hub network

Up to five levels of hubs may be cascaded. A two-level configuration is illustrated in Figure 12–3, with a header hub (HH) and intermediate hubs (IH). There can be a number of IHs; there must be one and only one HH. Each DTE or IH is connected to a hub via separate transmit and receive channels (normally two twisted pairs). An IH propagates signals from its DTEs toward the HH; it sends CP toward the HH in the event of a collision. The HH repeats the signals it receives from DTEs or IHs back down to all DTEs and IHs. The HH generates CP if more than one of its inputs becomes active. The IHs repeat the signals received from the HH, and broadcast to all the connected DTEs' receivers. Hubs do not distinguish whether input signals along the upward path emanate from DTEs or lower-level IHs. If a single input is active, the hub repeats the signal regardless of its source; if more than one is active, it generates CP.

A configuration involving four hub levels and a special link is illustrated in Figure 12–4. In this example, one IH is used for simple repeating (one connection upward and one connection downward). Other than having one link in and one link out, repeaters are identical to other hubs. Special links are connections, possibly containing active devices, that are used for situations requiring extra propagation delay or special transmission media.

12.2.2 Application perspective

The primary application area for type 1BASE5 is expected to be in office environments for networking DTEs such as personal computers or other workstations. In many cases, spare wiring contained in existing telephone wire bundles will be used.

12.2.3 Packet structure

Packets are transmitted from the PLS to the PMA as follows:

<silence> <preamble> <sfd> <data> <etd> <silence>

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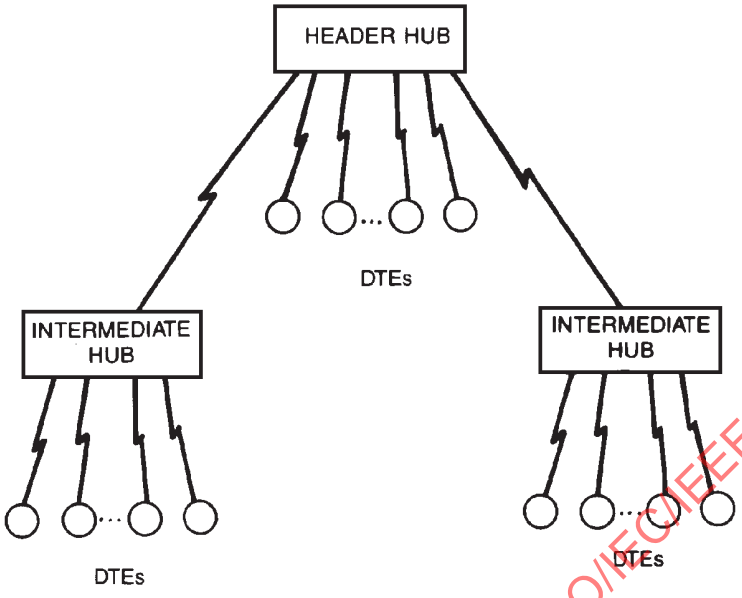

Figure 12–3—Network with two levels of hubs

The packet elements shall have the following characteristics:

Element	Characteristics
<silence>	No transitions
<preamble>	Alternating CD1 and CD0 for ≥56 bit times (ending in CD0)
<sfd>	CD1 CD0 CD1 CD0 CD1 CD0 CD1 CD1
<data>	8 × N instances of CD0 or CD1
<etd>	First part of IDL

12.2.3.1 Silence

The <silence> delimiter provides an observation window for an unspecified period of time during which no transitions occur. The minimum duration of <etd> followed by <silence> is the interFrameGap defined in 4.4.2.

12.2.3.2 Preamble

The <preamble> delimiter begins a packet transmission and provides a signal for receiver synchronization. The signal shall be an alternating pattern of CD1 and CD0. This pattern shall be transmitted by the DTE for a minimum of 56 bit times at the beginning of each packet. The last bit of the preamble (that is, the final bit of preamble before the start-of-frame delimiter) shall be a CD0.

The DTE is required to supply at least 56 bits of preamble in order to satisfy system requirements. System components consume preamble bits in order to perform their functions. The number of preamble bits sourced ensures an adequate number of bits are provided to each system component to correctly implement its function.

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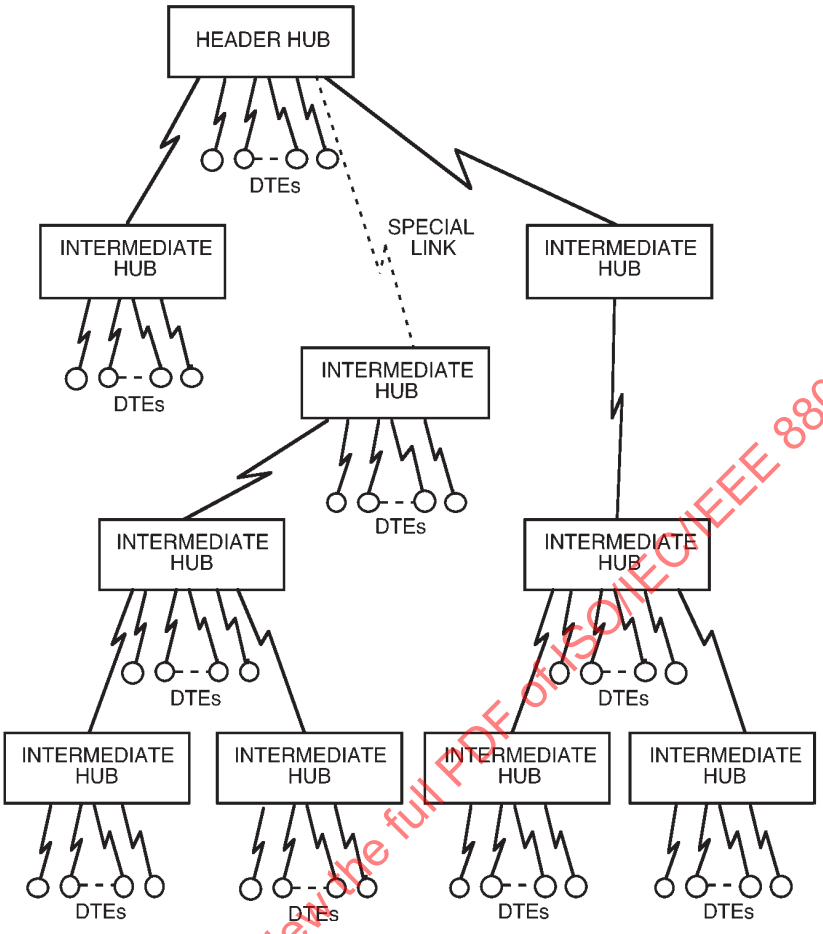

Figure 12–4—Network with four levels of hubs

12.2.3.3 Start-of-frame delimiter

The <sfd> indicates the start of a frame, and follows the preamble.

12.2.3.4 Data

The <data> in a transmission shall be in multiples of eight (8) encoded data bits (CD0s and CD1s).

12.2.3.5 End-of-transmission delimiter

The <etd> indicates the end of a transmission and serves to turn off the transmitter. The signal shall be the first part of an IDL.

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12.3 DTE physical signaling (PLS) specification

12.3.1 Overview

This subclause defines logical characteristics of the DTE PLS sublayer for IBASE5. The relationship of this specification to the entire standard is shown in Figure 12–5. The sublayer and its relationship to the MAC and PMA sublayers are described in an abstract way and do not imply any particular implementation.

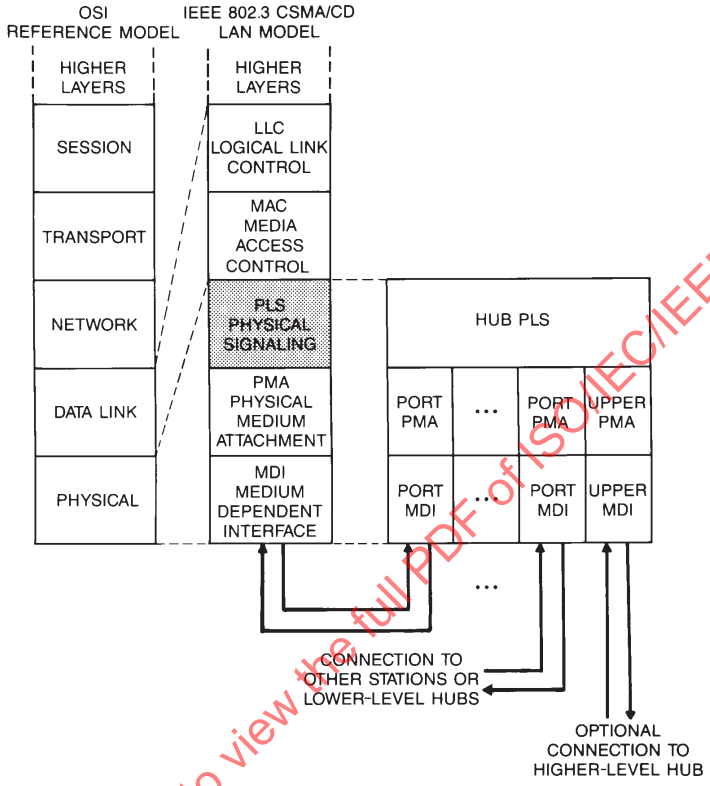

Figure 12–5—Station physical signaling, relationship to the ISO OSI reference model and the IEEE 802.3 CSMA/CD LAN model

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12.3.1.1 Summary of major concepts

a) There are two channels between the PLS and PMA sublayers. Output data are passed through the output channel and input data and control (CP) are passed through the input channel.
b) Each direction of data transfer through the PLS operates independently and simultaneously (that is, the PLS is full duplex).

12.3.1.2 Application perspective

The DTE PLS sublayer performs the following functions:

a) Encodes OUTPUT_UNITs from the MAC sublayer into a Manchester encoded waveform that it sends to the PMA sublayer output circuit
b) Decodes a Manchester encoded waveform from the PMA sublayer input circuit into INPUT_ UNITS, CARRIER_STATUS, and SIGNAL_STATUS

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12.3.2 Functional specification

This subclause provides a detailed model for the DTE PLS sublayer.

Many of the terms used in this subclause are specific to the interface between this sublayer and the MAC sublayer. These terms are defined in the service specification for the PLS sublayer (see 6.3).

12.3.2.1 PLS-PMA interface

The PLS and PMA communicate by means of the following messages:

Message	Meaning	Source
output	Output information	PLS
output_idle	No data to be output	PLS
input	Input information	PMA
input_idle	No input information	PMA

12.3.2.1.1 *output* message

The PLS sublayer sends an *output* message to the PMA sublayer when the PLS sublayer receives an OUTPUT_UNIT from the MAC sublayer.

The physical realization of the *output* message is a CD0 or a CD1 sent by the PLS to the PMA. The PLS sends a CD0 if the OUTPUT_UNIT is a ZERO or a CD1 if the OUTPUT_UNIT is a ONE. This message is time-coded. That is, once this message has been sent, the function is not completed until one bit time later. The *output* message cannot be sent again until the bit cell being sent as a result of sending the previous *output* message is complete.

12.3.2.1.2 *output_idle* message

The PLS sublayer sends an *output_idle* message to the PMA sublayer at all times when the MAC sublayer is not in the process of transferring output data across the MAC to PLS interface. The *output_idle* message is no longer sent (and the first OUTPUT_UNIT is sent using the *output* message) when the first OUTPUT_UNIT of a packet is received from the MAC sublayer. The *output_idle* message is again sent to the PMA when DATA_COMPLETE is received from the MAC sublayer.

The physical realization of the *output_idle* message is IDL sent by the PLS to the PMA.

12.3.2.1.3 *input* message

The PMA sublayer sends an *input* message to the PLS sublayer when the PMA has received a bit from the medium and is prepared to transfer this bit to the PLS.

The physical realization of the *input* message consists of data units, CD0, CD1, CVL, or CVH, derived from the incoming data stream. If ambiguity exists due to excessive noise or jitter, the PMA may send an arbitrary combination of these.

12.3.2.1.4 *input_idle* message

The PMA sublayer sends an *input_idle* message to the PLS sublayer when the PMA sublayer does not have data to send to the PLS sublayer. This condition exists when carrier is lost or IDL is received.

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12.3.2.2 PLS-MAC interface

The PLS and MAC communicate by means of the following messages:

Message	Meaning	Source
OUTPUT_UNIT	Data sent to the PMA	MAC
OUTPUT_STATUS	Response to OUTPUT_UNIT	PLS
INPUT_UNIT	Data received from the PMA	PLS
CARRIER_STATUS	Indication of input activity	PLS
SIGNAL_STATUS	Indication of error/no error condition	PLS

12.3.2.2.1 OUTPUT_UNIT

The MAC sublayer sends the PLS sublayer an OUTPUT_UNIT every time the MAC sublayer has a bit to send. Once the MAC sublayer has sent an OUTPUT_UNIT to the PLS sublayer, it may not send another OUTPUT_UNIT until it has received an OUTPUT_STATUS message from the PLS sublayer. The OUTPUT_ UNIT is a ONE if the MAC sublayer wants the PLS sublayer to send a CD1 to the PMA sublayer, a ZERO if a CD0 is desired, or a DATA_COMPLETE if an IDL is desired.

12.3.2.2.2 OUTPUT_STATUS

The PLS sublayer sends the MAC sublayer an OUTPUT_STATUS in response to every OUTPUT_UNIT received by the PLS sublayer. OUTPUT_STATUS sent is an OUTPUT_NEXT when the PLS sublayer is ready to accept the next OUTPUT_UNIT from the MAC sublayer. (The purpose of OUTPUT_STATUS is to synchronize the MAC sublayer data output with the data rate of the physical medium.)

12.3.2.2.3 INPUT_UNIT

The PLS sublayer sends the MAC sublayer an INPUT_UNIT every time the PLS receives an *input* message from the PMA sublayer. The INPUT_UNIT is a ONE if the PLS sublayer receives a CD1 from the PMA sublayer or a ZERO if the PLS sublayer receives a CD0 from the PMA sublayer. The INPUT_UNIT may be either ZERO or ONE if the PLS sublayer receives a CVL or CVH from the PMA sublayer.

12.3.2.2.4 CARRIER_STATUS

The PLS sublayer sends the MAC sublayer_CARRIER_STATUS whenever there is a change in carrier status, as detected by the PMA. The PLS sublayer sends CARRIER_ON when it receives an *input* message from the PMA and the previous CARRIER_STATUS that the PLS sublayer sent to the MAC sublayer was CARRIER_OFF. The PLS sublayer sends CARRIER_OFF when it receives an *input_idle* message from the PMA sublayer, and the previous CARRIER_STATUS that the PLS sublayer sent to the MAC sublayer was CARRIER_ON.

12.3.2.2.5 SIGNAL_STATUS

The PLS sublayer sends the MAC sublayer SIGNAL_STATUS whenever it detects the beginning or end of Collision Presence. The PLS sublayer sends SIGNAL_ERROR when it receives *input* message CVL or CVH from the PMA sublayer and the previous SIGNAL_STATUS the PLS sublayer sent was NO_SIGNAL_ERROR. The PLS sublayer sends NO_SIGNAL_ERROR when it receives an *input_idle* message from the PMA sublayer and the previous SIGNAL_STATUS that the PLS sent to the MAC sublayer was SIGNAL_ERROR. The PLS shall send SIGNAL_ERROR to the MAC sublayer when the

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Collision Presence pattern is detected; it may send SIGNAL_ERROR any time it receives an *input* message that is neither CD0 nor CD1.

12.3.2.3 PLS functions

The PLS sublayer functions consist of four simultaneous and asynchronous functions. These functions are Output, Input, Error Sense, and Carrier Sense. All of the four functions are started immediately following PowerOn. These functions are depicted in the state diagrams shown in Figure 12–6 through Figure 12–9, using the notation described in 1.2.1.

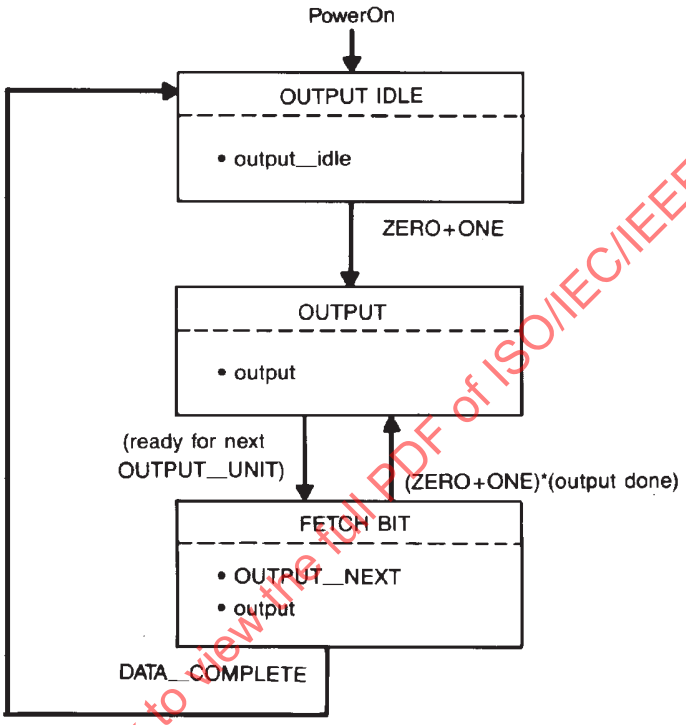

Figure 12–6—DTE PLS Output function

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12.3.2.3.1 State diagram variables

The variables used in the state diagrams and the corresponding descriptions are the following:

a) Inter Process Flags

disable_SIGNAL_ERRORUsed in the state diagrams and functions. It is used by the Input function to prevent false collision detection by the Error Sense function during preamble startup.

protectTimer Used by the Carrier Sense function to implement the protection period described in 12.5.3.2.3. It is started by "start-protectTimer." "protectTimer_done" is satisfied when the timer has expired.

12.3.2.3.2 Output function

The Output function transparently performs the task of data transfer from the MAC sublayer to the PMA sublayer. The state diagram of Figure 12–6 depicts the Output function operation.

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12.3.2.3.3 Input function

The Input function transparently performs the task of data transfer from the PMA sublayer to the MAC sublayer. The state diagram of Figure 12–7 depicts the Input function operation.

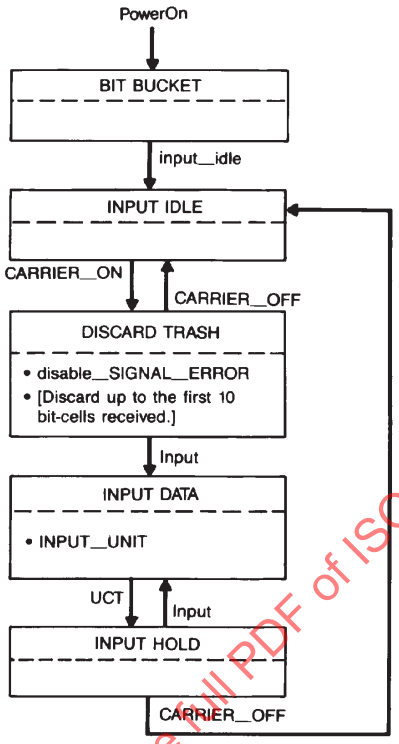

Figure 12–7—DTE PLS Input function

12.3.2.3.4 Error Sense function

The Error Sense function performs the task of sending SIGNAL_STATUS to the MAC sublayer at the beginning and end of the Collision Presence pattern. The state diagram of Figure 12–8 depicts the Error Sense function operation.

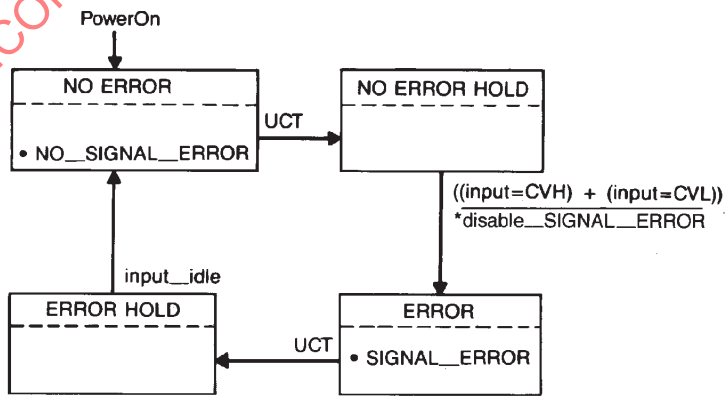

Figure 12–8—DTE PLS Error Sense function

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12.3.2.3.5 Carrier Sense function

The Carrier Sense function performs the task of sending CARRIER_STATUS to the MAC sublayer whenever the input becomes active or idle, as detected by the PMA sublayer. The state diagram of Figure 12–9 depicts the Carrier Sense function operation.

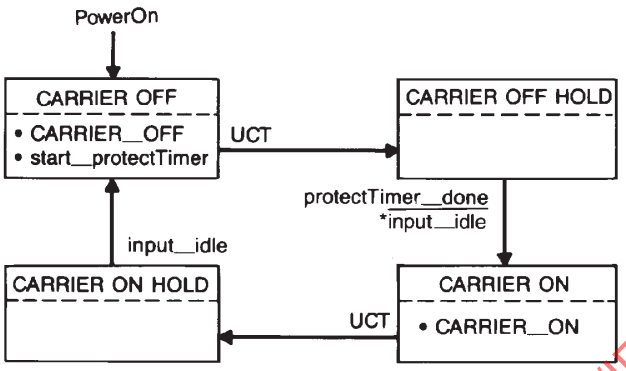

Figure 12–9—DTE PLS Carrier Sense function

A timer may be used by the Carrier Sense function to implement the protection period described in 12.5.3.2.3. It is started by "start-protectTimer" and asserts "protectTimer_done" after 0 to 30 μs since starting.

12.3.2.4 Signal encoding

Five distinct symbols can be transmitted on the line: CD0, CD1, CVL, CVH, and IDL. Of these, CVL and CVH are transmitted only as part of the collision presence reporting pattern CP.

12.3.2.4.1 Data transmission rate

The data transmission rate (BR) is 1 Mb/s ± 0.01%. A bit time (BT) is therefore nominally 1 μs.

12.3.2.4.2 Data symbol encoding

Manchester encoding is used for the transmission of packets. Manchester encoding is a binary signaling mechanism that combines data and clock into bit cells. Each bit cell is split into two halves with the second half containing the binary inverse of the first half; a transition always occurs in the middle of each bit cell. During the first half of the bit cell, the encoded signal is the logical complement of the bit value being encoded. During the second half of the bit cell, the encoded signal is the uncomplemented value of the bit being encoded. Thus, a CD0 is encoded as a bit cell in which the first half is HI and the second half is LO. A CD1 is encoded as a bit cell in which the first half is LO and the second half is HI. Examples of Manchester waveforms are shown in Figure 12–10. The zero crossings of an ideal Manchester waveform occur on precise half-bit-cell boundaries. The zero crossings of real waveforms may include timing jitter that causes deviation from these "idealized zero crossings."

12.3.2.4.3 Collision presence encoding

Two signals, CVL and CVH, that are transmitted only as part of the collision presence reporting pattern, CP, violate the normal Manchester encoding rule requiring a transition in the middle of each symbol. A CVH is encoded as a transition from LO to HI at the beginning of the bit cell, HI for the entire bit cell, and transition

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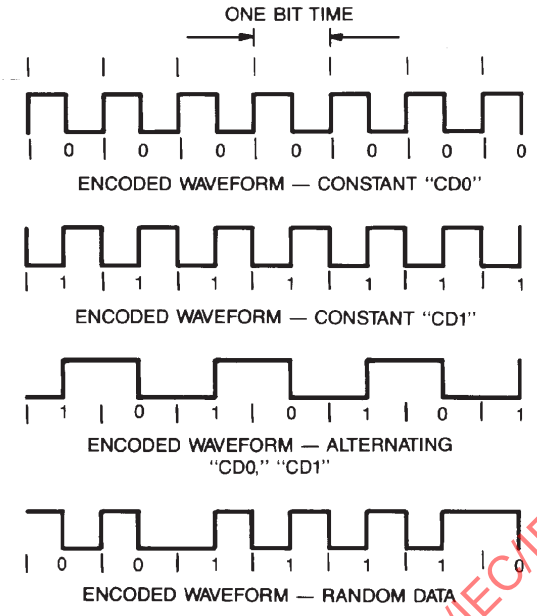

Figure 12–10—Examples of Manchester waveforms

from HI to LO at the end of the bit cell. A CVL is encoded as a transition from HI to LO at the beginning of the bit cell, LO for the entire bit cell, and transition from LO to HI at the end of the bit cell.

The Collision Presence reporting signal, CP, is a special sequence that differs from any legitimate Manchester-encoded signal. CP is encoded as a repeating sequence of 1 bit time LO, 1/2 bit time HI, 1 bit time LO, 1 bit time HI, 1/2 bit time LO, and 1 bit time HI. This may also be interpreted as repetitions of the five-symbol sequence CVL, CD0, CD1, CD0, CVH. Should a transmitter's or receiver's timing be shifted by 1/2 bit time, then the same sequence will be interpretable as repetitions of CD1, CVL, CVH, CD1, CD0. In either case, the presence of non-Manchester symbols distinguishes the sequence from data. Examples of Collision Presence waveforms are shown in Figure 12–11. See 12.3.2.2.5 and 12.4.3.2 for further details on the detection and generation of CP.

NOTE—CP is the minimal length sequence that meets the following design criteria:

a) The sequence should not look like legitimate Manchester-encoded data even if the receiver does not lock onto the correct bit-cell boundaries.
b) The sequence should maintain overall dc balance. That is, it should be HI 50% of the time and LO the other 50%.
c) The signal should occupy the same part of the frequency spectrum as normal data. That is, transitions should occur every half or whole bit time so that the fundamental signaling frequencies of BR/2 and BR are maintained. Furthermore, allowing more than one bit time to pass without a transition would introduce ambiguity with the idle line condition (IDL).

12.3.2.4.4 Idle line encoding

The line condition IDL is also used as an encoded signal. An IDL always starts with a HI signal level. Since IDL always starts with a HI signal, an additional transition will be added to the data stream if the last bit sent was a zero. This transition cannot be confused with clocked data (CD0 or CD1) since the transition will occur at the start of a bit cell. There will be no transition in the middle of the bit cell. The HI signal level, as sent by a transmitter, shall be maintained for a minimum of 2 bit times.

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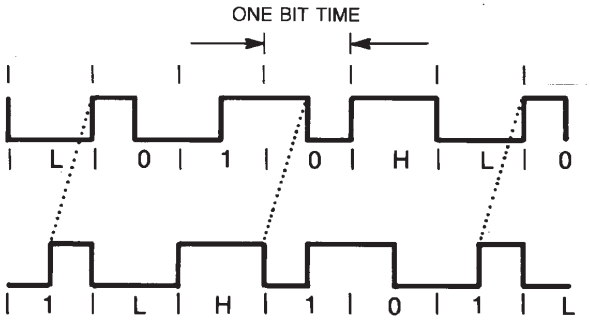

Figure 12–11—Examples of collision presence waveforms

12.4 Hub specification

12.4.1 Overview

This subclause defines the logical characteristics of the hub used in 1BASE5. The relationship of this specification to the entire standard is shown in Figure 12–12.

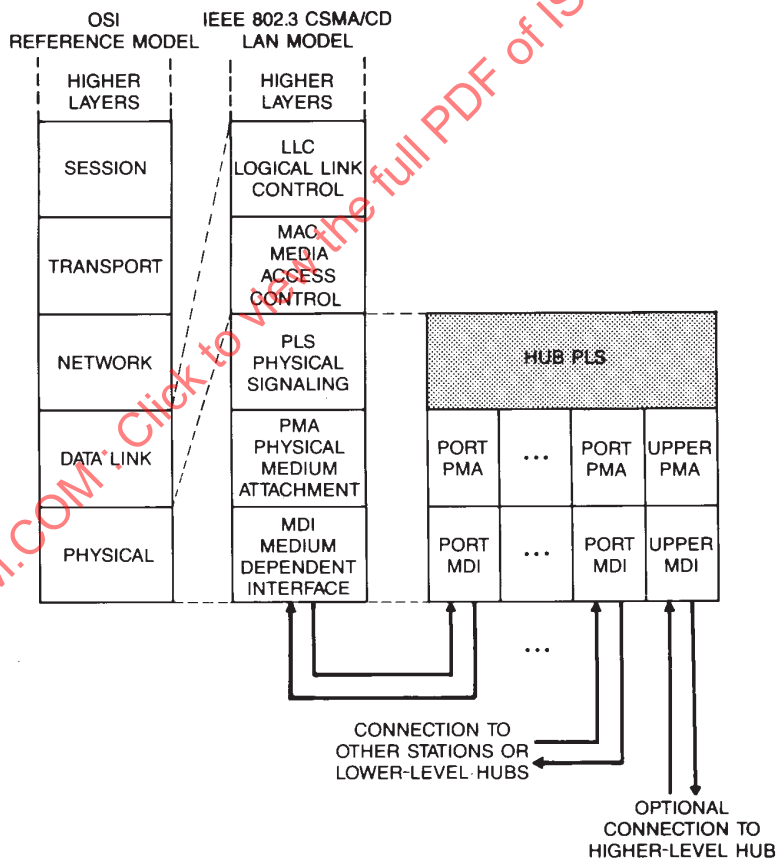

Figure 12–12—Hub relationship to the OSI reference model and the IEEE 802.3 CSMA/CD LAN model

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12.4.1.1 Summary of major concepts

a) A hub consists of a Hub PLS sublayer and a number of instances of the PMA sublayer.
b) One instance of the PMA sublayer, the "upper PMA," provides a connection to a higher-level hub. This PMA is not required for the header hub.
c) Each of the remaining instances of the PMA sublayer, called "port PMAs," provides a connection to a DTE or a lower-level hub.
d) The Hub PLS transfers data in two directions: upward from the port PMAs, to the upper PMA and downward from the upper PMA to the port PMAs.
e) The upward and downward "sides" of the hub operate independently and simultaneously.

12.4.1.2 Application perspective

The hub is a Physical Layer entity that performs two functions:

a) It retransmits incoming signals with amplitude and timing restored.
b) It detects collisions between any two or more ports and reports knowledge of the collision by transmitting a special collision presence reporting pattern.

12.4.2 Hub structure

Each hub is functionally divided into two parts: the upward side and the downward side. The upward side is responsible for combining the transmissions from DTEs and hubs lower in the network into a single transmission to the next level up. The downward side is responsible for distributing the combined signal (which is wrapped around from the upward side of the header hub) to each of the DTEs and hubs below. Except as specified in 12.4.3.2.3 and 12.4.3.2.6, the two sides function independently.

There is an upward input channel and a corresponding downward output channel for each DTE or hub immediately below the hub. Although there is no electrical connection between the two lines, they do share a connector and cable (see 12.6 and 12.7) and are collectively known as a hub port. Each port is accessed through an instance of the PMA sublayer referred to as a "port PMA."

The one output channel from the upward side and the one input channel to the downward side of a hub are similarly paired and, for all but the header hub, are connected to a port of the next-higher-level hub, They are accessed through an instance of the PMA sublayer referred to as the "upper PMA."

NOTE—A hub that includes n hub ports should be called an n-port hub, even though it may have an extra jack for the upper PMA. The latter connection should never be counted as a port, despite common engineering usage, because it does not meet the specific definition of a 1BASE5 hub port given above.

12.4.2.1 Upward side

The primary function of the upward side of a hub is to propagate signals from each of its inputs to its single output. If more than one input is active, then the Collision Presence signal CP is transmitted instead. In addition, the signals are retimed to restore the transitions to half-bit-time boundaries; see 12.4.3.2.5 for the details of retiming.

12.4.2.2 Downward side

The primary function of the downward side of a hub is to repeat signals from its one input to each of its outputs. In addition, the signals are retimed to restore the transitions to half-bit-time boundaries; see 12.4.3.2.5 for the details of retiming.

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12.4.3 Hub PLS functional specification

This subclause provides a detailed model for the Hub PLS sublayer.

12.4.3.1 Hub PLS to PMA interface

The interface between the Hub PLS and the PMA is the same as that specified in 12.3.2.1 for use between the DTE PLS and the PMA except that the *output* message from the Hub PLS to the PMA is used to transmit CVL and CVH in addition to CD0 and CD1.

12.4.3.2 Hub PLS functions

The Hub PLS sublayer functions consist of three asynchronous functions. These functions are Upward Transfer, Jabber, and Downward Transfer. All three functions are started immediately following PowerOn; an independent copy of the Jabber function is started for each port PMA. These functions are depicted in the state diagrams shown in Figure 12–13 through Figure 12–15, using the notation described in 1.2.1.

12.4.3.2.1 State diagram variables

The variables used in the state diagrams and the corresponding descriptions are the following:

a) *Port designators:* Instances of the PMA sublayer are referred to by index. PMA information is obtained by replacing the X in the desired function with the index of the PMA of interest. Furthermore, PMAs may be referenced by several special designators used as indices:

X Generic port PMA designator. When X is used in a state diagram its value indicates the particular instance of a generic function.

UPPERIndicates the upper PMA.

ALLPORTSIndicates that all port PMAs are to be considered. All port PMAs must meet a test condition in order for that test to pass.

ALLENABLEDPORTSIndicates that all port PMAs that are not disabled by the Jabber function are to be considered. All such port PMAs must meet a test condition in order for that test to pass.

ONEPORTIndicates that all port PMAs that are not disabled by the Jabber function are to be considered. One, but not more than one, such port PMA must meet a test condition in order for that test to pass.

>ONEPORTIndicates that all port PMAs that are not disabled by the Jabber function are to be considered. Two or more such port PMAs must meet a test condition in order for that test to pass.

N Defined by the PORT function on exiting from the UPWARD IDLE state of Figure 12–13. It indicates which port PMA caused the exit from the UPWARD IDLE state.

b) *Port functions*:

PORT(TestCondition)Returns the index of a port PMA passing the indicated test condition. If multiple port PMAs meet the test condition, the PORT function will return one and only one of the acceptable values.

c) *Input variables:*

INPUT(X) Indicates the state of activity on the designated PMA input channel. It may be either “idle” or “active.” The former indicates that *input_idle* is asserted; the latter indicates that it is not asserted.

input(X) Used to receive an *input* message (see 12.3.2.1) from the designated PMA input channel.

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probation_alternative Used to distinguish between the two allowed alternatives for exiting the JABBER JAM state of Figure 12–14 when an active port becomes idle. The implementer of a hub may treat the variable as either true or false.

d) *Output variables:*

output(X)Used to send an *output* message (see 12.3.2.1 and 12.4.3.1) to the designated PMA output channel.

output_idle(X)Used to send an *output_idle* message (see 12.3.2.1) on the designated PMA output channel.

e) *Inter process flags:*

send_collisionUsed by the Upward Signal Transfer function to indicate a series of *output* messages to the upper PMA sublayer, the effect of which is to transmit the CP signal, as described in 12.3.2.4.2, 12.3.2.4.3, and 12.4.3.2.7.

jabber_collisionUsed by the various instances of the Jabber function to signal the Upward Signal Transfer function that CP should be generated.

disable_input(X)Used to disable the designated PMA input channel. The input is re-enabled when disable-input(X) is no longer asserted. Only the Upward Signal Transfer function is affected by the disabling of a port (via the ALLENABLEDPORTS, ONEPORT, and >ONEPORT designators).

jabberTime1Used by the Jabber function (see 12.4.3.2.3) to detect excessively long transmissions. It is started by "start_jabberTime1." "jabberTime1_done" is satisfied when the timer has expired.

jabberTime2Used by the Jabber function (see 12.4.3.2.3) to determine when to disable ports due to excessively long transmissions. It is started by "start_jabberTime2." "jabberTime2_done" is satisfied when the timer has expired.

12.4.3.2.2 Upward Signal Transfer function

The Upward Signal Transfer function combines signals from the various port inputs and passes them on to the upper output. It also detects and reports collisions as appropriate. The state diagram of Figure 12–13 depicts its operation.

Signals are propagated upward according to the following rules, except as controlled by the Jabber function (see 12.4.3.2.3):

a) If IDL is present on all port inputs, then transmit IDL.
b) If IDL is present on all but one of the port inputs, then repeat the signal received from that one line. If that one signal is CP, then a hub may generate its own CP signal instead of repeating the received CP signal.
c) If two or more inputs are active (non-IDL) at the same time, then transmit CP and continue transmitting CP until all inputs indicate IDL again.

Whenever the hub finishes transmitting CP, it shall then transmit IDL, including the extended HI period.

12.4.3.2.3 Jabber function

The Jabber function detects abnormally long transmissions and takes appropriate action to abort them. The state diagram of Figure 12–14 depicts its operation.

Two timers are used by the Jabber function. They may be implemented either as local timers for each instance of the Jabber function or as global timers shared by all instances. Furthermore, because the two timers are always started concurrently, an implementation may share circuitry between the two.

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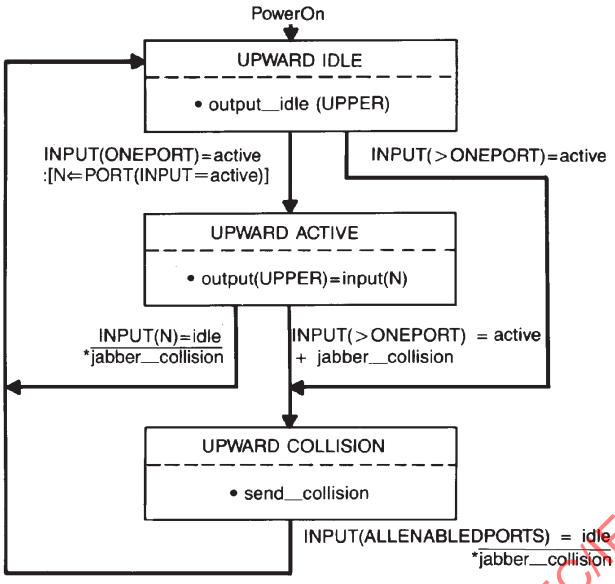

Figure 12–13—Hub PLS Upward Transfer function

The first timer is started by "start_jabberTime1" and asserts "jabberTime1_done" after 25 to 50 ms since starting. If implemented as a single global timer, assertion of start_jabberTime1 by any instance of the Jabber function with any other instance(s) still waiting for that timer shall not restart the timer, thereby shortening the waiting period for the latest instance.

Similarly, the second timer is started by "start_jabberTime2" and asserts "jabberTime2_done" after 51 to 100 ms since starting. If implemented as a single global timer, assertion of start_jabberTime2 by any instance of the Jabber function with any other instance(s) still waiting for that timer shall not restart the timer, thereby shortening the waiting period for the latest instance. Furthermore, if this second timer is implemented as a single global timer, then assertion of start_jabberTime1 by any instance of the Jabber function with any other instance(s) still waiting for just the second timer (in the JABBER JAM state) shall be treated as if the first timer expires immediately (asserting jabberTime1_done) for the latest instance, thereby causing that instance to join the other instance(s) waiting for the second timer.

Hardware within the upward side of a hub shall provide a window of 25 to 50 ms, during which time a normal packet or CP sequence may be propagated upward. If any port input (or, as an alternative implementation, the hub's combined upward signal) exceeds this duration without becoming idle, then the hub shall switch to transmitting CP until 51 to 100 ms after the beginning of the window and then, if that input is still active, disable that input (or all nonidle inputs) until it once again becomes active while the downward side is idle.

The "probation_alternative" input variable is used to distinguish between the two allowed alternatives for exiting the JABBER JAM state of Figure 12–14 when an active port becomes idle. The implementer of a hub may treat the variable as either true or false. If true, the port will enter the JABBER PROBATION state (via the JABBER SHUTOFF state); if false, the port will instead return to the JABBER IDLE state.

12.4.3.2.4 Downward Signal Transfer function

The Downward Signal Transfer function repeats signals from the upper input to the various port outputs. The state diagram of Figure 12–15 depicts its operation.

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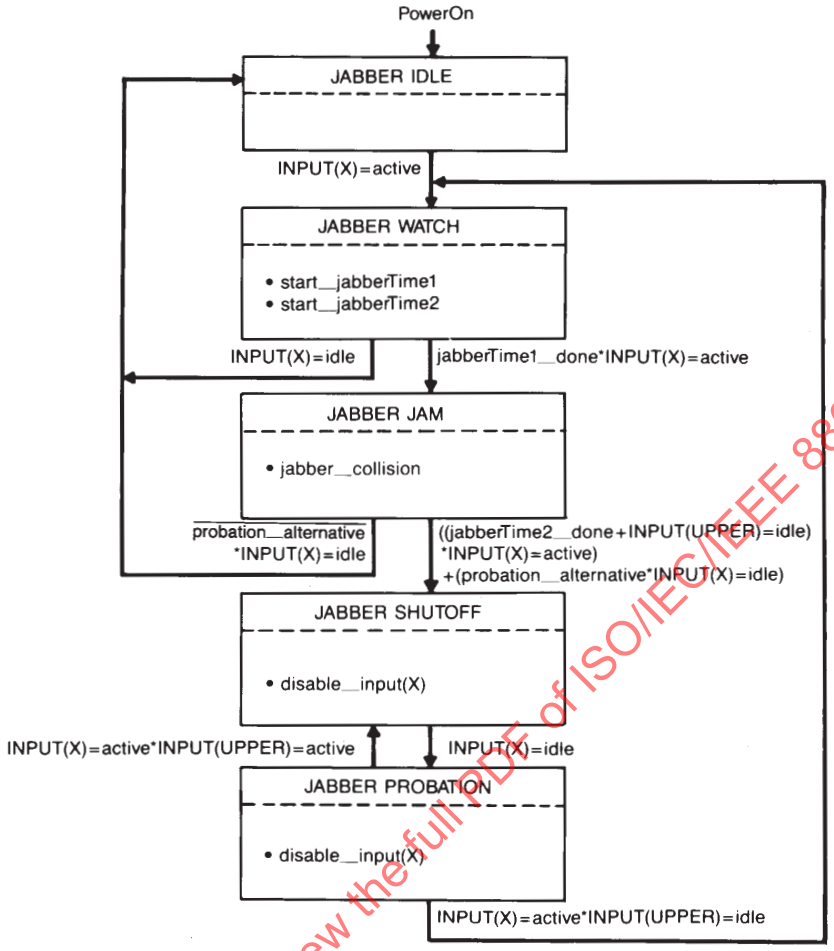

Figure 12–14—Hub PLS Jabber function for port X

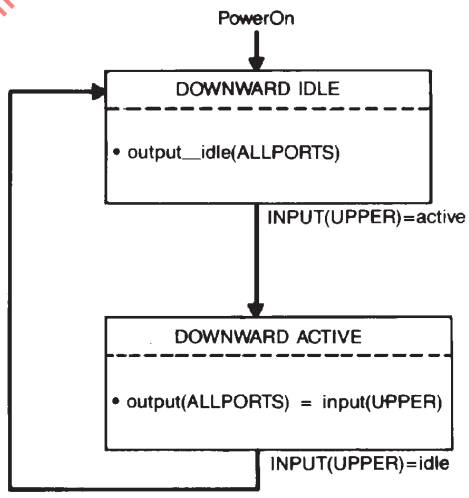

Figure 12–15—Hub PLS Downward Transfer function

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The downward side of a hub may detect the Collision Presence signal at the upper input and generate its own CP signal to be transmitted at the port outputs (in place of repeating the received CP signal).

Whenever the hub finishes transmitting CP, it shall then transmit IDL, including the extended HI period.

12.4.3.2.5 Retiming (jitter removal)

Each side of each hub shall retime any clocked signals that it propagates so that the transitions occur on half-bit-time boundaries, thereby avoiding accumulation of excessive jitter. Such retiming shall preserve the sequence of CD0, CD1, CVL, and CVH symbols being propagated.

If an ambiguity exists in the incoming bit cells due to excessive noise or jitter, than the appropriate side of the hub may either switch to generating CP or replace the erroneous bit cell with an arbitrary combination of half or whole bit cells.

Retiming also accounts for differences (if any) in clock rates between that used to send bit cells to the hub and that used to send them out from the hub. Excessive differences in clock rates (caused by clocks not meeting 12.3.2.4.1) and excessively long packets (caused by exceeding maxFrameSize) may each cause the capacity of the retiming function to be exceeded. In such circumstances, the appropriate side of the hub may either switch to transmitting CP or add or delete half or whole bit cells as needed.

Whenever bit cells are added, deleted, or replaced, the hub shall maintain synchronization of the outgoing bit cells to a half or whole bit cell boundary. Furthermore, it shall not generate periods of more than one bit time without a transition.

12.4.3.2.6 Header hub wrap-around

For each particular network configuration, one hub operates as the header hub and all others as intermediate hubs. It is suggested, but not required, that hub implementations be capable of being used for either purpose. Methods for switching between these two modes are beyond the scope of this standard.

For an intermediate hub, the upper output shall be connected to a port input of the next higher-level hub and the upper input shall be connected to a port output of a higher-level hub.

For the header hub, the upper output shall be connected to the upper input. This wraparound may appropriately bypass parts of the PMA specification so long as the resulting implementation is functionally equivalent to one with a wired connection. For example, signals internal to the hub need not be translated to the corresponding external levels and then translated back to internal levels. Similarly, it shall not be necessary to retime the wrapped signal twice, once in the upward side and then again in the downward side of the same header hub; a single retiming is permissible.

12.4.3.2.7 Collision presence startup

When a hub starts generating CP (as specified in 12.4.3.2.2 through 12.4.3.2.5) it shall synchronize the startup to a half or whole bit-cell boundary of any immediately preceding signal. If it was sending IDL immediately before the CP, no synchronization or preamble is required.

A hub may start transmission of CP at any point in the sequence that does not result in periods of more than one bit time without a transition during the switch from passing on data to sending CP. Depending on the preceding signal, it may start with L010H, 010HL, 10HL0, 0HL01, or HL010. Because startup may be synchronized to any half-bit-cell boundary, a hub may also transmit the shifted version of CP starting with 1LH10, LH101, H101L, 101LH, or 01LH1.

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12.4.3.3 Reliability

Hubs shall be designed to provide a mean time between failure (MTBF) of at least 45 000 hours of operation. Hubs, including the associated connectors and other passive components, should be designed to minimize the probability that, a particular failure results in total network failure. Furthermore, the port electronics of each hub should be designed so as to minimize the probability that the failure of one port prevents communication by equipment attached to the other ports.

12.5 Physical medium attachment (PMA) specification

12.5.1 Overview

This subclause defines the Physical Medium Attachment (PMA) sublayer for 1BASE5. The relationship of this specification to the entire International Standard is shown in Figure 12–16. The PMA sublayer connects the PLS sublayer to the Medium Dependent Interface (MDI).

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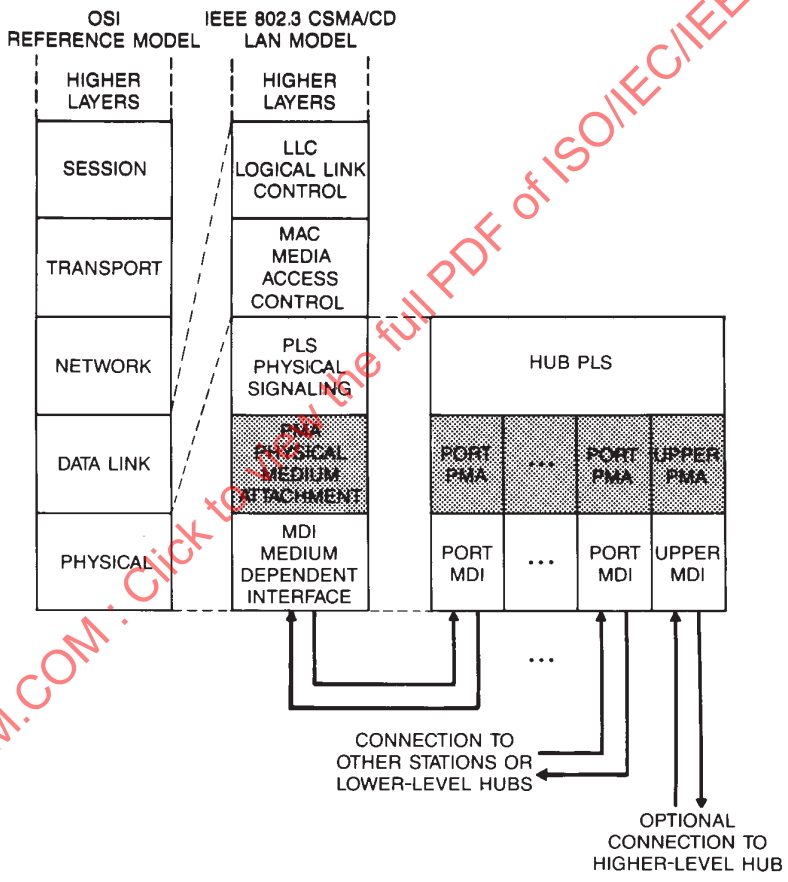

Figure 12–16—Physical medium attachment, relationship to the OSI reference model and the IEEE 802.3 CSMA/CD LAN model

12.5.2 PLS–PMA interface

The interface between the PLS and the PMA sublayers is specified in 12.3.2.1 for DTEs and in 12.4.3.1 for hubs.

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12.5.3 Signal characteristics

12.5.3.1 Transmitter characteristics

Transmitters should operate properly when loaded with any cable meeting the requirements of 12.7. To approximate the boundary conditions of such loading, two specific test loads are specified. Transmitters shall meet all requirements of this subclause when connected to both the "light" (115 Ω) load shown in Figure 12–17 and the "heavy" (approximately 80 Ω) load shown in Figure 12–18. It is expected that transmitters that perform correctly with these two loads will also perform acceptably under intermediate loading conditions.

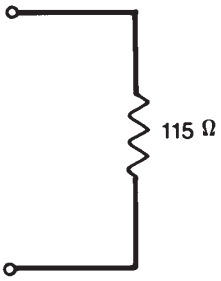

Figure 12–17—Simulated light load

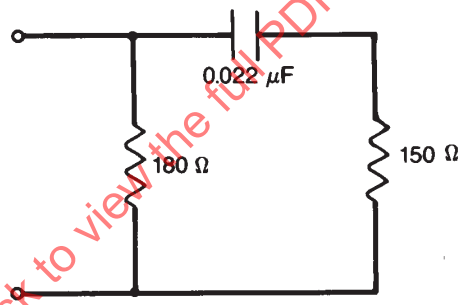

Figure 12–18—Simulated heavy load

12.5.3.1.1 Differential output voltage

For simplicity of explanation, the text and figures of this subclause describe the differential output voltage in terms of voltage magnitudes. The requirements of this subclause apply to the negative pulses as well as the positive ones.

Beginning with the second bit of the preamble (or CP, if no preamble is present), pulses of duration BT/2 shall meet the conditions of Figure 12–19. Pulses of duration BT shall meet the conditions of Figure 12–20. After the zero-crossing, the output shall exceed the voltage of a signal rising from the zero-crossing to 2.0 V with a slope of magnitude 20 mV/ns. The output shall remain above 2.0 V until 100 ns before the next, zero-crossing. The peak output voltage shall not exceed 3.65 V. While falling from 2.0 V to the zero-crossing, the signal shall exceed the voltage of a signal falling from 2.0 V to the zero-crossing with a slope of magnitude 20 mV/ns.

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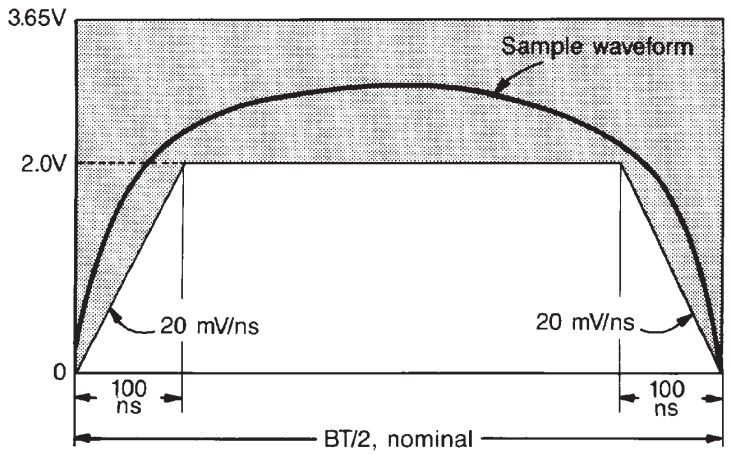

Figure 12–19—Differential output voltage, nominal duration BT/2

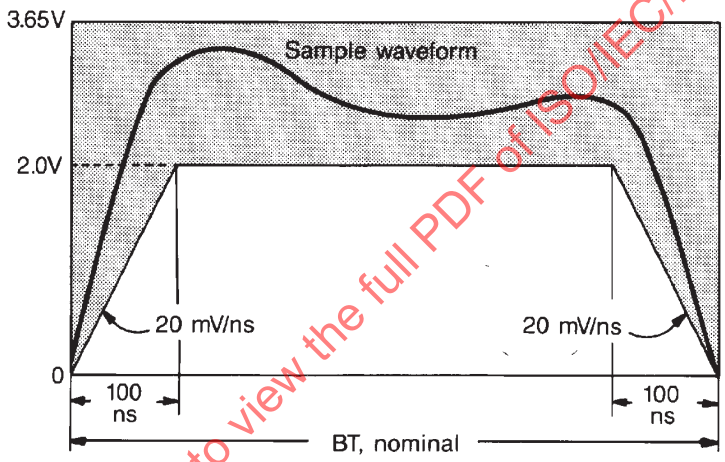

Figure 12–20—Differential output voltage, duration BT

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For pulses of duration BT, the average voltage that appears from 100 ns after the zero-crossing through BT/2 shall be between 0.95 and 1.8 times the average voltage that appears from time BT/2 through 100 ns before the following zero-crossing. Similarly, for pulses of duration BT, the peak voltage that appears from 100 ns after the zero-crossing through BT/2 shall be between 0.95 and 1.8 times the peak voltage that appears from time BT/2 through 100 ns before the following zero-crossing.

NOTE—The purpose of the above restrictions on average and peak voltages is to avoid transmitter waveforms that peak excessively during the second half of signals of duration BT, resulting in excessive jitter at the receiver. Some equalization to produce slight droop in the second half of signals of duration BT, on the other hand, may help decrease jitter at the far end of long cables.

The amplitude of the power spectrum at the output of the transmitter for all possible sequences of signals shall not exceed that produced by an idealized transmitter sending corresponding rectangular waveforms with magnitude 3.65 V at any frequency.

When a transmitter enters the idle state, it shall maintain a minimum differential output, voltage of 2.0 V from 100 ns through 2 BT after the last low-to high transition, as illustrated in Figure 12–21. The differential

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output voltage shall then fall to 1.1 V within 3 BT after that same low-to-high transition. Starting when the differential output voltage first reaches 1.1 V, the magnitude of the output voltage driven into the test loads indicated in Figure 12–22 and Figure 12–23 shall then remain within the limits indicated in Figure 12–21 until the transmitter leaves the idle state.

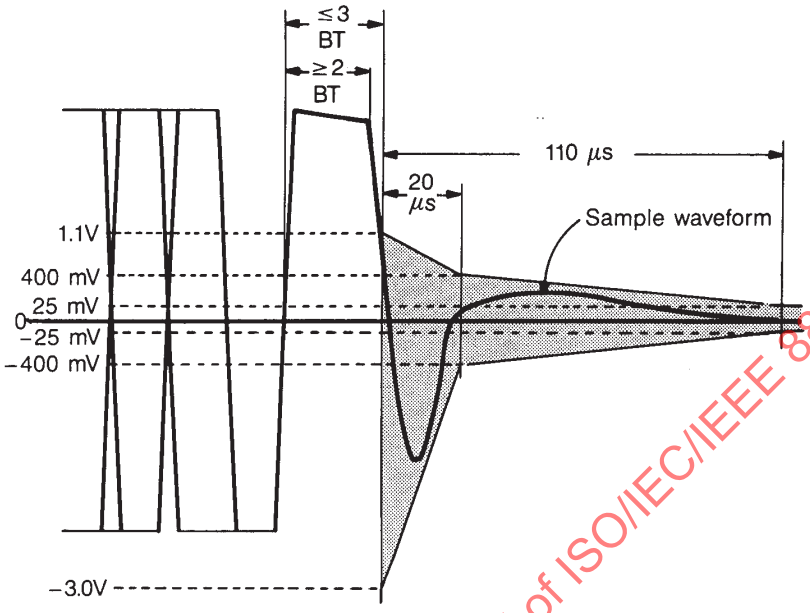

Figure 12–21—Transmitter waveform for idle

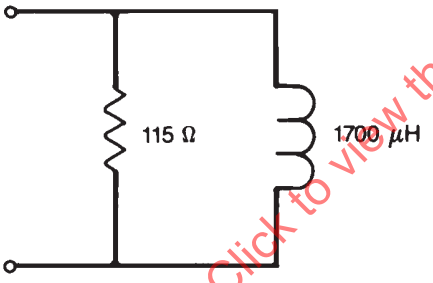

Figure 12–22—Start-of-idle test load #1

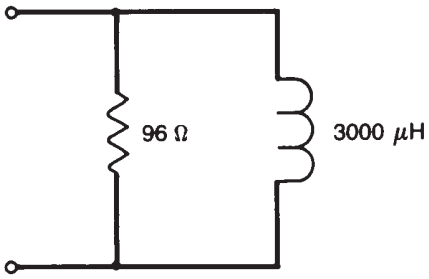

Figure 12–23—Start-of-idle test load #2

The transmitter output at the start of idle may exhibit overshoot, ringing, slow voltage decay, or a combination thereof due to the following factors:

a) Change in transmitter source impedance between the active and idle states
b) Difference in the magnitudes of the differential output voltage between the high and low output states (ΔV_{OD})
c) Waveform asymmetry at the transmitter (ΔT)
d) Transmitter and receiver (transformer) inductance (L)

NOTE 1—The contribution to the undershoot from each of these can be computed with the following equations:

$$V_{\Delta V_{OD}} = \pm V_{OD} \times (R_{OFF}/2R_N)$$

$$V_{\Delta T} = (\pm \Delta T/1000\ \text{ns}) \times V_P (R_{OFF}/R_{ON})$$

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$$V_L = V_P \times (1 - e^{-2.75\ \mu s/(L_P/R_{ON})}) \times (R_{OFF}/R_{ON})$$

where

$R_{OFF} = (R_{SRC\text{-}OFF} \parallel R_L)$

$R_{ON} = (R_{SRC\text{-}ON} \parallel R_L)$

$R_{SRC\text{-}OFF}$ = source impedance (Ω) when the driver is off

$R_{SRC\text{-}ON}$ = source impedance (Ω) when the driver is on

R_L = load impedance (Ω)

L_P = combined inductance (μH) of the transmitter and receiver transformers

ΔV_{OD} = the difference (V) in magnitude of the HI and LO output voltages

ΔT = asymmetry of the waveform equals the difference between the average HI and average LO pulse widths (ns) at the transmitter

VP = the maximum output voltage (V) during the start of IDL

NOTE 2—The waveform shown in Figure 12–21 and the equations in the preceding note apply to a transmitter connected to the test loads of Figure 12–22 and Figure 12–23. An actual receiver may present a more complex termination impedance and so the undershoot or overshoot may exceed that encountered with the test loads.

12.5.3.1.2 Output timing jitter

The transmitted signal zero-crossings shall deviate from the idealized zero-crossings by no more than ± 10 ns.

12.5.3.1.3 Transmitter impedance balance

The longitudinal to metallic impedance balance of the transmitter, defined as 20 $\log_{10}(E_{test}/E_{dif})$, where E_{test} is an externally applied ac voltage, as shown in Figure 12–24, shall exceed 44 dB at all frequencies up to and including 4BR in the idle and nonidle states.

NOTE—It may be difficult to measure the transmitter impedance balance in the nonidle state. A frequency-selective wavemeter or other measurement technique may be required. Furthermore, the balance of the test equipment (such as the matching of the 400 Ω resistors) must exceed that required of the transmitter.

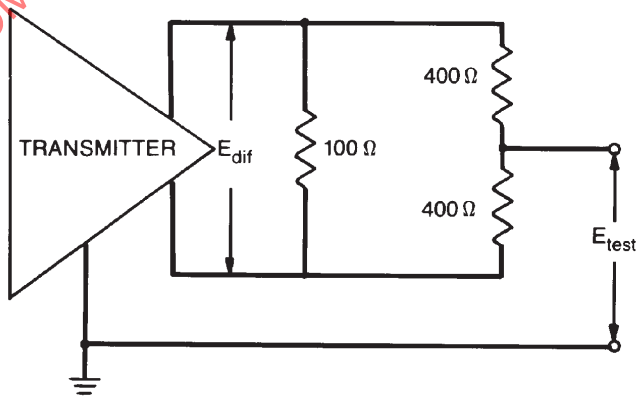

Figure 12–24—Transmitter impedance balance

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12.5.3.1.4 Common-mode output voltage

The magnitude of the total common-mode output voltage of the transmitter, E_{cm}, measured as shown in Figure 12–25, shall not exceed 300 mV.

NOTE—The implementer should consider any applicable local, national, or international regulations and standards concerning RF emission. Driving unshielded twisted pairs with high-frequency common-mode voltages may result in interference to other equipment.

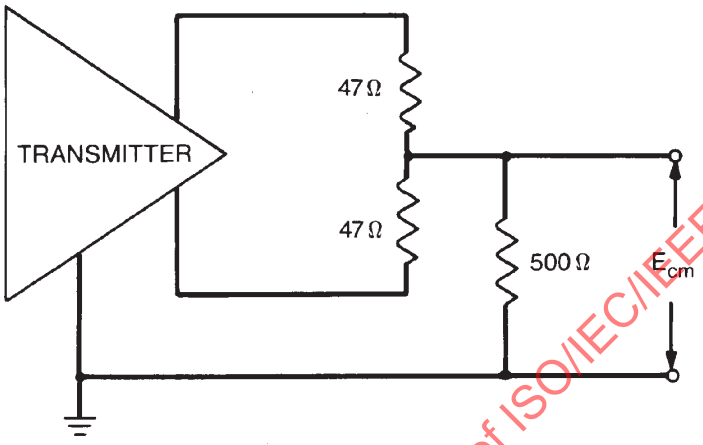

Figure 12–25—Common-mode output voltage

12.5.3.1.5 Common-mode tolerance

Transmitters shall meet the requirements of 12.5.3.1.1 and 12.5.3.1.2 even in the presence of common-mode sinusoidal voltage, E_{cm} (as shown in Figure 12–26), of ± 20 V peak at frequencies from 40 kHz through 6BR.

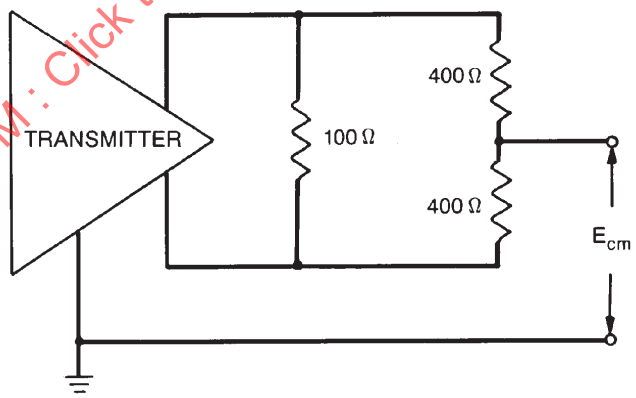

Figure 12–26—Transmitter common-mode tolerance

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12.5.3.1.6 Transmitter fault tolerance

Transmitters, both when idle and when nonidle, shall tolerate the application of short circuits across their outputs for an indefinite period of time without damage and shall resume normal operation after such faults are removed. The magnitude of the current through such a short circuit shall not exceed 300 mA.

Transmitters, both when idle and when nonidle, shall withstand, without damage, a 1000 V common-mode impulse of either polarity, applied as indicated in Figure 12–27. The shape of the impulse shall be 0.3/50 μs (300 ns virtual front time, 50 μs virtual time of half value), as defined in IEC 60060.

NOTE—Tolerance of, and recovery from, the application of the telephony voltages described in 12.10.2 is optional, but the safety requirements of that subclause are mandatory.

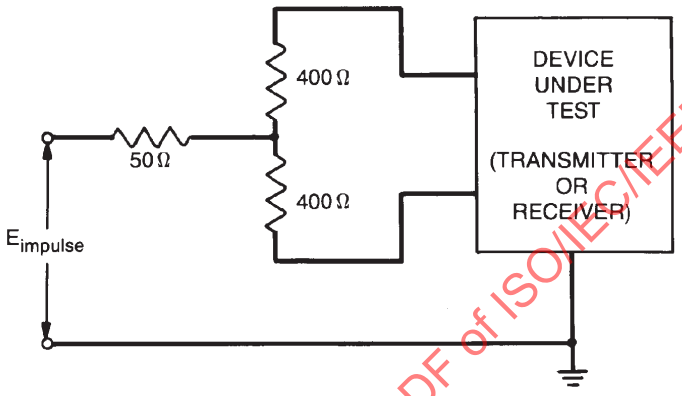

Figure 12–27—Common-mode impulse test

12.5.3.2 Receiver characteristics

12.5.3.2.1 Differential input voltage

The receiver shall operate properly when a signal meeting the minimum magnitude requirements of Figure 12–28 is received. When less than 300 mV, the magnitude of the voltage will exceed that of a straight line through the nearest zero-crossing with slope of magnitude 9 mV/ns. That is, the average slew rate near each zero-crossing will exceed 9 mV/ns. The magnitude of the voltage will also remain at or above 1.0 V for some period lasting at least 150 ns (650 ns for pulses of duration BT) that starts within 250 ns of the preceding zero-crossing and its peak will be at least 1.1 V.

12.5.3.2.2 Input timing jitter

Receivers shall operate properly with zero-crossing jitter of up to ± 32 ns from the ideal.

12.5.3.2.3 Idle input behavior

The IDL condition shall be detected within 1.8 bit times of the last low-to-high transition at the receiver.

NOTE 1—It is necessary to distinguish CVH from IDL.
NOTE 2—System jitter considerations make it impractical to detect IDL (<etd>, end-of-transmission delimiter) any sooner than 1.3 bit times. The specific implementation of the clock recovery mechanism, or equivalent, determines the lower bound on the actual IDL detection time. Adequate margin should be provided between the lower bound and 1.8 bit times.

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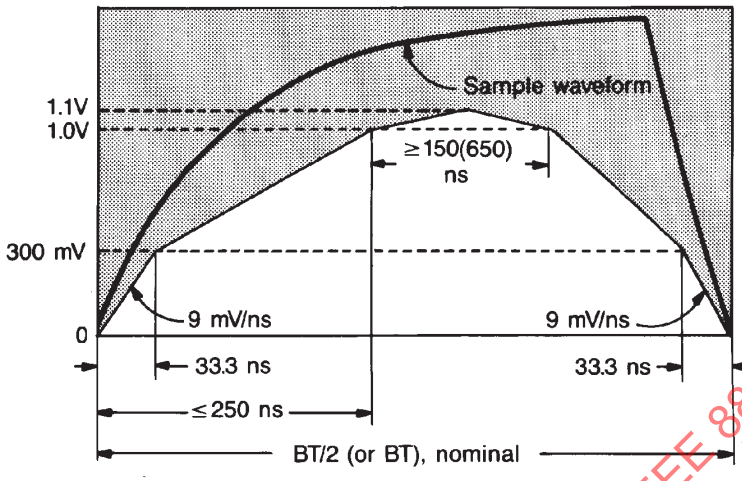

Figure 12–28—Receiver signal envelope

The receiver shall take precautions to ensure that the HI-to-silence transition of the start of IDL is not falsely interpreted as a silence-to-nonidle transition, even in the presence of signal droop, overshoot, ringing, slow voltage decay, or a combination thereof due to capacitive and inductive effects in the transmitter, cable, and receiver, including those discussed in 12.5.3.1.1.

To this end, a receiver in a hub shall treat its input as if it were idle for between 20 and 30 μs after detecting IDL. The timing of this "protection" period for the port PMAs may use a single timer that is started when all ports have become idle or disabled by the Jabber function. Receivers in DTEs may include a similar protection period of up to 30 μs.

NOTE—The protection period is required in hubs because erroneously interpreting the start-of-idle as a new transmission will result in propagation of the error to DTEs, despite any precautions taken in those DTEs. The protection period is optional in DTEs because any implementation error in a DTE will affect only that particular DTE.

12.5.3.2.4 Differential input impedance

The (complex) differential input impedance of the receiver, $Z_{receiver}$, shall be such that the reflection attenuation, defined as $20 \log_{10} (|Z_{receiver} + Z_{cable}|/| Z_{receiver} - Z_{cable}|)$, where Z_{cable} is the differential characteristic impedance of the attached cable, exceeds 16 dB over the range BR/2 through 2BR for all cables meeting the requirements of 12.7.2.

12.5.3.2.5 Common-mode rejection

Receivers shall assume the proper output state for any differential input signal, E_s, that results in a signal, E_{dif}, that meets 12.5.3.2.1 and 12.5.3.2.2, even in the presence of common-mode sinusoidal, voltages, E_{cm} (as shown in Figure 12–29), of ±20 V peak at frequencies from 40 kHz through 6BR.

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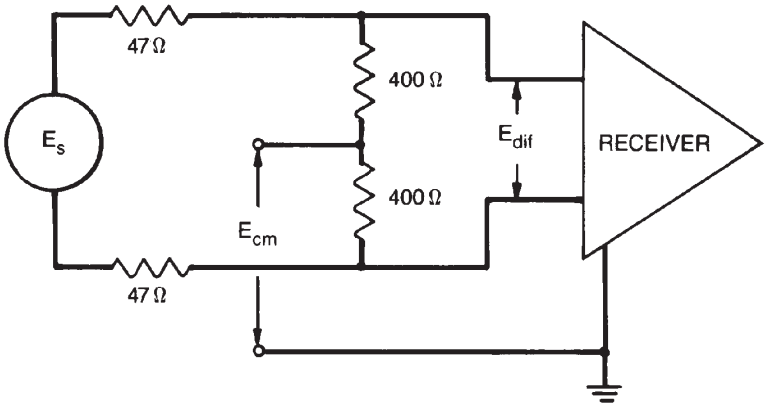

Figure 12–29—Receiver common-mode rejection

12.5.3.2.6 Noise immunity

Receivers shall meet the following limits on average error ratios when the noise described in 12.7.4 is added to the signals described in 12.5.3.2.1 and 12.5.3.2.2:

a) When nonidle, the receiver error ratio shall not exceed one error in 10^8 bits.
b) When idle, a receiver used in a DTE shall not falsely detect carrier more than one in 100 s.
c) When idle, a receiver used in a hub shall not falsely detect carrier more than once in 1500 s.

NOTE—Receivers whose inputs include a 2–4 MHz, 2-pole, low-pass, Butterworth filter and a 560 mV squelch level will meet this last requirement for idle-mode noise immunity yet still perform properly with the weakest signal allowed by 12.5.3.2.1.

12.5.3.2.7 Receiver fault tolerance

Receivers shall tolerate the application of short circuits across their inputs for an indefinite period of time without damage and shall resume normal operation after such faults are removed.

Receivers shall withstand, without damage, a 1000 V common-mode impulse of either polarity, applied as indicated in Figure 12–27. The shape of the impulse shall be 0.3/50 μs (300 ns virtual front time, 50 μs virtual time of half value), as defined in IEC 60060.

NOTE—Tolerance of, and recovery from, the application of the telephony voltages described in 12.10.2 is optional, but the safety requirements of that subclause are mandatory.

12.6 Medium Dependent Interface (MDI) specification

12.6.1 Line interface connector

8-pin connectors meeting the requirements of Clause 3 and Figure 1 through Figure 5 of IEC 60603-7 shall be used as the compatibility interface between the PMA and the medium. The use of other types of connectors, if any, within a PMA or within the medium, although not explicitly prohibited, is outside the scope of this standard.

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12.6.2 Connector contact assignments

The contacts of the connectors, as depicted in Figure 12–32 and Figure 12–31, shall correspond to signaling circuits as indicated below:

Contact	Signal
1	Upward Data+ (positive for HI signal)
2	Upward Data– (negative for HI signal)
3	Downward Data+ (positive for HI signal)
4	not used by 1BASE5
5	not used by 1BASE5
6	Downward Data– (negative for HI signal)
7	reserved
8	reserved

For DTEs and the upper MDI of hubs, contacts 1 and 2 are used for transmitting and contacts 3 and 6 are used for receiving. For the port MDIs of hubs, however, contacts 1 and 2 are used for receiving and contacts 3 and 6 are used for transmitting.

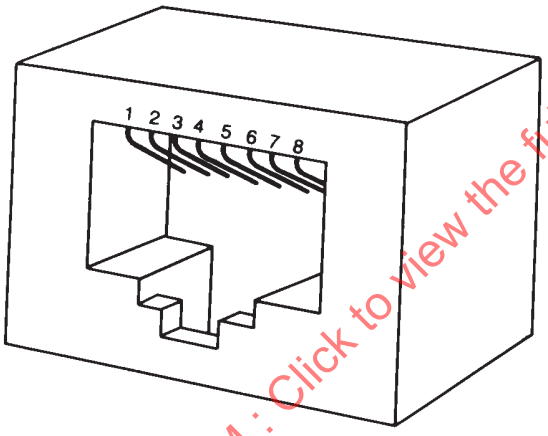

Figure 12–30—DTE and hub connector

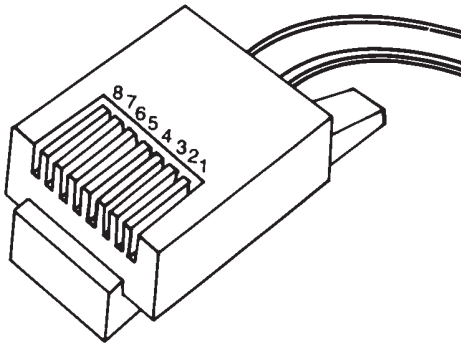

Figure 12–31—Cable connector

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12.6.3 Labeling

To distinguish 1BASE5 connectors from those used for other purposes, it is recommended that appropriate labels be affixed to wall outlets and other connectors. This is particularly important in environments in which the specified 8-contact connectors are used for more than one purpose.

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12.7 Cable medium characteristics

12.7.1 Overview

A significant number of IBASE5 networks are expected to utilize in-place building wiring. In this environment, DTEs connect to wall outlets using twisted-pair telephone cord. The wall outlets, in turn, connect to wiring closets, where hubs could be located, using standard telephone wiring. This wiring typically consists of 0.4–0.6 mm diameter (26–22 gauge) unshielded twisted pairs.

12.7.2 Transmission parameters

Each wire pair used to interconnect DTEs and hubs shall meet the requirements of 12.9.3 and also have the following characteristics.

12.7.2.1 Attenuation

Total cable attenuation between a transmitter and the corresponding receiver shall be no more than 6.5 dB at all frequencies between BR/2 and BR, 9.2 dB at frequencies between BR and 2BR, and 13.8 dB at frequencies between 2BR and 4BR.

12.7.2.2 Differential characteristic impedance

The magnitude of the differential characteristic impedance at frequency BR, Z_{BR}, of each wire pair used shall be between 80 Ω and 115 Ω. In addition, the magnitude and phase angle of the characteristic impedance at each of the following frequencies shall be within the corresponding ranges indicated:

Magnitude			Phase angle	
Frequency	**Minimum**	**Maximum**	**Minimum**	**Maximum**
BR/4	Z_{BR}	Z_{BR} + 7 Ω	–10°	0°
BR/2	Z_{BR}	Z_{BR} + 5 Ω	–8°	0°
BR	Z_{BR}	Z_{BR}	–6°	0°
2BR	Z_{BR} – 4 Ω	Z_{BR}	–4°	0°
4BR	Z_{BR} – 5 Ω	Z_{BR}	–3°	0°

12.7.2.3 Medium timing jitter

Intersymbol interference and reflections due to impedance mismatches between the sections of a cable segment can introduce jitter in the timing of the zero-crossings. A cable segment terminated in 96 Ω shall add no more than ± 17 ns, referenced to the transmit clock, of edge jitter when driven with a rectangular signal of magnitude 2.5 V through a source impedance 22 Ω. The driving signal shall be a Manchester-encoded pseudo-random sequence of data with a repetition period of at least 511 bits.

NOTE 1—The reflections caused by splicing two cable sections that have different characteristic impedances (but that each meet the requirements of 12.7.2.2) will not contribute significantly to timing jitter if the splice is within 10 m of either end of the segment.
NOTE 2—Branches off a wire pair (often referred to as “bridged taps” or “stubs”) will generally cause excessive jitter and so should be avoided.
NOTE 3—Jitter can be measured at the receiving end of a segment using an oscilloscope. The oscilloscope is triggered

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on zero-crossings; the deviation of subsequent zero-crossings from multiples of BT/2 is then observed. The deviation of each zero-crossing must not exceed ±34 ns.

12.7.2.4 Dispersion

Each wire pair shall produce an output signal that meets the zero-crossing edge rate described in 12.5.3.2.1 when driven with a 1 MHz trapezoidal signal of magnitude 2.0 V (that is, 4.0 V peak-to-peak) with edge rate 20 mV/ns.

12.7.3 Coupling parameters

To avoid excessive coupling of signals between pairs of a cable, the crosstalk and imbalance must be limited.

Crosstalk attenuation is specified with the far end of both the disturbed and the disturbing pairs and the near end of the disturbed pair terminated in 96 Ω.

12.7.3.1 Pair-to-pair crosstalk

The near-end, differential, crosstalk attenuation between each wire pair and each other pair in the same cable shall be at least 45 dB frequencies up to BR and at least $45 - 15 \log_{10}(f/\mathrm{BR})$ dB for each frequency f between BR and 4BR.

12.7.3.2 Multiple-disturber crosstalk

The near-end, differential, crosstalk attenuation between multiple disturbing wire pairs and a disturbed pair in the same cable shall be at least 38.5 dB at frequency BR and at least $38.5 - 15 \log_{10}(f/\mathrm{BR})$ dB for each frequency f between BR and 4BR.

When two or more disturbers are present in a common cable sheath, the multiple-disturber, near-end, crosstalk attenuation (MDNEXT) into each pair, measured in dB, may be determined using the following equations:

$$H_j = \sum_{i \neq j} 10^{(-X_{ij}/20)} \cos\theta_{ij}$$

$$V_j = \sum_{i \neq j} 10^{(-X_{ij}/20)} \sin\theta_{ij}$$

$$MDNEXT_j = 10 \log_{10}(H_j^2 + V_j^2)$$

where

i iterates over each disturbing pair
j is the disturbed pair
X_{ij} is the magnitude of the near-end, differential, crosstalk attenuation from pair i to pair j
θ_{ij} is the phase angle of the near-end, differential, crosstalk attenuation from pair i to pair j

If only the probability distribution of X_{ij} is known, then the distribution of MDNEXT can be determined using Monte Carlo methods with that X_{ij} distribution and a phase angle uniformly distributed between 0 and 2π rad.

NOTE—See B.3 for example computations of MDNEXT distributions.

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12.7.3.3 Balance

The longitudinal to metallic balance of the cable, defined as 20 $\log_{10}$ (E_{test}/ 2E_x), where E_{test} is an externally applied voltage, as shown in Figure 12–32, shall exceed 44 dB at all frequencies up to 4BR.

NOTE—The balance of the test equipment (such as the balance of the transformer and the matching of the 300 Ω resistors) must exceed that required of the cable.

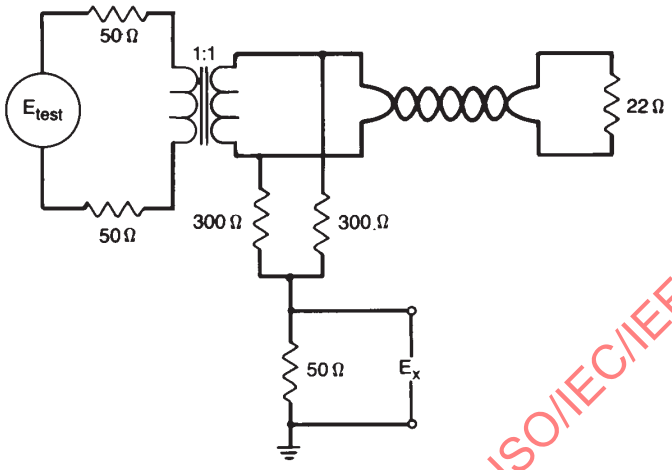

Figure 12–32—Cable balance test

12.7.4 Noise environment

Links used with 1BASE5 shall provide a noise environment no worse than that described below. The total noise environment generally results from two primary contributions: self-crosstalk from other 1BASE5 wire pairs and externally induced impulse noise, typically from telephone ringing and dialing signals, and office machinery. For the purposes of this standard, it can be assumed that the two components contribute independently and so the total error ratio can be appropriately split between the two.

12.7.4.1 Impulse noise

The noise voltage on wire pairs terminated at both ends in 96 Ω, as measured through the following specified filters, shall not exceed the corresponding threshold voltages more than 9 times per 1800 s interval. Following the start of any particular impulse that is counted, any additional impulses shall be ignored (that is, not counted) for a period of 100 μs. Each filter is a 2-pole Butterworth low-pass filter with the indicated cut-off (3 dB point) frequency.

Cut-off frequency	Threshold
2 MHz	170 mV
4 MHz	275 mV
10 MHz	560 mV

The impulse noise occurrence rate changes inversely by one decade for each 7 dB change in the threshold voltage. That is, if the noise occurrence rate is 9 counts per 1800 s at a particular threshold voltage, then a rate of 9 counts per 18 000 s will occur at a threshold 7 dB above that voltage. If a count rate of *N* counts per

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1800 s is measured on a specific cable and filter at the specified voltage threshold, the media noise margin is 7 $\log_{10}(9/N)$ dB.

12.7.4.2 Crosstalk

The level of crosstalk noise on a pair depends on the level of the disturbing signal(s) and the crosstalk attenuation from the pair(s) carrying the signal(s). With the maximum transmit level specified in 12.5.3.1, the sinusoidal crosstalk attenuations specified in 12.7.3.1 and 12.7.3.2, and multiple, synchronized, random Manchester disturbers, the peak self-crosstalk (that is, crosstalk from other 1BASE5 signals) noise levels, as measured through the following specified filters, shall be less than or equal to the levels indicated below. Each filter is a 2-pole Butterworth low-pass filter with the indicated cut-off (3 dB point) frequency.

Cut-off frequency	Level
2 MHz	105 mV
4 MHz	160 mV

12.8 Special link specification

12.8.1 Overview

Some 1BASE5 networks may require extension beyond the limits imposed by 12.7 or, due to the installation environment, may require special media such as optical fiber, high-grade cable, or even free-space transmission. The detailed design of special links that replace standard links for use in such circumstances is beyond the scope of this standard, but the end-to-end characteristics are specified. It shall be the responsibility of the supplier to ensure the proper operation of special links with other 1BASE5 equipment.

12.8.2 Transmission characteristics

Special links shall meet the overall attenuation, jitter, and dispersion specifications of 12.7.2.1, 12.7.2.3, and 12.7.2.4, respectively. Total noise introduced due to crosstalk or other sources shall not exceed that allowed for standard media, as specified in 12.7.4. To the extent that it affects operability with 1BASE5 transmitters and receivers, special links shall also meet the impedance and balance requirements of 12.7.2.2 and 12.7.3. The delay and preamble loss allowed for special links is specified in 12.9.4.

12.8.3 Permitted configurations

No more than one special link is permitted in the path between any DTE and the header hub. That is, special links may be installed in parallel but not in series.

NOTE—Special links may be combined with other 1BASE5 components, such as hubs. Such combinations are subject to the performance specifications of this standard only as visible at their external interfaces. For example, explicit MDIs are not required internal to such combinations.

12.9 Timing

12.9.1 Overview

The successful interconnection of multivendor system components mandates that delay and bit loss be allocated fairly and realistically among the various system elements. The balance of this subclause defines the upper limits of delay and bit loss allocated to each component. These values allow proper operation with the

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worst-case system configuration of five levels of hubs, special links, maximum-length cable segments throughout the network, and colliding DTEs at extremes of the network.

12.9.2 DTE timing

DTE Initial Transmit Delay is the time from the first full transition (due to the first OUTPUT_UNIT of preamble) from the MAC to the first full transition (after startup bit loss, if any) at the MDI. This delay shall not exceed 3 BT. The start bit loss shall not exceed 1 bit.

DTEs shall correctly receive frames that are preceded by 13 or more bits of preamble plus 8 bits of <sfd>.

There is a delay between the reception of signal at the PMA input of a DTE and operation of the deferral process in the MAC. Therefore, there is a window in which a DTE may fail to defer to a transmission even after it has arrived at the input. The DTE Deference Delay is the time from the receipt of the first transition of the preamble at the MDI until the last moment that the DTE might start transmitting at the MDI. This delay includes the following components:

a) The delay from the first input transition at the MDI to CARRIER_ON at the PLS-MAC interface
b) The delay through the MAC processes from CARRIER_ON to the last moment that a new transmission would miss being deferred
c) The delay from the first OUTPUT_UNIT at the MAC-PLS interface to the first output transition at the MDI

The DTE Deference Delay shall be no more than 21 BT.

The DTE Collision Shutdown Delay is the time from the first CVL or CVH arriving at the MDI of a transmitting DTE until that DTE transmits IDL at that interface. This time shall be no more than 26 BT + jamSize=58 BT. This limit shall not start until after the <sfd> has been transmitted.

12.9.3 Medium timing

The Medium Transit Delay is the time from when a signal enters the medium until that signal leaves the medium. This delay shall not exceed 4 BT.

12.9.4 Special link timing

The Special Link Transit Delay is the time from when a signal enters a special link until that signal leaves the special link. This delay shall not, exceed 15 BT. The preamble leaving a special link shall be no more than 2 bit cells longer than the preamble sent to that special link and no more than 1 bit cell shorter than the preamble sent to that special link. For the purposes of these limits only, the first bit transmitted shall be considered part of the silence of the preceding IDL unless it meets the requirements for the succeeding bits specified in 12.5.3.1.1 and 12.5.3.1.2.

12.9.5 Hub timing

Hub Startup Delay is the time from when the first bit cell of the preamble arrives at a hub until the first bit cell (also preamble) leaves that hub. This time shall be no greater than 12 BT. The preamble sent by a hub shall be no more than 1 bit cell longer than the preamble sent to that hub or more than 4 bit cells shorter than the preamble sent to that hub. For the purposes of these limits only, the first bit transmitted shall be considered part of the silence of the preceding IDL unless it meets the requirements for the succeeding bits specified in 12.5.3.1.1 and 12.5.3.1.2.

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Hub Idle Collision Startup Delay applies to any case in which CP arrives preceded by fewer (or no) bit times of preamble than the Hub Startup Delay. The time from arrival of the first bit cell (either preamble or CP) until the first bit cell leaves the hub shall be no greater than 12 BT.

Hub Transit Delay is the time from the arrival of any bit cell at a hub to the transmission of the corresponding bit cell from the hub. This delay shall not exceed 9 BT, excluding the cumulative effects of clock tolerance.

The transit (propagation) delay between the upward and downward sides of the Header Hub shall be negligible.

Hub Delay Stretch/Shrink is the increase or decrease in a hub's transit delay due to the effects of differing clock rates. The clock rate tolerance of 0.01% specified in 12.3.2.4.1 and the maximum frame size of 1518 octets specified in 4.4.2 yield a maximum stretch or shrink of $(56 + 8 + 1518 \cdot 8) \cdot 0.01\% \cdot 2 < 3$ BT, both at any given hub and through an entire network.

Hub Collision Detect Delay is the time required for a hub to detect multiple incoming signals and initiate transmission of CP. The time until transmission of the first CVH or CVL shall be no greater than 21 BT.

Hub Active Collision Startup Delay is the time from the arrival of the first CVH or CVL of a CP pattern at a hub that is repeating bit cells until transmission of the first CVH or CVL from the hub. This delay shall be no greater than 12 BT in either the upward or downward direction.

Hub Collision Shutdown Delay is the time from IDL arriving at a hub that is passing on or generating CP until that hub starts transmitting IDL. This delay shall be limited to 9 BT. The limit is relaxed to 25 BT, however, for the upward side of a hub that is generating CP. This extra allowance is made to avoid requiring implementation of a separate <etd> detection mechanism in each port of the hub.

12.10 Safety

Implementers are urged to consult the relevant local, national, and international safety regulations to ensure compliance with the appropriate standards. EIA CB8-1981 (see [B26]) provides additional guidance concerning many relevant regulatory requirements.

Sound installation practice, as defined by applicable codes and regulations, shall be followed. ECMA-97 (see [B25]) describes safety requirements for local area networks.

12.10.1 Isolation

Each PMA/MDI interface lead shall be isolated from frame ground. This electrical separation shall withstand at least one of the following electrical strength tests:

a) 1500 V (rms) at 50 to 60 Hz for 60 s, applied as specified in Section 5.3.2 of IEC 60950: 1991.
b) 2250 V (dc) for 60 s, applied as specified in Section 5.3.2 of IEC 60950: 1991.
c) A sequence of ten 2400 V impulses of alternating polarity, applied at intervals of not less than 1 s. The shape of the impulses shall be 1.2/50 µs (1.2 µs virtual front time, 50 µs virtual time of half value), as defined in IEC 60060.

There shall be no insulation breakdown, as defined in Section 5.3.2 of IEC 60950: 1991, during the test. The resistance after the test shall be at least 2 MΩ, measured at 500 Vdc.

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12.10.2 Telephony voltages

The use of building wiring brings with it the possibility of wiring errors that may connect telephony voltages to 1BASE5 equipment. Other than voice signals (which are very low voltage), the primary voltages that may be encountered are the “battery” and ringing voltages. Although there is no universal standard that constrains them, the following maximums generally apply:

a) Battery voltage to an on-hook telephone line is about –56 Vdc applied to the line through a balanced 400 Ω source impedance. This voltage is used to power the telephone instrument and detect the off-hook condition. Source inductance can cause large spikes on disconnect.
b) Battery voltage to an off-hook telephone line is also about –56 Vdc applied to the line through a balanced 400 Ω source impedance, but most of the voltage appears across the source impedance because the telephone instrument’s impedance is relatively much lower.
c) Ringing voltage is a composite signal. The first portion can be up to 175 V peak at 20 to 66 Hz, limited by a 100 Ω source resistance or a 400 to 600 Ω source inductive impedance. The second portion is –56 Vdc limited by a 300 to 600 Ω source impedance. Large spikes can occur at the start and end of each ring.

Although 1BASE5 equipment is not required to survive such wiring hazards without damage, application of any of the above voltages shall not result in any safety hazard.

NOTE—Wiring errors may impose telephony voltages differentially across the 1BASE5 transmitters or receivers. Because the termination resistance likely to be present across a receiver’s input is of substantially lower impedance than an off-hook telephone instrument, however, receivers will generally appear to the telephone system as off-hook telephones. Full ring voltages, therefore, will be applied for only short periods of time. Transmitters that are coupled using transformers will similarly appear like off-hook telephones (though perhaps a bit more slowly) due to low resistance of the transformer coil.

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13. System considerations for multisegment 10 Mb/s baseband networks

NOTE—This clause relates to clauses that are not recommended for new installations. This clause is not recommended for new installations. Since March 2012, maintenance changes are no longer being considered for this clause.

13.1 Overview

This clause provides information on building 10 Mb/s multisegment baseband networks within a single collision domain. The proper operation of a CSMA/CD network requires network size to be limited to control round-trip propagation delay to meet the requirements of 4.2.3.2.3 and 4.4.2, and the number of repeaters between any two DTEs to be limited in order to limit the shrinkage of the interpacket gap as it travels through the network.

This clause provides two network models. Transmission System Model 1 is a set of configurations that have been validated under conservative rules and have been qualified as meeting the two requirements set forth above. Transmission System Model 2 is a set of calculation aids that allow a configuration to be qualified against the two requirements. This set of calculation aids allows those configuring a network to test a proposed configuration against a simple set of criteria that allows it to be qualified. The Model 2 Transmission System Model validates an additional broad set of topologies that are fully functional and do not fit within the simpler but more restrictive rules of Model 1. Figure 13–1 illustrates an example of such a topology. The five repeaters are beyond the scope of the Model 1 rules yet this topology is fully functional within the limits of round-trip delay and can be validated as such by Model 2.

The physical size of a CSMA/CD network is limited by the characteristics of individual network components. These characteristics include the following:

a) Media lengths and their associated propagation time delay
b) Delay of repeater units (start-up and steady-state)
c) Delay of MAUs (start-up and steady-state)
d) Interpacket gap shrinkage due to repeater units
e) Delays within the DTE associated with the CSMA/CD access method
f) Collision detect and deassertion times associated with MAUs

Table 13–1 summarizes the delays for the various network media segments. In addition, Clause 14 summarizes the delays for the 10BASE-T MAU (Table 14–2); Clause 8, the delays for the 10BASE5 MAU; Clause 10, the delays for the 10BASE2 MAU; Clause 9, the delays of the Fiber Optic Inter Repeater Link (FOIRL) and the repeater (Tables 9–1, 9–2, and 9–3); Clause 16, the delays for the 10BASE-FP MAU (Table 16–1, also see

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15.1); Clause 17, the delays for the 10BASE-FB MAU (Table 17–1, also see 15.1), and Clause 18, the delays for the 10BASE-FL MAU (Table 18–1, also see 15.1).

Table 13–1—Delays for network media segments

Media type	Maximum number of MAUs per segment	Maximum segment length (m)	Maximum medium delay per segment (ns)
Mixing segment			
10BASE5	100	500	2165
10BASE2	30	185	950
10BASE-FP	33[a]	1000[b]	5000
Link segment			
FOIRL	2	1000	5000
10BASE-T	2	100[c]	1000
10BASE-FB	2	2000	10 000
10BASE-FL	2	2000	10 000
AUI[d] 1 DTE/1 MAU		50	257

[a]Actual number depends on the passive-star characteristics; see 16.5.2.1.
[b]In addition, a MAU to passive-star link will not exceed 500 m.
[c]Actual maximum segment length depends on cable characteristics; see 14.1.1.3.
[d]AUI is not a segment.

For a more detailed description of the calculation methods used to arrive at Transmission System Model 2, see B.1.5.

13.1.1 Repeater usage

Repeaters are the means used to connect segments of network medium together, thus allowing larger topologies and a larger MAU base than are allowed by the rules governing individual segments. Different media/segment types can only be connected to each other using repeaters.

13.2 Definitions

See 1.4.

13.3 Transmission System Model 1

The following network topology constraints apply to networks using Transmission System Model 1. If no segment length constraints are given for a segment type, the maximum segment length, as defined in the relevant MAU clause, applies.

a) Repeater sets are required for all segment interconnection.
b) MAUs that are part of repeater sets count toward the maximum number of MAUs on a segment.
c) The transmission path permitted between any two DTEs may consist of up to five segments, four repeater sets (including optional AUIs), two MAUs, and two AUIs.
d) AUI cables for 10BASE-FP and 10BASE-FL shall not exceed 25 m. (Since two MAUs per segment are required, 25 m per MAU results in a total AUI cable length of 50 m per segment.)
e) When a transmission path consists of four repeater sets and five segments, up to three of the segments may be mixing and the remainder must be link segments (Figure 13–2, Figure 13–3, and

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Figure 13–6). When five segments are present, each fiber optic link segment (FOIRL, 10BASE-FB, or 10BASE-FL) shall not exceed 500 m, and each 10BASE-FP segment shall not exceed 300 m.

f) When a transmission path consists of three repeater sets and four segments (Figure 13–4 and Figure 13–5), the following restrictions apply:
   1) The maximum allowable length of any inter-repeater fiber segment shall not exceed 1000 m for FOIRL, 10BASE-FB, and 10BASE-FL segments and shall not exceed 700 m for 10BASE-FP segments.
   2) The maximum allowable length of any repeater to DTE fiber segment shall not exceed 400 m for 10BASE-FL segments and shall not exceed 300 m for 10BASE-FP segments and 400 m for segments terminated in a 10BASE-FL MAU.
   3) There is no restriction on the number of mixing segments in this case.

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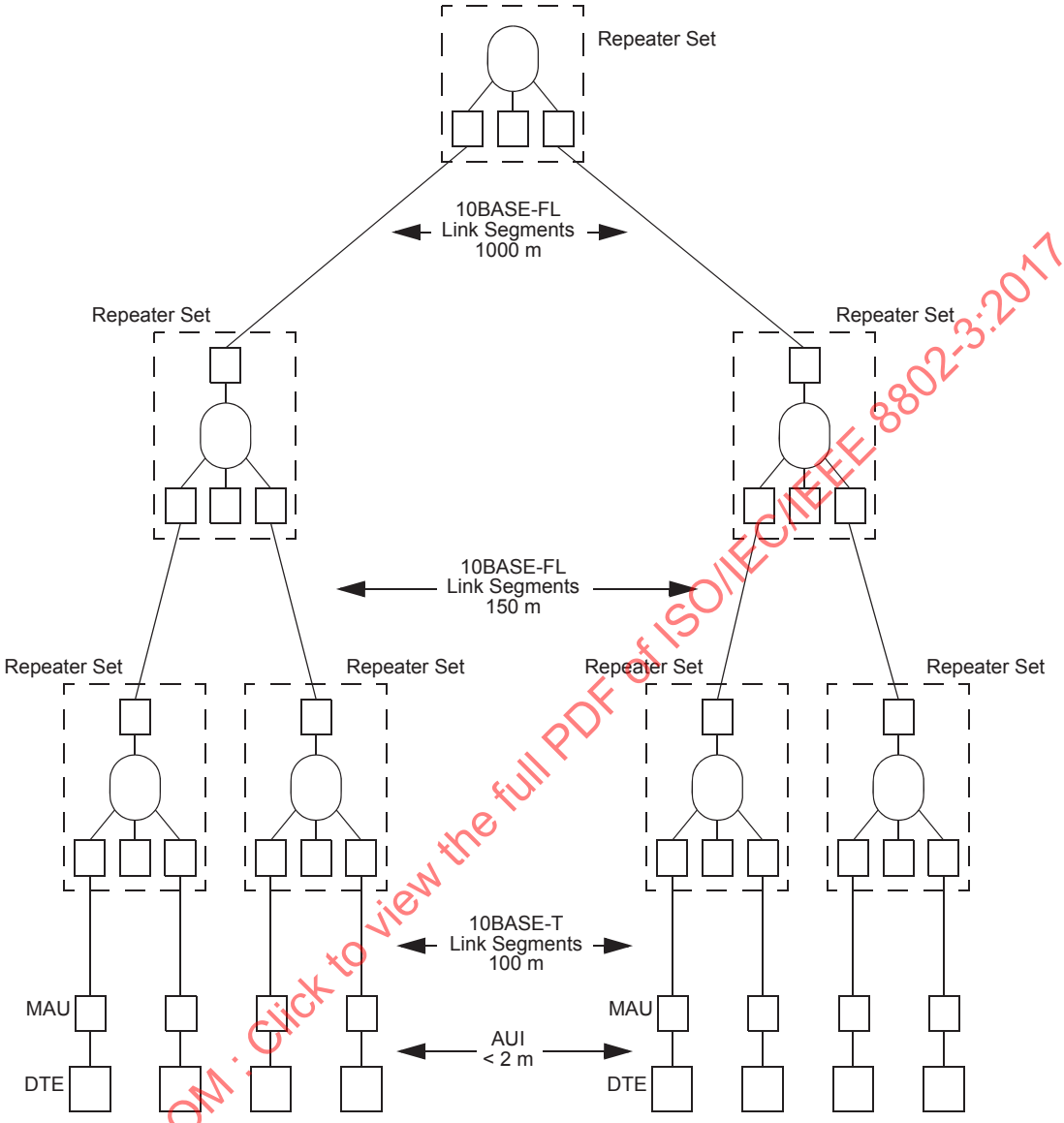

Figure 13–1—Example of maximum transmission path with five repeater sets enabled by Model 2 Transmission System validation

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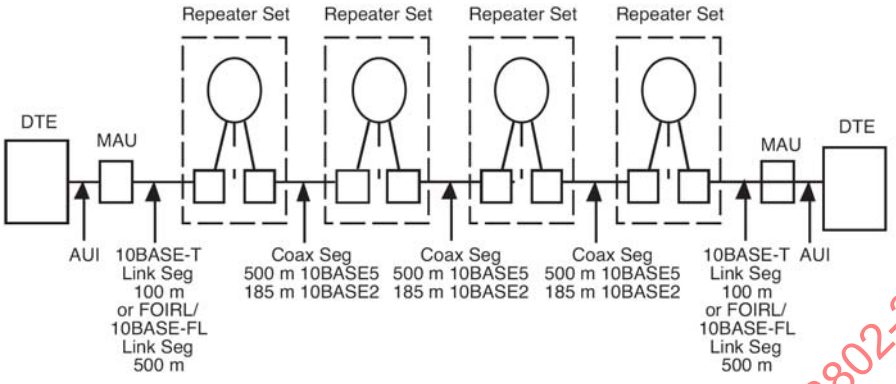

Figure 13–2—Maximum transmission path with three coaxial cable segments and two link segments

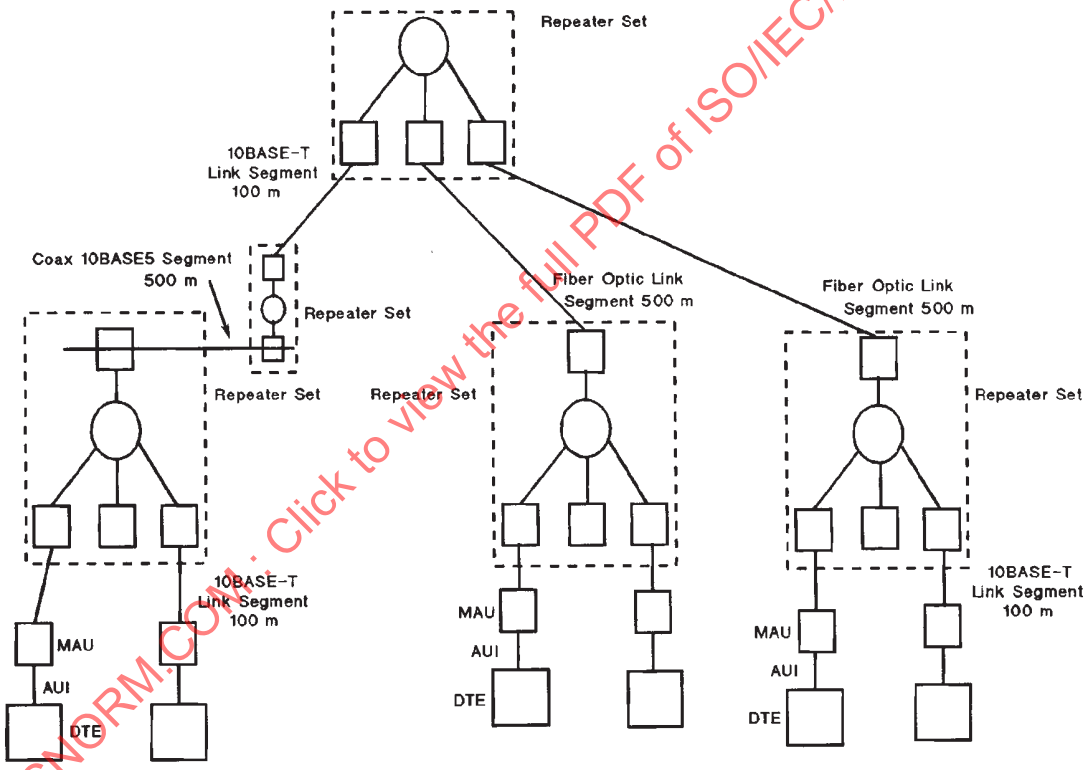

Figure 13–3—Example of maximum transmission path using coaxial cable segments, 10BASE-T link segments, and fiber optic link segments

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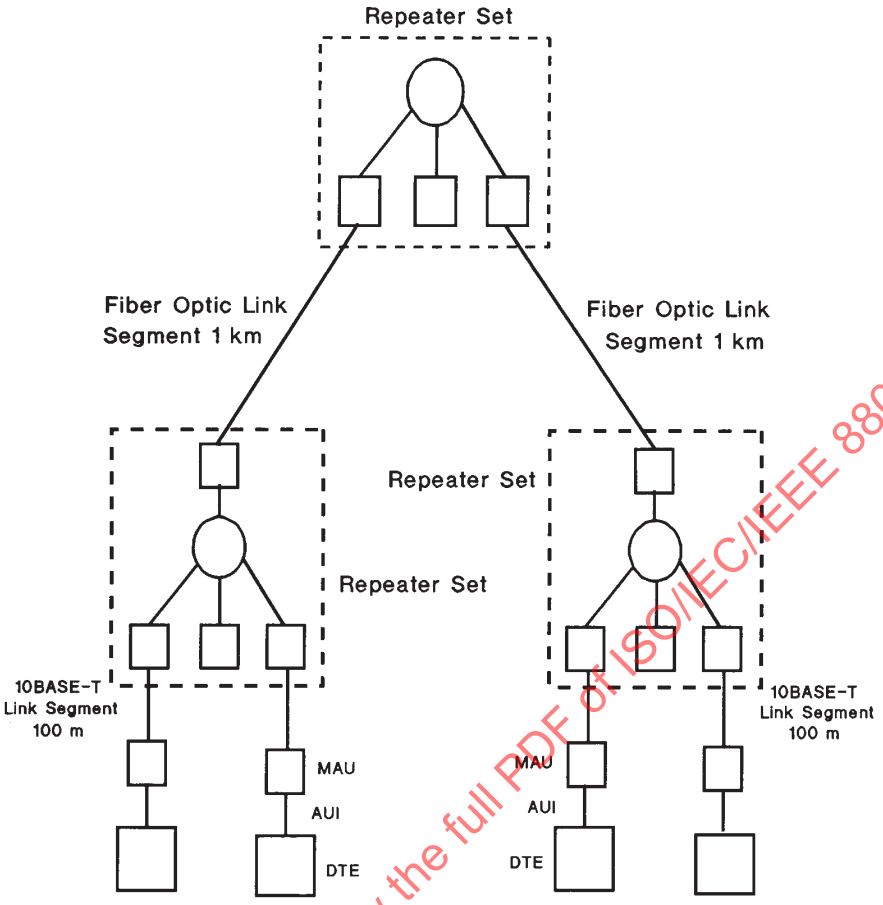

Figure 13–4—Example of maximum transmission path with three repeater sets, four link segments (two are 100 m 10BASE-T and two are 1 km fiber)

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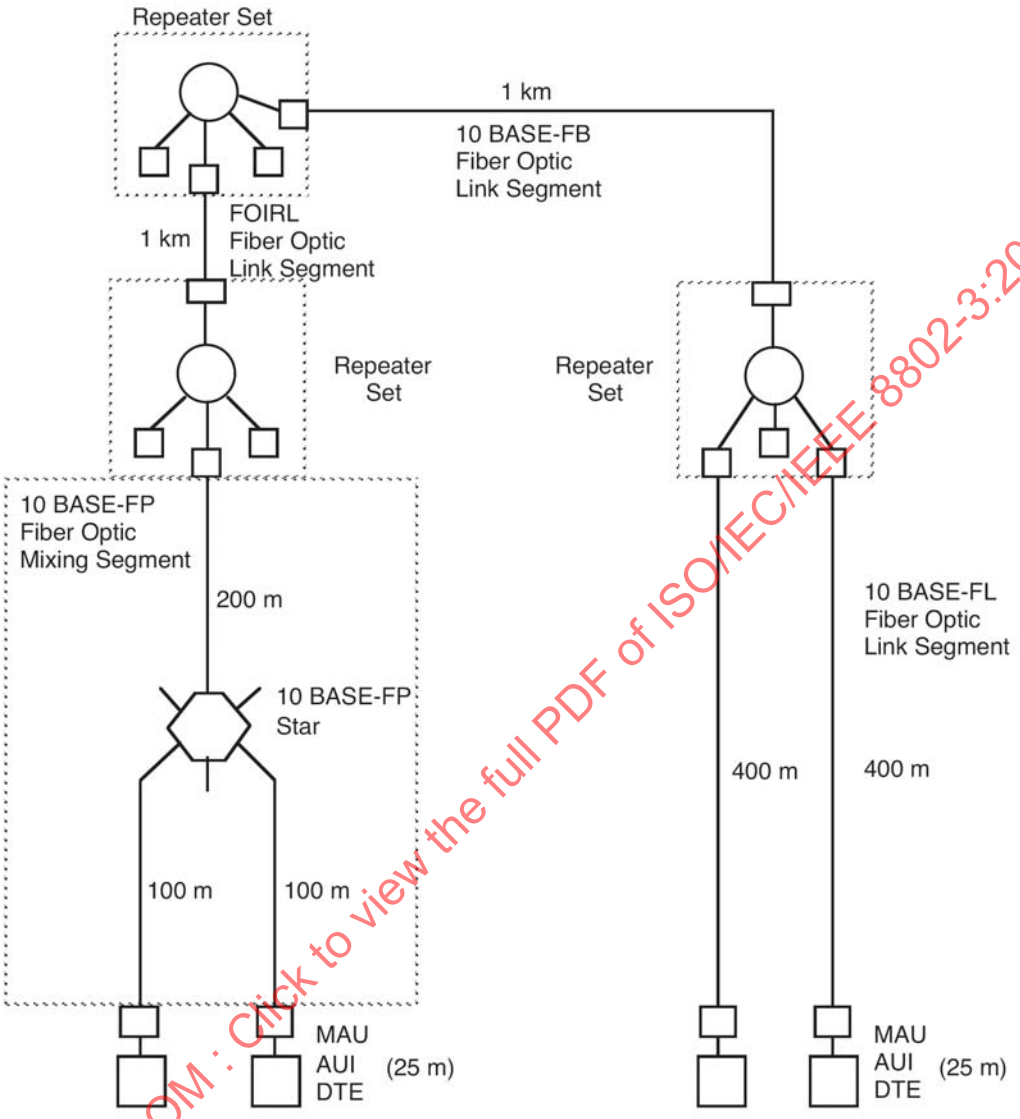

Figure 13–5—Example of maximum transmission path with three repeater sets, four segments (one 1 km 10BASE-FB, one 1 km FOIRL, one 400 m 10BASE-FL, and one 300 m 10BASE-FP)

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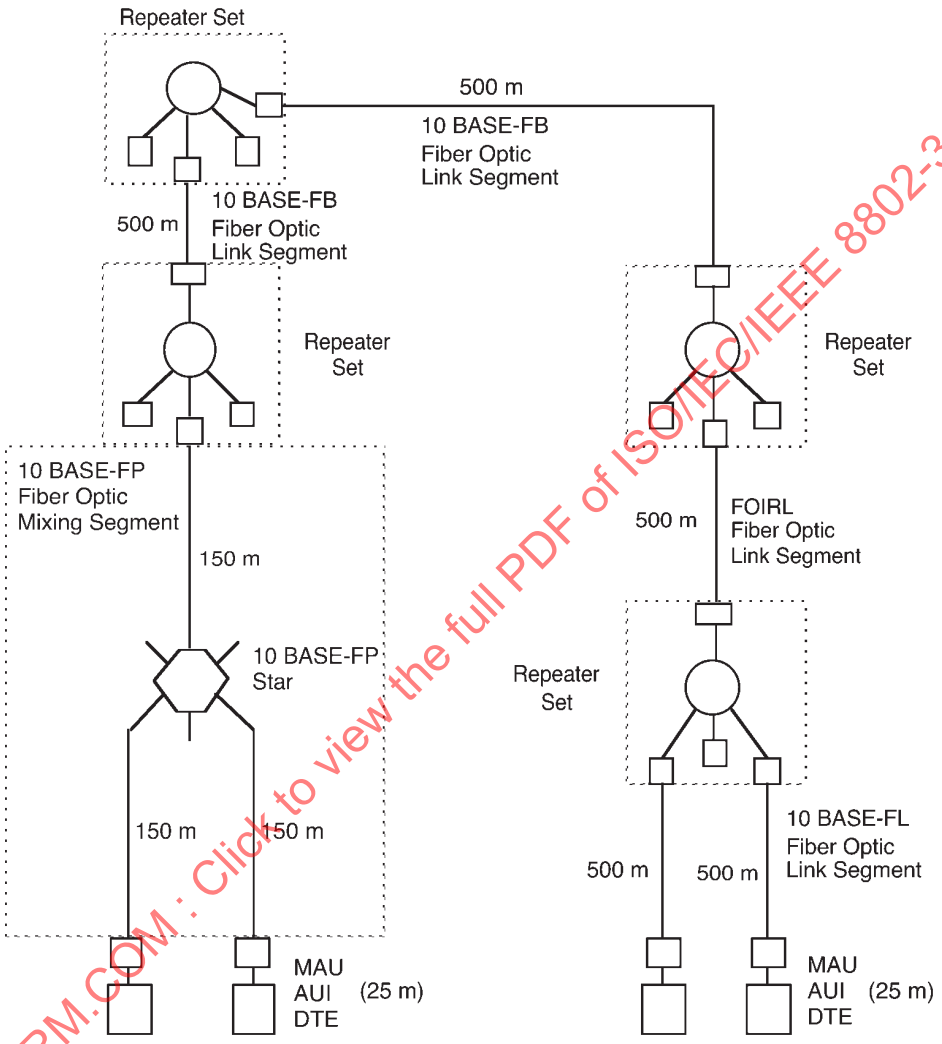

Figure 13–6—Example of maximum transmission path with four repeater sets, five segments (two 500 m 10BASE-FB, one 500 m FOIRL, one 500 m 10BASE-FL, and one 300 m 10BASE-FP)

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13.4 Transmission System Model 2

The physical size and number of topological elements in a 10 Mb/s baseband network is limited by two factors, round-trip collision delay and interpacket gap shrinkage. A network configuration must be validated against each of these separately. A model of the network is required for each of the calculations. The model consists of a series of segments consisting of a left-end segment, mid-segments, and a right-end segment. The model of the network used in the calculations consists of the worst-case path through the network for that particular calculation. The calculations are sufficiently straightforward that they can be done manually. They are also easy to implement in a spreadsheet. In general, the worst-case path for the two calculations is not the same for any single network. The requirements for each calculation and its respective model are detailed in the following subclauses and in Figure 13–7.

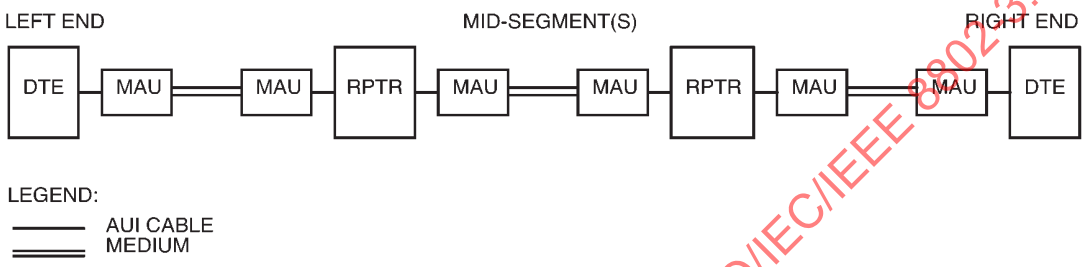

Figure 13–7—Generalized transmission path model

13.4.1 Round-trip collision delay

For a network to be valid, it must be possible for any two DTEs on that network to contend for the network at the same time. Each station attempting to transmit must be notified of the contention by the returned "collision" signal within the "collision window" (see 4.1.2.2 and 5.2.2.1.10). Additionally, the maximum length fragment created must contain less than 511 bits after the Start Frame Delimiter (SFD). This requirement limits the physical diameter (maximum distance between DTEs) of a network. The maximum round-trip delay must be qualified between all pairs of DTEs in the network. In practice this means that the qualification must be done between those that, by inspection of the topology, are candidates for the longest delay.

The following network modeling methodology is provided to assist that calculation.

13.4.1.1 Worst-case path delay value (PDV) selection

The worst-case path through a network to be validated shall be identified. The worst case consists of the path between the two DTEs at opposite ends of the network that have the longest round-trip time (see Figure 13–7).

13.4.1.2 Worst-case PDV calculation

Once a set of paths is chosen for calculation, each shall be checked for validity against the following formulas. (If a candidate for worst-case path has end segments of different types, calculations for the path must be performed twice, considering first one end segment as the left end, and then the other, and the maximum value obtained used as the PDV.)

a) Determine the Segment Delay Value (SDV) from Table 13–2 for each of the segments in the path.

$$SDV = \text{Base} + [\text{Length} \times (\text{Round-Trip Delay/meter})]$$

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(For mixing segments, length is the length between the repeater and the farthest end of the segment for end segments, or the length between two repeaters for mid-segments.)

or

SDV = Max

(Max is equal to the value above for the maximum media segment length. It is provided for ease of calculation with segments that are at their maximum length or as a default value when the length is not known).

NOTE—The SDV figure in the table includes allowance for an AUI at each end of the segment (except for 10BASE-FB) and up to 2 m of AUI cable. In 10BASE5 segments, AUI cables are normally longer than 2 m. Care should be exercised to assure that provision is made for the delay associated with their actual length.

b) From Table 13–2, determine the SDV for the sum of all AUI cables in excess of 2 m (except the AUI associated with the left end DTE, which does not contribute to the PDV).

c) Sum all SDVs from item a) and item b) plus a margin of up to 5 bits to form the PDV. The margin may be from 0 to 5 bits; 5 bits is recommended. If the PDV is less than or equal to 575, the path is qualified in terms of worst-case delay.

Table 13–2—Segment round-trip delay values in bit times (PDV not to exceed 572)

Segment type	Max length	Left end		Mid-segment		Right end		RT delay/ meter
		Base	Max	Base	Max	Base	Max	
10BASE5 Coax	500	11.75	55.05	46.5	89.8	169.5	212.8	0.0866
10BASE2 Coax	185	11.75	30.731	46.5	65.48	169.5	188.48	0.1026
FOIRL	1000	7.75	107.75	29	129	152	252	0.1
10BASE-T	100[a]	15.25	26.55	42	53.3	165	176.3	0.113
10BASE-FP	1000	11.25	111.25	61	161	183.5	284	0.1
10BASE-FB	2000	N/A[b]	N/A[b]	24	224	N/A[b]	N/A[b]	0.1
10BASE-FL	2000	12.25	212.25	33.5	233.5	156.5	356.5	0.1
Excess length AUI	48	0	4.88	0	4.88	0	4.88	0.1026

[a]Actual maximum segment length depends on cable characteristics; see 14.1.1.3.
[b]Not Applicable, 10BASE-FB does not support end connections.

13.4.2 Interpacket gap (IPG) shrinkage

The worst-case variabilities of transmission elements in the network plus some of the signal reconstruction facilities required in the 10 Mb/s baseband repeater specification combine in such a way that the gap between two packets travelling across the network may be reduced below the interFrameGap specified in 4.4.2. This parameter limits the equipment (i.e., number of repeaters) between any two DTEs. Again this limit applies to all combinations of DTEs on any network but the worst case is apparent from an inspection of a map or schematic representation of the topology in question.

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13.4.2.1 Worst-case path variability value (PVV) selection

A worst-case path through a network to be validated shall be identified.

It should be noted that the receive end segment is not counted in this scenario. This means that in an asymmetrical network where the end segments are of different types, the end segment with the worst variability shall be designated as the "Transmitting End" for this evaluation.

13.4.2.2 Worst-case path variability value (PVV) calculation

Once a set of paths is chosen for calculation each shall be checked for qualification by the following method:

a) Determine the Segment Variability Value (SVV) from Table 13–3 for each of the segments in the Path, excluding the end segment with the lower SVV.
b) Sum all of the SVVs from item 1 to form the PVV. If the PVV is less than or equal to 49, the path is qualified in terms of worst-case variability.

Table 13–3—Segment variability values in bit times (PVV not to exceed 49)

Segment type	Transmitting end	Mid-segment
Coax	16	11
Link except 10BASE-FB	10.5	8
10BASE-FB	N/A[a]	2
10BASE-FP	11	8

[a]Not Applicable, 10BASE-FB does not support end connections.

13.5 Full duplex topology limitations

Unlike half duplex CSMA/CD networks, the physical size of full duplex 10 Mb/s networks is not limited by the round-trip collision propagation delay. Instead, the maximum link length between DTEs is limited only by the signal transmission characteristics of the specific cable.

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14. Twisted-pair medium attachment unit (MAU) and baseband medium, type 10BASE-T including type 10BASE-Te

14.1 Scope

14.1.1 Overview

Clause 14 defines the functional, electrical, and mechanical characteristics of the type 10BASE-T MAU and one specific medium for use with that MAU. This clause also specifies the functional, electrical, and mechanical characteristics of the energy-efficient version of 10BASE-T, the type 10BASE-Te MAU, and one specific medium for use with that MAU. The relationship of this clause to the entire IEEE 802.3 LAN International Standard is shown in Figure 14–1. The purpose of the MAU is to provide a simple, inexpensive, and flexible means of attaching devices to the medium.

NOTE—Support for both 10BASE-T and 10BASE-Te signal levels in a single device is not required.

This MAU and medium specification is aimed primarily at office applications where twisted-pair cable is often installed. Installation and reconfiguration simplicity is allowed by the type of cable and connectors used.

The 10BASE-T specification builds upon Clause 1 through Clause 7 and Clause 9 of this standard.

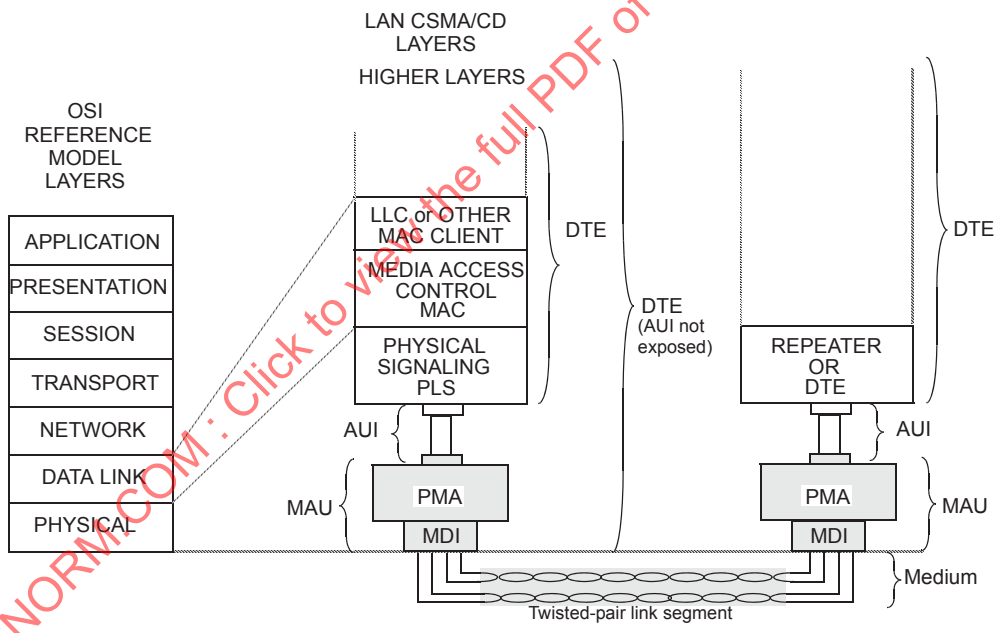

Figure 14–1—10BASE-T relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

14.1.1.1 Medium Attachment Unit (MAU)

The MAU has the following general characteristics:

a) Enables coupling the Physical Signaling (PLS) sublayer by way of the Attachment Unit Interface (AUI) to the baseband twisted-pair link defined in Clause 14.

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b) Supports message traffic at a data rate of 10 Mb/s.
c) Provides for operating over 0 m to at least 100 m of twisted pair without the use of a repeater.
d) Permits the Data Terminal Equipment (DTE) or repeater to confirm operation of the MAU and availability of the medium.
e) Supports network configurations using the CSMA/CD access method defined in this standard with baseband signaling.
f) Supports a point-to-point interconnection between MAUs and, when used with repeaters having multiple ports, supports a star wiring topology.
g) Allows incorporation of the MAU within the physical bounds of a DTE or repeater.
h) Allows for either half duplex operation, full duplex operation, or both.
i) Provides for operation with reduced peak differential voltage on the TD circuit for type 10BASE-Te. A 10BASE-Te MAU interoperates with a 10BASE-T MAU if the minimum cabling requirements of a 10BASE-Te MAU are met.
j) All references to 10BASE-T include 10BASE-Te unless otherwise stated.

14.1.1.2 Repeater unit

The repeater unit is used to extend the physical system topology and provides for coupling two or more segments. Repeaters are an integral part of all 10BASE-T networks with more than two DTEs (see Figure 13–1 and Figure 13–2). The repeater unit is defined in Clause 9. Multiple repeater units are permitted within a single collision domain to provide the maximum connection path length specified in Clause 13. The repeater unit is not a DTE and therefore has slightly different requirements for its attached MAUs, as defined in 9.4.1. Repeater sets with 10BASE-T MAUs are required to provide the auto-partition/reconnection algorithm on those ports, as specified in 9.6.6.2.

14.1.1.3 Twisted-pair media

The medium for 10BASE-T is twisted-pair wire. The performance specifications of the 10BASE-T except 10BASE-Te simplex link segment are contained in 14.4. This wiring normally consists of 0.4 mm to 0.6 mm diameter (26 AWG to 22 AWG) unshielded wire in a multipair cable. The performance specifications are generally met by 100 m of 0.5 mm telephone twisted pair. Longer lengths are permitted providing the simplex link segment meets the requirements of 14.4. A length of 100 m, the design objective, will be used when referring to the length of a twisted-pair link segment.

The medium for 10BASE-Te is twisted-pair wire. The performance specifications of the 10BASE-Te simplex link segment (either pure 10BASE-Te or mixed 10BASE-T, 10BASE-Te) is a channel meeting or exceeding the requirements of the Class D channel specified by ISO/IEC 11801:1995. These channel requirements can also be met by the Category 5 channel specified by ANSI/TIA/EIA-568-A.

NOTE—ISO/IEC 11801:2002 provides a specification for media that exceeds the minimum requirements of this standard.

14.1.2 Definitions

See 1.4 for additional definitions.

14.1.2.1 twisted-pair link: A twisted-pair link segment and its two attached MAUs (see Figure 14–1).

14.1.2.2 twisted-pair link segment (duplex link segment): Two simplex link segments for connecting two MAUs (see Figure 14–2).

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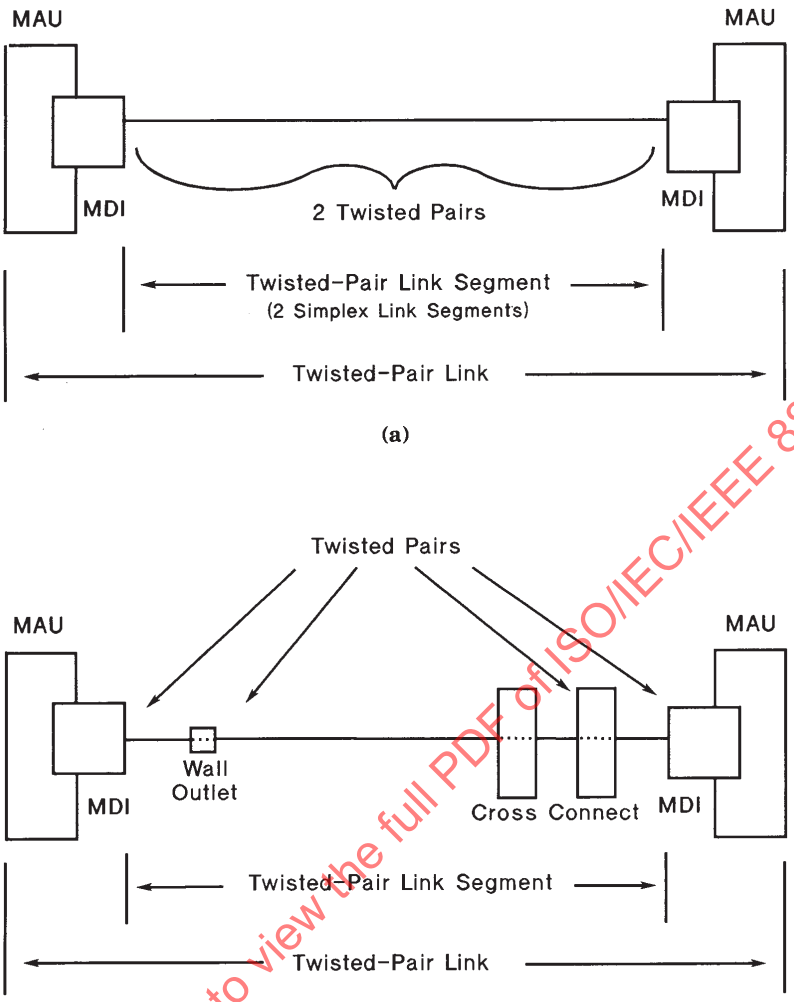

Figure 14–2—Twisted-pair link

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14.1.3 Application perspective

This clause states the broad objectives and assumptions underlying the specifications defined throughout Clause 14.

14.1.3.1 Objectives

a) Provide the physical means for communication between LAN Data Link Layer entities.
b) Ensure compatibility of independently developed physical and electrical interfaces.
c) Provide a communication channel with a mean bit error ratio, at the Physical Layer service interface of less than one part in 10^8.
d) Provide for ease of installation and service.
e) Ensure that fairness of DTE access is not compromised.
f) Provide for low-cost networks, as related to both equipment and cabling.
g) Make use of telephone twisted-pair building wiring and telephony wiring practices.

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14.1.3.2 Compatibility considerations

All implementations of the twisted-pair link shall be compatible at the MDI. The MAU and the medium are defined to provide compatibility among devices designed by different manufacturers. Designers are free to implement circuitry within the MAU in an application-dependent manner provided the MDI and AUI (when implemented) specifications are met.

14.1.3.3 Modes of operation

The 10BASE-T MAU is capable of operating in *normal* mode only (see 7.1.4). The MAU shall not operate in *monitor* mode.

When normal mode is in operation, the MAU functions as a direct connection between the medium and the DTE or repeater. Data from the DTE or repeater is output to one of the simplex link segments of the link segment, and data received on the other simplex link segment is input to the DTE or repeater.

The operation of a 10BASE-T MAU differs depending on whether the attached DTE is operating in the half duplex or full duplex mode (see 1.1.2). In the full duplex mode, functions relating to the loopback of transmitted data (DO) onto the receive path (DI) are disabled (see 14.2.1.3 and 14.2.1.6). The requirements specified in subclauses of this standard labeled “half duplex mode only” do not apply to a MAU used with a DTE configured for full duplex operation.

14.1.4 Relationship to PLS and AUI

A close relationship exists between Clause 14 and Clause 7. Clause 14 specifies the physical medium parameters and the PMA logical functions residing in the physical MAU. The MAU provides services to the PLS defined in Clause 7 by means of the AUI. 10BASE-T MAUs support a subset of the AUI services specified in Clause 7. 10BASE-T MAUs do not support the optional isolate function, the optional CO circuit, or the optional CS1 signal on the CI circuit.

The design of an external MAU component requires the use of both Clause 14 and Clause 7 for the PLS and AUI specifications.

The figures and numerous textual references throughout Clause 14 refer to terminology associated with the AUI (that is, DO, DI, and CI). Since an embodiment of the 10BASE-T MAU does not require the implementation of an AUI, the DO, DI, and CI circuits may not physically exist. However, they are logically present and MAU operation is defined in terms of them.

14.2 MAU functional specifications

The MAU provides the means by which signals on the three AUI signal circuits to and from the DTE or repeater and their associated interlayer messages are coupled to the twisted-pair link segment. The MAU provides the following functional capabilities to handle message flow between the DTE or repeater and the twisted-pair link segment:

a) Transmit function. Provides the ability to transfer Manchester-encoded data from the DO circuit to the TD circuit. While not sending Manchester-encoded data on the TD circuit, the MAU sends an idle signal, TP_IDL, on the TD circuit.
b) Receive function. Provides the ability to transfer Manchester-encoded data from the RD circuit to the DI circuit. While not sending Manchester-encoded data on the DI circuit, the MAU sends an idle signal, IDL, on the DI circuit.

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c) Loopback function (half duplex mode only). Provides the ability to transfer Manchester-encoded data from the DO to the DI circuit when the MAU is sending Manchester-encoded data to the TD circuit.
d) Collision Presence function. Provides the ability to detect simultaneous occurrence of Manchester-encoded data on the RD and DO circuits and to report such an occurrence as a collision. MAUs connected to full duplex mode DTEs are permitted, but not required, to implement the Collision Presence function.
e) *signal_quality_error* Message (SQE) Test function. Provides the ability to indicate to the DTE that the Collision Presence function is operational and that the *signal_quality_error* message can be sent by the MAU.
f) Jabber function. Provides the ability to prevent abnormally long reception of Manchester-encoded data on the DO circuit from indefinitely disrupting transmission on the network. While such a condition is present, transfer of Manchester-encoded data by the Transmit and Loopback functions is disabled.
g) Link Integrity Test function. Provides the ability to protect the network from the consequences of failure of the simplex link attached to the RD circuit. While such a failure is present, transfer of Manchester-encoded data by the Transmit, Receive, and Loopback functions is disabled.
h) Auto-Negotiation. Optionally provides the capability for a device at one end of a link segment to advertise its abilities to the device at the other end (its link partner), to detect information defining the abilities of the link partner, and to determine if the two devices are compatible.

14.2.1 MAU functions

The MAU shall provide the Transmit, Receive, Loopback, Collision Presence, Jabber, and Link Integrity Test functions for half duplex mode DTEs and repeater units. The MAU shall provide the Transmit, Receive, Jabber, and Link Integrity Test functions, and shall not provide the Loopback function for full duplex mode DTEs. The SQE Test function shall be performed by MAUs that are connected to half duplex DTEs and shall not be performed by MAUs that are connected to repeaters.

MAUs connected to full duplex mode DTEs are permitted, but not required, to implement the Collision Presence function, the SQE Test function, and the generation of the CS0 signal on the CI circuit by the Jabber function. If these optional capabilities are implemented in a MAU connected to a full duplex mode DTE, either all of the optional functions shall be implemented, or none of them shall be.

The MAU function requirements are summarized in the table below:

	MAU connected to:		
Functions	**Repeater**	**Half duplex DTE**	**Full duplex DTE**
Transmit	Required	Required	Required
Receive	Required	Required	Required
Loopback	Required	Required	Required
Jabber	Required	Required	Required
Link Integrity Test	Required	Required	Required
Collision Presence	Required	Required	Optional (Note 2)
SQE Test	Required	Required	Optional (Note 2)
Generation of CS0 signal on the CI circuit by jabber	Required	Required	Optional (Note 2)

NOTE 1—The functional requirements of a MAU connected to a full duplex DTE are a proper subset of the requirements for half duplex operation.
NOTE 2—Optional capabilities, if implemented, must be implemented as a group (i.e., all or none).

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A capability may be provided in the MAU to activate or inhibit the SQE Test function, or to configure the MAU for full or half duplex operation. It is not required that a MAU determine that it is connected to either a DTE or a repeater and automatically activate or inhibit the SQE Test function. It is also not required that a MAU determine that it is connected to either a half duplex or full duplex DTE and automatically activate or inhibit the appropriate functions for those modes. The use of the Auto-Negotiation algorithm of Clause 28 in 10BASE-T MAUs is discussed in 14.2.1.8. The MAU may optionally provide the Auto-Negotiation algorithm. When provided, the Auto-Negotiation algorithm shall be implemented in accordance with Clause 28.

14.2.1.1 Transmit function requirements

The MAU shall receive the signals on the DO circuit and send them to the TD circuit of the MDI. A positive signal on the A lead relative to the B lead of the DO circuit shall result in a positive signal on the TD+ (Transmit Data +) lead of the MDI with respect to the TD– lead.

At the start of a packet transmission, no more than 2 bits may be received from the DO circuit and not transmitted on the TD circuit. In addition, it is permissible for the first bit sent to contain phase violations or invalid amplitude. All subsequent bits of the packet shall be reproduced with the differential voltage specified in 14.3.1.2.1 and with no more jitter than is specified in 14.3.1.2.3. The second bit transmitted on the TD circuit shall be transmitted with the correct timing and signal levels. The steady-state propagation delay between the DO circuit input and the TD circuit shall not exceed 2 BT.

For any two packets that are separated by 9.6 µs or less, the start-up delay (bit loss plus steady-state propagation delay) of the first packet shall not exceed that of the second packet by more than 2 BT.

Whenever data is not being transmitted on the TD circuit, an idle signal, TP_IDL, shall be transmitted on the TD circuit. TP_IDL is a start of idle, as defined in 14.3.1.2.1, followed by a repeating sequence of a 16 ms ± 8 ms period of silence (the time where the differential voltage remains at 0 mV ± 50 mV) and a link test pulse (see 14.3.1.2.1). Following a packet and start of idle, the repeating sequence shall start with a period of silence.

Transmission of TP_IDL may be terminated at any time with respect to the link test pulse. It shall be terminated such that no more than the first transmitted bit of a packet is corrupted, and with no more delay than is specified for bit loss and steady-state propagation.

For a MAU that implements the Auto-Negotiation algorithm defined in Clause 28, Clause 28 shall define the allowable transmitted link pulse sequence.

14.2.1.2 Receive function requirements

The MAU shall receive the signals on the RD circuit of the MDI and send them to the DI circuit. A positive signal on the RD+ (Receive Data +) lead relative to the RD– lead of the MDI shall result in a positive signal on the A lead with respect to the B lead of the DI circuit.

At the start of a packet reception from the RD circuit, no more than 5 bits may be received on the RD circuit and not transmitted onto the DI circuit. In addition, it is permissible for the first bit sent on the DI circuit to contain phase violations or invalid data; however, all successive bits of the packet shall be sent with no more than the amount of jitter specified in 14.3.1.3.1. The steady-state propagation delay between the RD circuit and the DI circuit shall not exceed 2 BT.

For any two packets that are separated by 9.6 µs or less, the start-up delay of the first packet shall not exceed that of the second packet by more than 2 BT.

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14.2.1.3 Loopback function requirements (half duplex mode only)

When the MAU is transmitting on the TD circuit and is not receiving *RD_input* messages (14.2.2.4) on the RD circuit, the MAU shall transmit on the DI circuit the signals received on the DO circuit in order to provide loopback of the transmitted signal. At the start of packet transmission on the TD circuit, no more than 5 bits of information may be received from the DO circuit and not transmitted to the DI circuit. In addition, it is permissible for the first bit sent on the DI circuit to contain phase violations or invalid data; however, all successive bits of the packet shall meet the jitter specified in 14.3.1.3.1 (that is, 13.5 ns plus 1.5 ns). The steady-state propagation delay between the DO circuit and the DI circuit shall not exceed 1 BT.

14.2.1.4 Collision Presence function requirements (half duplex mode only)

The MAU shall detect as a collision the simultaneous occurrence of activity on the DO circuit and the RD circuit while in the Link Test Pass state. While a collision is detected, a CS0 signal (see 7.3.1.2) shall be sent on the CI circuit. The signal shall be presented to the CI circuit no more than 9 BT after the occurrence of a collision. The signal shall be deasserted within 9 BT after the DO circuit or the RD circuit changes from active to idle.

When CS0 is asserted on the CI circuit due to a collision, the data on the RD circuit shall be sent to the DI circuit within 9 BT.

When the RD circuit changes from active to idle and data is present on the DO circuit, the data on the DO circuit shall be sent to the DI circuit within 9 BT.

The signal presented on the CI circuit in the absence of collision, SQE test, or Jabber shall be the IDL signal.

MAUs connected to full duplex mode DTEs are permitted, but not required, to implement the Collision Presence function (see 14.2.1).

14.2.1.5 *signal_quality_error* Message (SQE) Test function requirements

The SQE Test function shall be performed by MAUs that are connected to DTEs in half duplex mode, and shall not be performed by MAUs that are connected to repeaters. When the SQE test is performed, the MAU shall send CS0 on the CI circuit for a time "SQE_test" beginning a time "SQE_test_wait" after the last positive transition of a packet on the DO circuit. The value of "SQE_test" shall be 10 BT ± 5 BT and the value of "SQE_test_wait" shall be between 0.6 µs and 1.6 µs. This function should use as much of the normal collision detection and signaling circuitry as possible without introducing extraneous signals on the TD circuit or the DI circuit.

The CS0 signal shall not be sent by the SQE Test function while in any of the Link Test Fail states.

MAUs connected to full duplex mode DTEs are permitted, but not required, to implement the SQE Test function (see 14.2.1).

14.2.1.6 Jabber function requirements

The MAU shall contain a self-interrupt capability to prevent an illegally long transmission by a DTE from permanently disrupting transmission on the network and to disable loopback to the DI circuit (Figure 14–5). The MAU shall provide a window "xmit_max" during which time the Transmit function may continuously transmit *TD_output* messages to the TD circuit. The value of "xmit_max" shall be between 20 and 150 ms. If a transmission exceeds this duration, the Jabber function shall

a) Inhibit the Loopback function and the transmission of *TD_output* messages by the Transmit function, and shall

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b) Send the CS0 signal on the CI circuit, when the MAU is connected to a DTE operating in half duplex mode. MAUs connected to DTEs operating in full duplex mode are permitted, but not required, to send the CS0 signal on the CI circuit in this manner (see 14.2.1).

These actions shall continue until *output_idle* has been continuously present on the DO circuit for a time "unjab." The value of "unjab" shall be 0.5 s ± 0.25 s.

It is permissible to activate the Jabber function when the TD circuit transmitter is sending *TD_output* messages for longer than "xmit_max."

The MAU shall not activate its Jabber function when the repeater's MAU Jabber Lockup Protection function operates at its longest permitted time as specified in 9.6.5.

14.2.1.7 Link Integrity Test function requirements

In order to protect the network from the consequences of a simplex link segment failure, the MAU shall monitor the RD circuit for *RD_input* and link test pulse activity. If neither *RD_input* nor a link test pulse is received for a time "link_loss," the MAU shall enter the Link Test Fail state and cause the *input_idle* message to be sent on the DI circuit and the *TD_idle* message to be sent on the TD circuit (Figure 14–6). The value of "link_loss" shall be between 50 ms and 150 ms. When RD_input or a number "lc_max" of consecutive link test pulses is received on the RD circuit, the MAU shall exit the Link Test Fail state. The value of "lc_max" shall be between 2 and 10 inclusive.

Only link test pulses that occur within time "link_test_max" of each other shall be considered consecutive. The value of "link_test_max" shall be between 25 ms and 150 ms. In addition, detected pulses that occur within a time "link_test_min" of a previous pulse or packet shall be ignored while in the Link Test Pass state. In the Link Test Fail state, such pulses shall reset the counted number of consecutive link test pulses to zero. The value of "link_test_min" shall be between 2 ms and 7 ms. Re-enabling shall be deferred until the signals on the RD and DO circuits become idle. The MAU shall not detect a link test pulse as *RD_input*. Additionally, a MAU may exit the Link Test Fail Extend state and enter the Link Test Pass state when the RD circuit becomes idle and the Jabber function has disabled transmission on the TD circuit.

While the MAU is not in the Link Test Pass state, the Link Integrity Test function shall disable the bit transfer of the Transmit, Receive, and Loopback functions, and the Collision Presence and SQE Test functions.

At PowerOn, in place of entering the Link Test Pass state as shown in Figure 14–6, a MAU may optionally enter the Link Test Fail Reset state.

For a MAU that implements the Auto-Negotiation algorithm defined in Clause 28, the MAU shall enter the LINK TEST FAIL RESET state at power-on as specified in Clause 28. For a MAU that does not implement the Auto-Negotiation algorithm defined in Clause 28, it is highly recommended that it also power-on in the LINK TEST FAIL RESET state, although implementations may power-on in the LINK TEST PASS state. For a MAU that implements the Auto-Negotiation function defined in Clause 28, the Auto-Negotiation Technology Dependent Interface shall be supported. Supporting the Technology Dependent Interface requires that in the Link Integrity Test function state diagram "link_status=OK" is added to the LINK TEST PASS state and "link_status=FAIL" is added to the LINK TEST FAIL RESET state. Note these ISO message variables follow the conventions of Clause 21.

If a visible indicator is provided on the MAU to indicate the link status, it is recommended that the color be green and that the indicator be labeled appropriately. It is further recommended that the indicator be on when the MAU is in the Link Test Pass state and off otherwise.

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14.2.1.8 Auto-Negotiation

It is strongly recommended that Auto-Negotiation be used for the determination of half or full duplex operation. When Auto-Negotiation is used in an exposed AUI-based MAU implementation, the MAU must be capable of operating in the half duplex mode, and shall not advertise the ability to operate in full duplex mode.

10BASE-T MAUs used in an embedded system (i.e., where the MAU is incorporated within the physical bounds of the DTE), or incorporating a physical implementation of the MII interface of Clause 22 with a DTE operating in full duplex mode, may indicate the capability to operate in full duplex mode using the Auto-Negotiation algorithm in accordance with Clause 28.

NOTE—Since there is no way to communicate the half or full duplex abilities between a DTE or repeater and a MAU separated by an AUI, caution must be used when connecting full duplex capable DTEs or MAUs that are manually configured.

Manual configuration is not recommended. Connecting incompatible DTE/MAU combinations such as a full duplex mode DTE to a half duplex mode MAU, or a full-duplex mode station (DTE and MAU) to a repeater or other half duplex network, can lead to severe network performance degradation, increased collisions, late collisions, CRC errors, and undetected data corruption.

14.2.2 PMA interface messages

The messages between the PLS in the DTE and the PMA in the MAU shall comply with the PMA interface messages described in 7.2.1. These messages also are used in repeater unit to PMA communication. These and the messages between the PMAs over the MDI are summarized below.

14.2.2.1 PLS to PMA messages

The following messages are sent by the PLS in the DTE or repeater to the PMA in the MAU:

Message	Circuit	Signal	Meaning
output	DO	CD1,CD0	Output information
output_idle	DO	IDL	No data to be output

14.2.2.1.1 PMA to PLS messages

The following messages are sent by the MAU to the PLS in the DTE or repeater:

Message	Circuit	Signal	Meaning
input	DI	CD1,CD0	Input information
input_idle	DI	IDL	No information to input
mau_available	CI	IDL	MAU is available for output
signal_quality_error	CI	CS0	Error detected by MAU

Retiming of CD1 and CD0 signals within the MAU is neither prohibited nor required. Considerable jitter may be present (see 14.3.1.3.1).

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14.2.2.2 PMA to twisted-pair link segment messages

Message	Circuit	Signal	Meaning
TD_output	TD	CD1,CD0	Output information
TD_idle	TD	TP_IDL	No information to output

The encoding for TP_IDL is defined in 14.2.1.1. The encoding for CD1 and CD0 is the same as that used on the AUI. Retiming of CD1 and CD0 signals within the MAU is neither prohibited nor required.

14.2.2.3 Twisted-pair link segment to PMA messages

Message	Circuit	Signal	Meaning
RD_input	RD	CD1,CD0	Input information
RD_idle	RD	TP_IDL	No information to input

The encoding for TP_IDL is defined in 14.2.1.1. The encoding for CD1 and CD0 is the same as that used on the AUI.

14.2.2.4 Interface message time references

Delay and bit loss specifications are measured from the occurrence of messages at the MDI and MAU AUI. The following describes the point where each message starts:

Message	Reference
output	leading bit cell boundary (BCB) of first valid CD1 or CD0
output_idle	last positive-going transition prior to start of IDL
input	leading BCB of first valid CD1 or CD0
input_idle	last positive-going transition prior to start of IDL
signal_quality_error	first transition of valid amplitude
mau_available	last positive-going transition prior to start of IDL
TD_output	leading BCB of first valid CD1 or CD0
TD_idle	last positive-going transition prior to start of TP_IDL
RD_output	leading BCB of first valid CD1 or CD0
RD_idle	last positive-going transition prior to start of TP_IDL

14.2.3 MAU state diagrams

The state diagrams of Figure 14–3a), Figure 14–3b), Figure 14–4, Figure 14–5, and Figure 14–6 depict the full set of allowed MAU state functions relative to the circuits of the AUI and MDI.

The notation used in the state diagrams follows the conventions in 1.2.1. The variables and timers used in the state diagrams are defined in the following subclauses.

14.2.3.1 State diagram variables

Variables are used in the state diagrams to indicate the status of MAU inputs and outputs, to control MAU operation, and to pass state information between functions.

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In the variable definitions, the name of the variable is followed by a brief description of the variable and a list of values the variable may take. For those variables that are state diagram outputs, one value will be identified as the default. The variable has the default value when no active state contains a term assigning a different value.

For example, the variable “xmit” has the value “disable” whenever the Jabber function or the Link Integrity Test function is in a state that asserts “xmit=disable.” The variable has the default value “enable” all other times.

The variables used in the state diagrams are defined as follows:

DI. Controls the signal sent by the MAU on the DI circuit.
Values:idle; MAU is sending *input_idle*, IDL (default).
DO; MAU sends the signal received on the DO circuit.
lpbk = disable overrides this and causes *input_idle* to be sent.
RD; MAU sends the signal received on the RD circuit.
rcv = disable overrides this and causes *input_idle* to be sent.

CI. Controls the signal sent by the MAU on the CI circuit.
Values:idle; MAU sends *mau_available*, IDL (default).
SQE; MAU sends *signal_quality_error*, CS0.

DO. Status of the signal received by the MAU on the DO circuit.
Values:idle; MAU is receiving *output_idle*, IDL.
active; MAU is receiving *output*, CD0 or CD1.

TD. Controls the signal sent by the MAU on the TD circuit.
Values:idle; MAU sends *TD_idle*, TP_IDL (default).
DO; MAU sends the signal received on the DO circuit.
xmit = disable overrides this and causes *TD_idle* to be sent.

RD. Status of the signal received by the MAU on the RD circuit.
Values:idle; MAU is receiving silence or a link test pulse.
active; MAU is detecting signals which meet the requirements of 14.3.1.3.2.

link_test_rcv. Status of the link test signal received by the MAU on the RD circuit.
Values:false; MAU is not detecting a link test pulse.
true; MAU is detecting a link test pulse.

link_count. Count of the number of consecutive link test pulses received while in the Link Fail state.
Values:non-negative integers.

lc_max. The number of consecutive link test pulses required before exit from the Link Fail state.
Values:positive integer between 2 and 10 inclusive.

rcv. Controls the path from the RD circuit to the DI circuit.
Values:enable; receive is enabled (default).
disable; the output to the DI circuit is *input_idle* when DI=RD.

lpbk. Controls the path from the DO circuit to the DI circuit.
Values:enable; loopback is enabled (default).
disable; the output to the DI circuit is *input_idle* when DI=DO.

xmit. Controls the path from the DO circuit to the TD circuit.
Values:enable; transmit is enabled (default).
disable; transmit is disabled and the signal sent on the TD circuit is TP_IDL.

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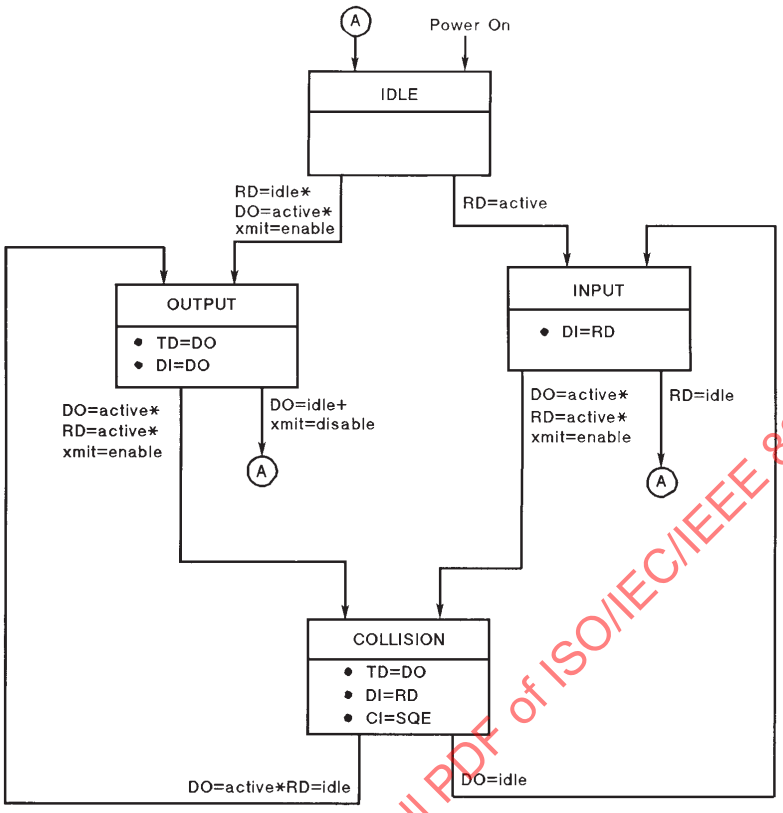
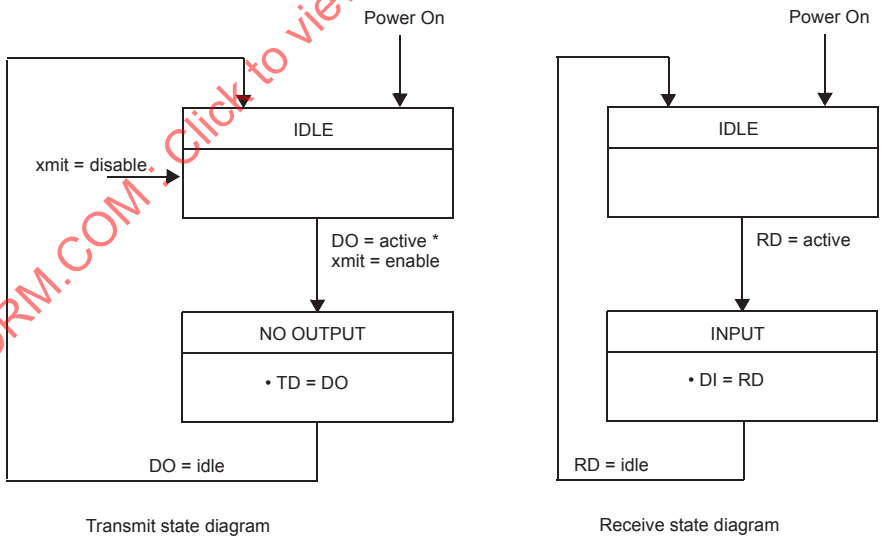


a) MAU Transmit, Receive, Loopback, and Collision Presence functions (half duplex mode)



b) MAU Transmit and Receive functions (full duplex mode)

Figure 14–3—MAU state diagrams

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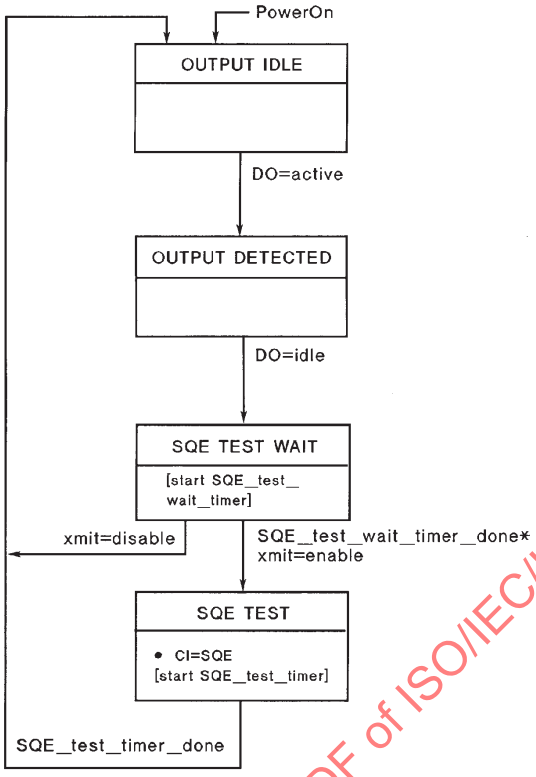

Figure 14–4—*signal_quality_error* Message Test function state diagram

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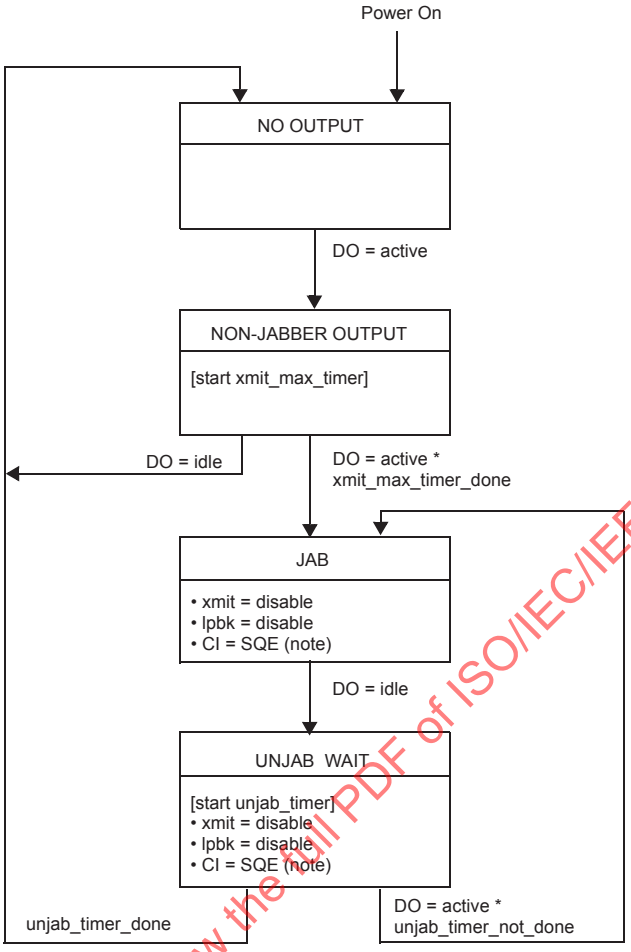

NOTE 1— Sending SQE on CI is optional for MAUs connected to DTEs operating in full duplex mode.

NOTE 2—The implementation of the Collision Presence function is not required in a MAU connected to a full duplex mode DTE, and is not shown in Figure 14–3b).

NOTE 3—The implementation of the SQE Test function shown in Figure 14–4 is not required in a MAU connected to a full duplex mode DTE.

NOTE 4—The enabling of the variable *lpbk* in Figure 14–6 is applicable only in half duplex mode.

Figure 14–5—Jabber function state diagram

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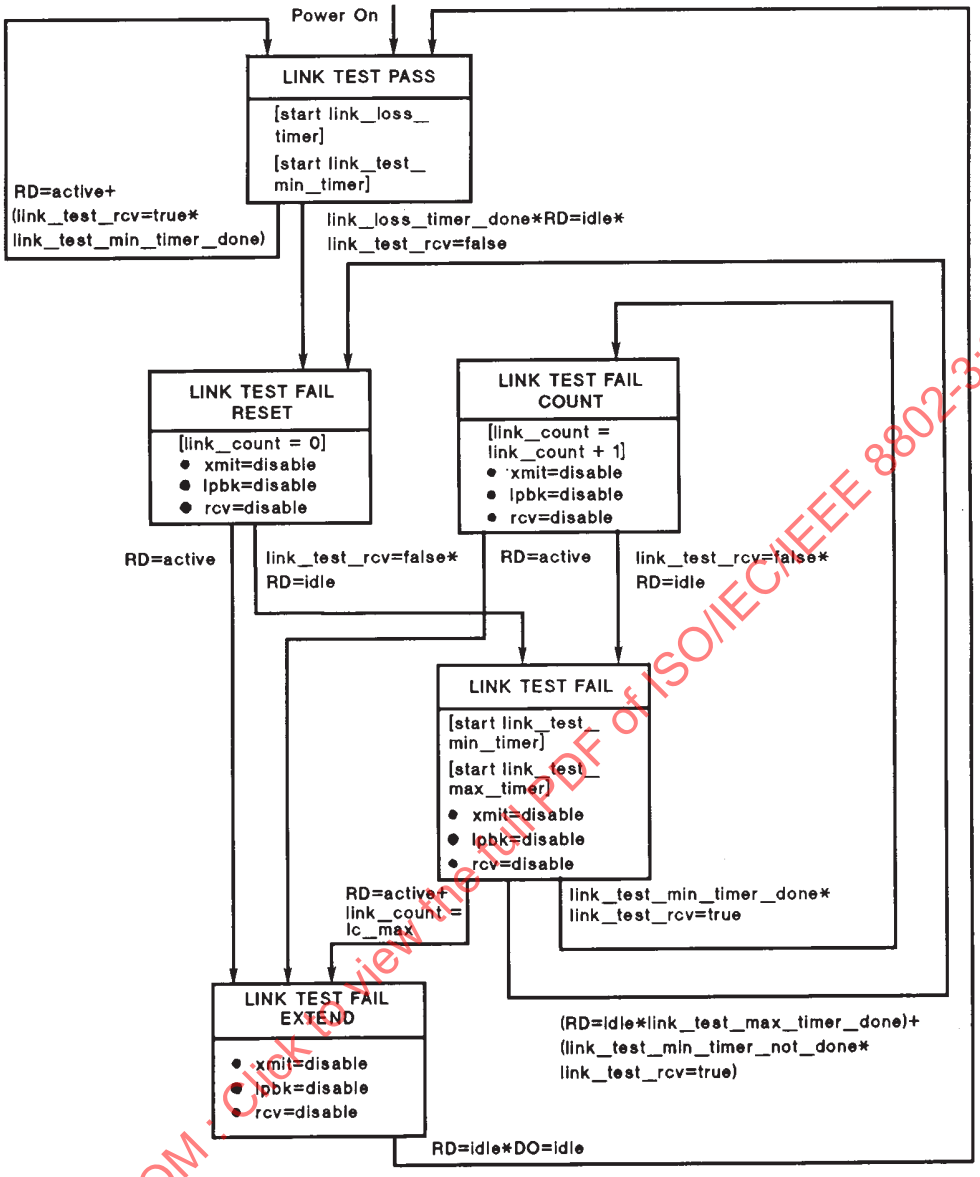

Figure 14–6—Link Integrity Test function state diagram

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14.2.3.2 State diagram timers

All timers operate in the same fashion. A timer is reset and starts counting upon entering a state where "start x_timer" is asserted. Time "x" after the timer has been started, "x_timer_done" is asserted and remains asserted until the timer is reset. At all other times, "x_timer_not_done" is asserted.

When entering a state where "start x_timer" is asserted, the timer is reset and restarted even if the entered state is the same as the exited state; for example, when in the Link Test Pass state of the Link Integrity Test function state diagram, the "link_loss_timer" and the "link_test_min_timer" are reset each time the term "RD = active + (link_test_rcv=true * link_test_min_timer_done)" is satisfied.

link_loss_timer. Timer for longest time input activity can be missing before the MAU determines that a link fail condition exists (14.2.1.7).

link_test_min_timer. Timer for the minimum time between valid link test pulses (14.2.1.7).

link_test_max_timer. Timer for maximum time input activity can be missing before Link Test Fail state is exited (14.2.1.7).

SQE_test_timer. Timer for the duration of the CS0 signal used for the SQE Test function (14.2.1.5).

SQE_test_wait_timer. Timer for the delay from end of packet to the start of the CS0 signal used for the SQE Test function (14.2.1.5).

unjab_timer. Timer for the length of time the DO circuit must be continuously idle to allow transmission to be re-enabled (14.2.1.6).

xmit_max_timer. Timer for excessively long transmit time (14.2.1.6).

14.3 MAU electrical specifications

This subclause defines the electrical characteristics of the MAU at the MDI and the AUI. The MAU shall also meet the AUI requirements specified in Clause 7 when the AUI is implemented.

Additional information relative to conformance testing is given in B.4.3.

The ground for all common-mode tests is circuit PG, Protective Ground of the AUI. In implementations without an AUI, chassis ground is used as circuit PG. All components in test circuits shall be ±1% unless otherwise stated.

14.3.1 MAU-to-MDI interface characteristics

14.3.1.1 Isolation requirement

A MAU with a MDI that is a PI (see 33.1.3) shall meet the isolation requirements defined in 33.4.1.

A MAU with a MDI that is not a PI shall provide isolation between the DTE Physical Layer circuits including frame ground and all MDI leads including those not used by 10BASE-T.

This electrical isolation shall withstand at least one of the following electrical strength tests.

a) 1500 V rms at 50 Hz to 60 Hz for 60 s, applied as specified in subclause 5.2.2 of IEC 60950-1:2001.
b) 2250 V dc for 60 s, applied as specified in subclause 5.2.2 of IEC 60950-1:2001.

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c) A sequence of ten 2400 V impulses of alternating polarity, applied at intervals of not less than 1 s. The shape of the impulses shall be 1.2/50 µs (1.2 µs virtual front time, 50 µs virtual time of half value), as defined in IEC 60950-1:2001 Annex N.

There shall be no insulation breakdown, as defined in subclause 5.2.2 of IEC 60950-1:2001, during the test. The resistance after the test shall be at least 2 MΩ, measured at 500 V dc.

14.3.1.2 Transmitter specifications

The MAU shall provide the Transmit function specified in 14.2.1.1 in accordance with the electrical specifications of this subclause.

Where a load is not specified, the transmitter shall meet requirements of this subclause when connected to a 100 Ω resistive load. The use of 100 Ω terminations simplifies the measurement process when using 50 Ω measurement equipment as 50 Ω to 100 Ω impedance matching transformers are readily available.

Some tests in this subclause require the use of an equivalent circuit that models the distortion introduced by a simplex link segment. This twisted-pair model shall be constructed according to Figure 14–7 or a type 10BASE-T MAU that is not a type 10BASE-Te MAU and according to Figure 14–8 for a type 10BASE-Te MAU with component tolerances as follows: Resistors, ±1%; capacitors, ±5%; inductors, ±10%. Component tolerance specifications shall be met from 5.0 MHz to 15 MHz. For all measurements, the TD circuit shall be connected through a balun to section 1 and the signal measured across a load connected to section 4 of the model. The balun shall not affect the peak differential output voltage specified in 14.3.1.2.1 by more than 1% when inserted between the 100 Ω resistive load and the TD circuit. Also, the value of the resistor that is in series with the inductors includes the series resistance of the inductor itself. The actual value of the resistor that is used is computed by subtracting the series resistance of the inductor from the resistor value shown in the figure.

For a type 10BASE-T MAU that is not a type 10BASE-Te MAU, the insertion loss of the twisted-pair model when measured with a 100 Ω source and 100 Ω load shall be between 9.70 dB and 10.45 dB at 10 MHz, and between 6.50 dB and 7.05 dB at 5 MHz.

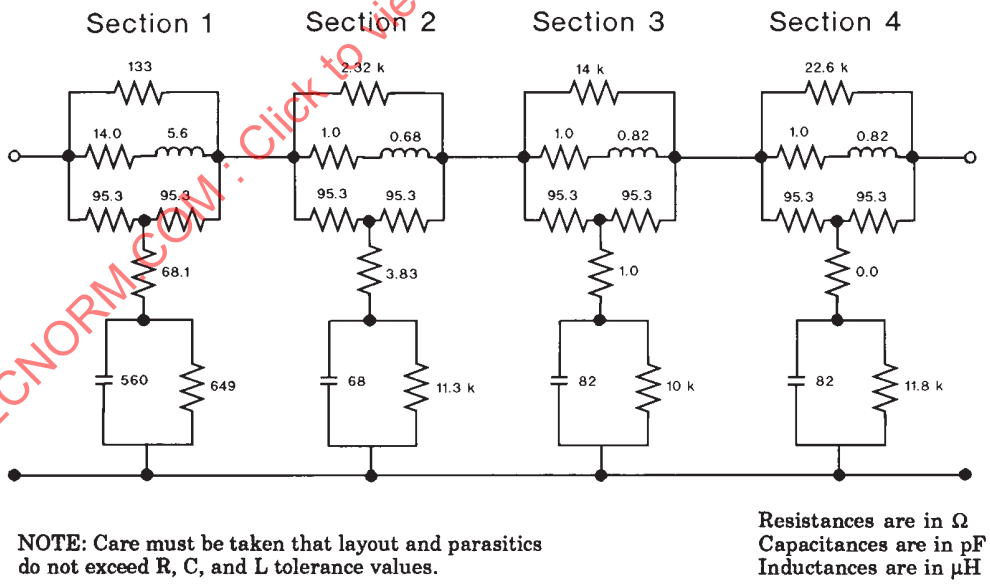

Figure 14–7—Twisted-pair model for 10BASE-T

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For a type 10BASE-Te MAU, the insertion loss of the twisted-pair model when measured with a 100 Ω source and 100 Ω load shall be between 6.8 dB and 7.4 dB at 10 MHz, and between 4.75 dB and 5.25 dB at 5 MHz.

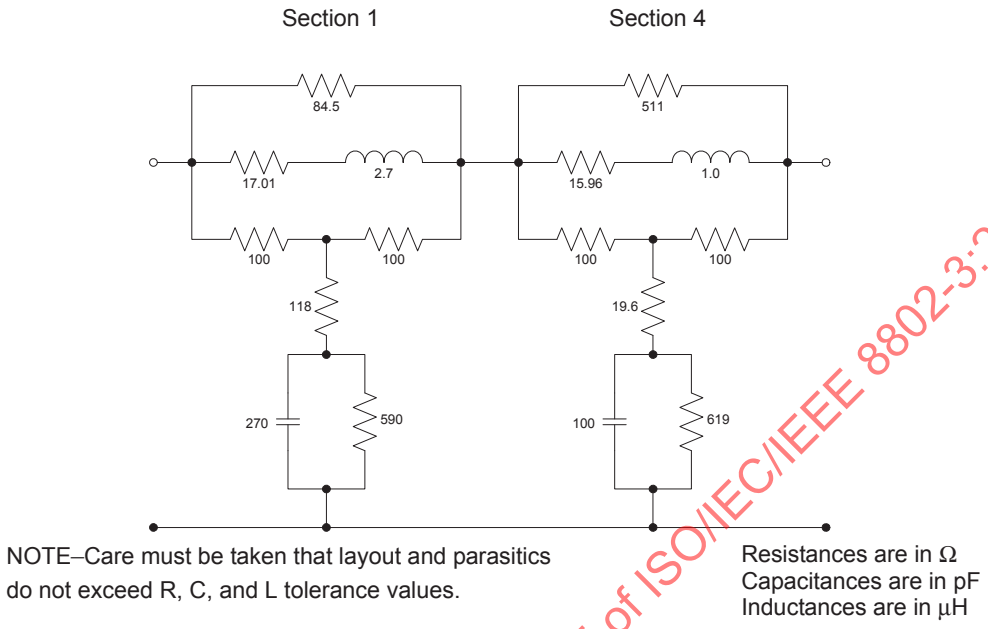

Figure 14–8—Twisted-pair model for 10BASE-Te

14.3.1.2.1 Differential output voltage

Some of the text and figures of this subclause describe the differential voltage in terms of magnitudes. These requirements apply to negative as well as positive pulses.

The peak differential voltage on the TD circuit when terminated with a 100 Ω resistive load shall be between 2.2 V and 2.8 V for all data sequences for a type 10BASE-T MAU that is not a type 10BASE-Te MAU. For a type 10BASE-Te MAU, the peak differential voltage on the TD circuit when terminated with a 100 Ω resistive load shall be between 1.54 V and 1.96 V for all data sequences. When the DO circuit is driven by an all-ones Manchester-encoded signal, any harmonic measured on the TD circuit shall be at least 27 dB below the fundamental.

NOTE—The specification on maximum spectral components is not intended to ensure compliance with regulations concerning RF emissions. The implementer should consider any applicable local, national, or international regulations. Additional filtering of spectral components may therefore be necessary.

The output signal V_o is defined at the output of the twisted-pair model as shown in Figure 14–9. The specific twisted-pair model used in Figure 14–9 shall be the equivalent circuit shown in Figure 14–7 for 10BASE-T except 10BASE-Te and shall be the equivalent circuit shown in Figure 14–8 for 10BASE-Te. The TD transmitter shall provide equalization such that the output waveform shall fall within the template shown in Figure 14–10 for all data sequences. Voltage and time coordinates for inflection points on Figure 14–10 are given in Table 14–1. (Zero crossing points are different for external and internal MAUs. The zero crossings depicted in Figure 14–10 apply to an external MAU.) The template voltage may be scaled by a factor of 0.9 to 1.1 but any scaling below 0.9 or above 1.1 shall not be allowed. The recommended measurement procedure is described in B.4.3.1. Time t = 0 on the template represents a zero crossing, with positive slope, of the output waveform. During this test the twisted-pair model shall be terminated in 100 Ω and driven by a

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transmitter with a Manchester-encoded pseudo-random sequence with a minimum repetition period of 511

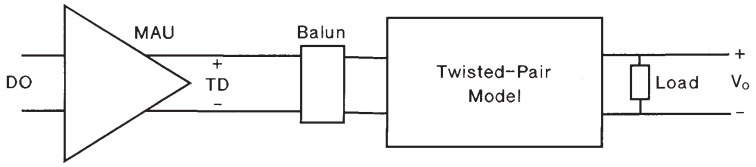

Figure 14–9—Differential output voltage test

bits.

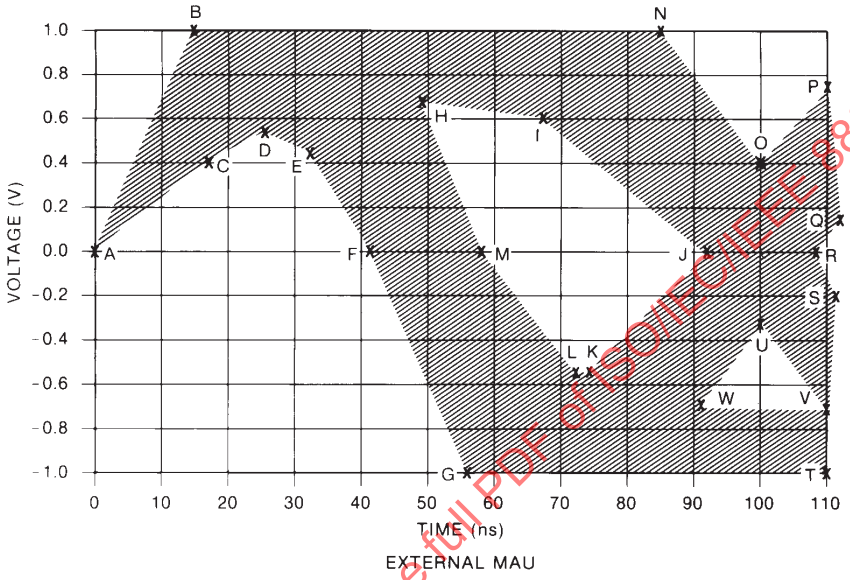

Figure 14–10—Voltage template

Table 14–1—Voltage template values for Figure 14–10

Reference	Time (ns)		Voltage (V)
	External MAU	Internal MAU	
A	0	0	0
B	15	15	1.0
C	15	15	0.4
D	25	25	0.55
E	32	32	0.45
F	42	39	0
G	57	57	–1.0
H	48	48	0.7
I	67	67	0.6
J	92	89	0
K	74	74	–0.55
L	73	73	–0.55
M	58	61	0
N	85	85	1.0
O	100	100	0.4
P	110	110	0.75
Q	111	111	0.15
R	108	111	0
S	111	111	–0.15
T	110	110	–1.0
U	100	100	–0.3

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Table 14–1—Voltage template values for Figure 14–10 *(continued)*

Reference	Time (ns)		Voltage (V)
	External MAU	Internal MAU	
V	110	110	–0.7
W	90	90	–0.7

This test shall be repeated with the template inverted about the time axis. In that case, t = 0 on the template represents a zero crossing, with negative slope, of the output waveform. When testing an external MAU the input waveform to the DO circuit of the MAU shall contribute no more than 0.5 ns of jitter. Adherence to this template does not verify that the requirements of 14.3.1.2.3 are met. (See B.4.3.3 for modification of the template to test jitter.)

The TP_IDL shall always start with a positive waveform when a waveform conforming to Figure 7–12 is applied to the DO circuit. If the last bit transmitted was a CD1, the last transition will be at the bit cell center of the CD1. If the last bit transmitted was a CD0, the PLS will generate an additional transition at the bit cell boundary following the CD0. After the zero crossing of the last transition, the differential voltage shall remain within the shaded area of Figure 14–11. Once the differential voltage has gone more negative than –50 mV, it shall not exceed +50 mV. The template requirements of Figure 14–11 shall be met when measured across each of the test loads defined in Figure 14–12, both with the load connected directly to the TD circuit and with the load connected through the twisted-pair model as defined in Figure 14–7 and Figure 14–9 for 10BASE-T except 10BASE-Te, and Figure 14–8 and Figure 14–9 for 10BASE-Te.

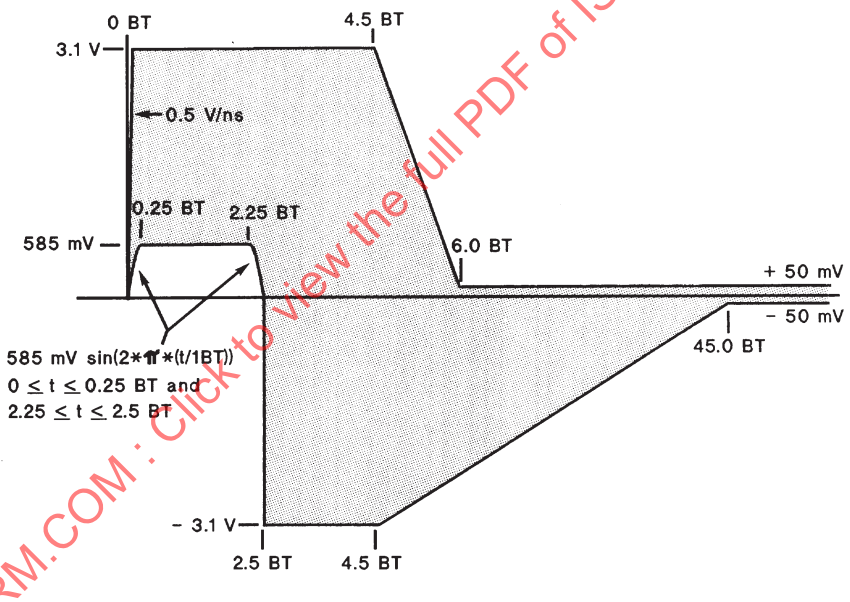

Figure 14–11—Transmitter waveform for start of TP_IDL

The link test pulse shall be a single positive (TD+ lead positive with respect to TD– lead) pulse, which falls within the shaded area of Figure 14–13. Once the differential output voltage has become more negative than –50 mV, it shall remain less than +50 mV. The template requirements of Figure 14–13 shall be met when measured across each of the test loads defined in Figure 14–12; both with the load connected directly to the TD circuit and with the load connected through the twisted-pair model as defined in Figure 14–7 and Figure 14–9 for 10BASE-T except 10BASE-Te, and Figure 14–8 and Figure 14–9 for 10BASE-Te.

For a MAU that implements the Auto-Negotiation algorithm defined in Clause 28, the FLP Burst Sequence will consist of multiple link test pulses. All link test pulses in the FLP Burst sequence shall meet the

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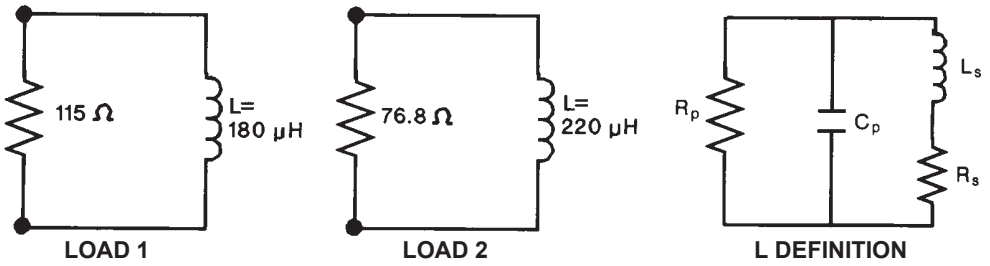

All parameters are defined over the frequency range of 250 kHz to 6 MHz.

$L_s = L \pm 1\%$ $R_p \geq 2\ k\Omega$
$C_p = 12\ pF \pm 20\%$ $R_s \leq 0.5\ \Omega$

Figure 14–12—Start-of-TP_IDL test load

template requirements of Figure 14–13 when measured across each of the test loads defined in Figure 14–12; both with the load connected directly to the TD circuit and with the load connected through the twisted-pair model as defined in Figure 14–7 and Figure 14–9 for 10BASE-T except 10BASE-Te, and Figure 14–8 and Figure 14–9 for 10BASE-Te.

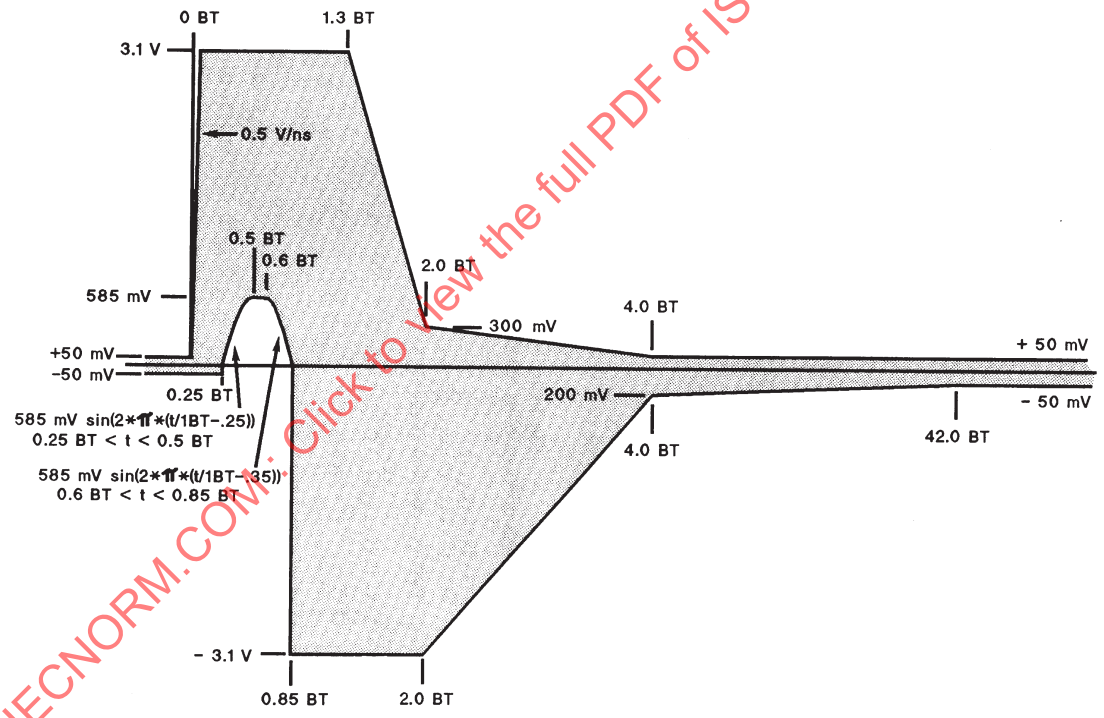

Figure 14–13—Transmitter waveform for link test pulse

14.3.1.2.2 Transmitter differential output impedance

The differential output impedance as measured on the TD circuit shall be such that any reflection, due to differential signals incident upon the TD circuit from a simplex link segment having any impedance within the range specified in 14.4.2.2, shall be at least 15 dB below the incident, over the frequency range of

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5.0 MHz to 10 MHz. This return loss shall be maintained at all times when the MAU is powered, including when the TD circuit is sending TP_IDL.

14.3.1.2.3 Output timing jitter

The transmitter output jitter is measured at the output of the twisted-pair model terminated in a 100 Ω load, as shown in Figure 14–9. The jitter added to the signal on the DO circuit as it propagates through the MAU and the twisted-pair model shall be no more than ±3.5 ns. Additionally, the MAU shall add no more than ±8 ns of jitter to the signal received on the DO circuit when the TD circuit is directly driving a 100 Ω resistive load.

14.3.1.2.4 Transmitter impedance balance

The common-mode to differential-mode impedance balance of the TD circuit shall exceed $29-17\log_{10}(f/10)$ dB (where f is the frequency in MHz) over the frequency range 1.0 MHz to 20 MHz. This balance is defined as $20\log_{10}(E_{cm}/E_{dif})$, where E_{cm} is an externally applied sine wave voltage as shown in Figure 14–14.

NOTE—The balance of the test equipment (such as the matching of the 147 Ω resistors) must exceed that required of the transmitter.

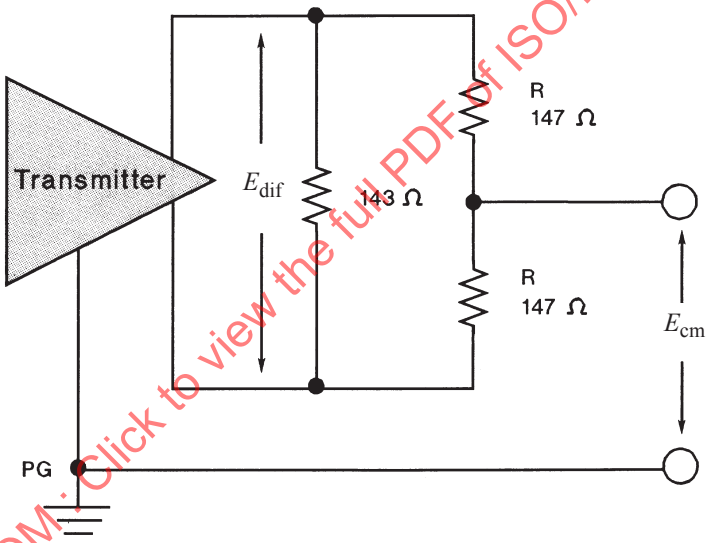

Figure 14–14—Transmitter impedance balance and common-mode rejection test circuit

14.3.1.2.5 Common-mode output voltage

The magnitude of the total common-mode output voltage of the transmitter, E_{cm}, measured as shown in Figure 14–15, shall be less than 50 mV peak at frequencies above 1 MHz.

NOTE—This specification is not intended to ensure compliance with regulations concerning RF emissions. The implementer should consider any applicable local, national, or international regulations. Driving unshielded twisted pairs with high-frequency, common-mode voltages may result in interference to other equipment.

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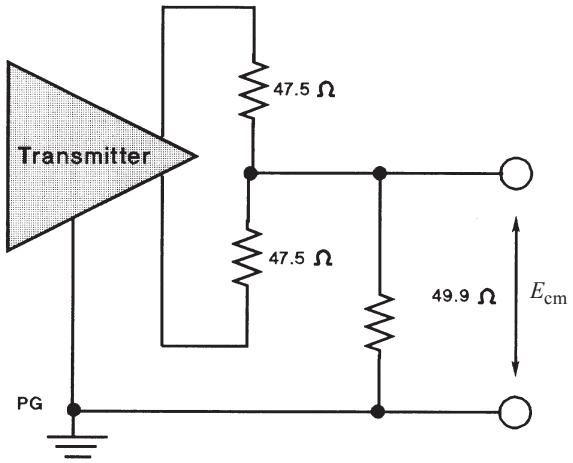

Figure 14–15—Common-mode output voltage test circuit

14.3.1.2.6 Transmitter common-mode rejection

The application of E_{cm}, as shown in Figure 14–14, shall not change the differential voltage at the TD circuit, E_{dif}, by more than 100 mV for all data sequences. Additionally, the edge jitter added by the application of E_{cm} shall be no more than 1.0 ns. E_{cm} shall be a 15 V peak 10.1 MHz sine wave.

14.3.1.2.7 Transmitter fault tolerance

Transmitters, when either idle or non-idle, shall withstand without damage the application of short circuits across the TD circuit for an indefinite period of time and shall resume normal operation after such faults are removed. The magnitude of the current through such a short circuit shall not exceed 300 mA.

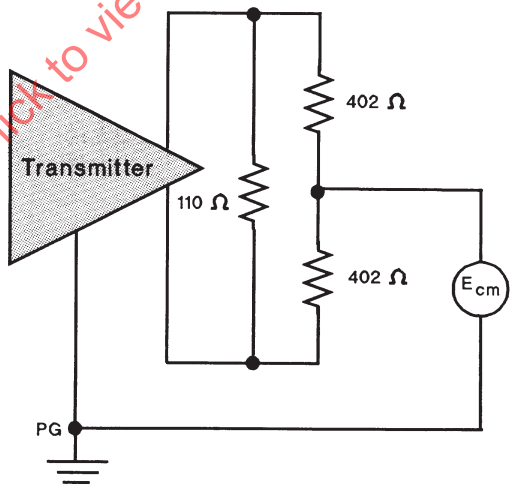

Figure 14–16—Transmitter fault tolerance test circuit

Transmitters, when either idle or non-idle, shall withstand without damage a 1000 V common-mode impulse applied at E_{cm} of either polarity (as indicated in Figure 14–16). The shape of the impulse shall be 0.3/50 µs (300 ns virtual front time, 50 µs virtual time of half value), as defined in IEC 60060.

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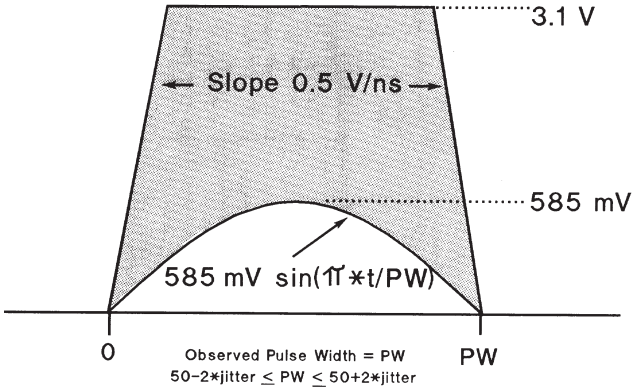

Figure 14–17—Receive differential input voltage—narrow pulse

14.3.1.3 Receiver specifications

The MAU shall provide the Receive function specified in 14.2.1.2 in accordance with the electrical specifications of this clause.

14.3.1.3.1 Receiver differential input signals

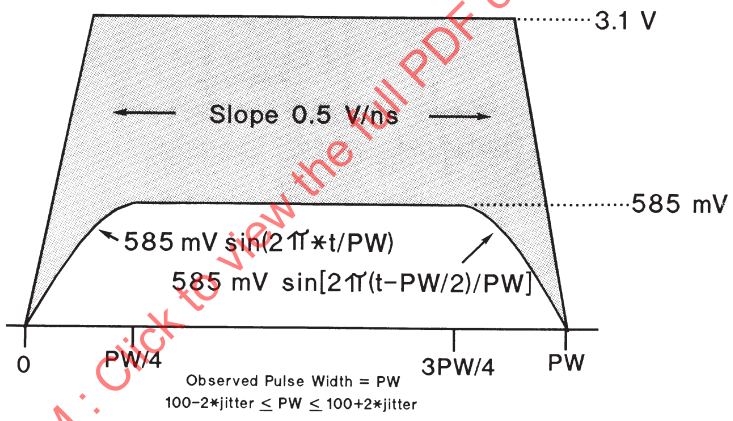

Figure 14–18—Receiver differential input voltage—wide pulse

Differential signals received on the RD circuit that are within the envelope of Figure 14–17 and Figure 14–18, and have a maximum zero crossing jitter up to ±13.5 ns from the ideal shall be sent to the DI circuit. The 13.5 ns includes jitter caused by an encoder, AUI cable and transmitting MAU, the twisted pair, and noise. Additionally, the MAU receiver shall add no more than ±1.5 ns jitter to the receive signal before sending the signal to the DI circuit.

14.3.1.3.2 Receiver differential noise immunity

The receiver, when presented with Manchester-encoded data meeting the requirements of 14.3.1.3.1, shall send this data to the DI circuit with a bit loss of no more than that specified in 14.2.1.2. In addition, the receiver, when presented with a signal meeting the requirements of 14.2.1.1 and within the envelope of Figure 14–13, shall accept it as a link test pulse.

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The receiver, while in the Idle state, shall reject as *RD_input* the following signals:

a) All signals that when measured at the output of the following filter would produce a peak magnitude less than 300 mV. The filter is a 3-pole low-pass Butterworth with a 3 dB cutoff at 15 MHz (refer to B.4.2).
b) All continuous sinusoidal signals of amplitude less than 6.2 V peak-to-peak and frequency less than 2 MHz.
c) All sine waves of single cycle duration, starting with phase 0 or 180 degrees, and of amplitude less than 6.2 V peak-to-peak where the frequency is between 2 MHz and 15 MHz. For a period of 4 BT before and after this single cycle, the signal shall be less than 300 mV when measured through the filter specified in a) above.

14.3.1.3.3 Idle input behavior

The idle condition shall be detected within 2.3 BT of the last low-to-high transition at the receiver. The receiver shall take precautions to ensure that the high-to-silence transition of the start of idle is not falsely interpreted as a silence-to-non-idle-transition, even in the presence of signal droop, overshoot, ringing, slow voltage decay, or a combination thereof due to capacitive and inductive effects in the transmitter, link segment, and receiver.

14.3.1.3.4 Receiver differential input impedance

The differential input impedance shall be such that any reflection, due to differential signals incident upon the RD circuit from a twisted pair having any impedance within the range specified in 14.4.2.2 shall be at least 15 dB below the incident over the frequency range of 5.0 MHz to 10 MHz. The return loss shall be maintained when the MAU is powered.

14.3.1.3.5 Common-mode rejection

Receivers shall assume the proper state on DI for any differential input signal E_s that results in a signal E_{dif} that meets 14.3.1.3.1 even in the presence of common-mode voltages E_{cm} (applied as shown in Figure 14–19). E_{cm} shall be a 25 V peak-to-peak square wave, 500 kHz or lower in frequency, with edges no slower than 4 ns (20%–80%). Additionally, E_{cm} shall contribute no more than 2.5 ns of edge jitter to the signal transmitted on the DI circuit. The combination of the receiver timing jitter of 14.3.1.3.1 and the common-mode induced jitter are such that the MAU shall add no more than 4.0 ns of edge jitter to E_s before sending the signal on the DI circuit.

14.3.1.3.6 Receiver fault tolerance

The receiver shall tolerate the application of short circuits between the leads of the RD circuit for an indefinite period of time without damage and shall resume normal operation after such faults are removed. Receivers shall withstand without damage a 1000 V common-mode impulse of either polarity ($E_{impulse}$ as indicated in Figure 14–20). The shape of the impulse shall be 0.3/50 µs (300 ns virtual front time, 50 µs virtual time of half value), as defined in IEC 60060.

14.3.2 MAU-to-AUI specification

When a MAU contains a physical AUI connector, the following specifications shall be met.

14.3.2.1 MAU-AUI electrical characteristics

The electrical characteristics for the driver and receiver components within the MAU that are connected to the AUI shall be identical to those specified in 7.4 and 7.5. Additionally, the AUI DO receiver, while in the Idle state, shall reject an input waveform of less than ±160 mV differential.

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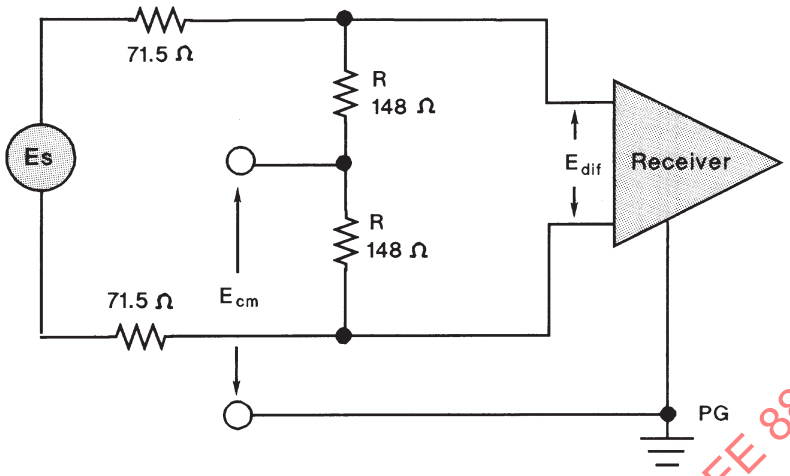

Figure 14–19—Receiver common-mode rejection test circuit

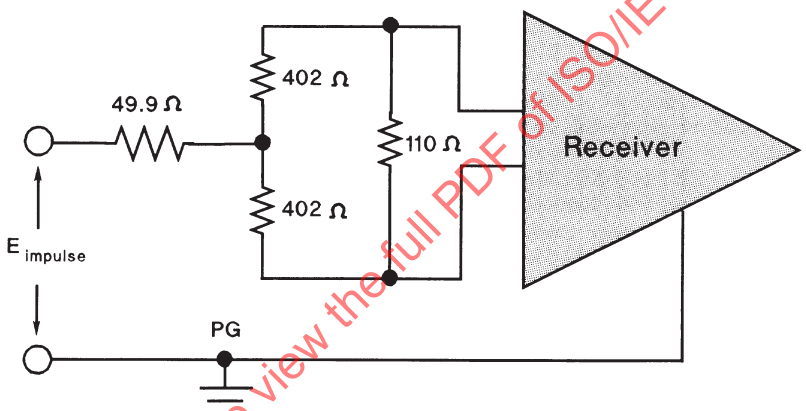

Figure 14–20—Common-mode impulse test circuit

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14.3.2.2 MAU–AUI mechanical connection

The MAU shall be provided with a 15-pin male connector as specified in 7.6.

14.3.2.3 Power consumption

Following PowerOn, the surge current drawn by the MAU shall be such that $I_p \times T_w$ is less than or equal to 2×10^{-3} ampere-seconds, where I_p is the peak surge current and T_w is the time during which the current exceeds the larger of 0.5 A or $0.5 \times I_p$. After the 100 ms following PowerOn, the current drawn by the MAU shall not exceed 0.5 A when powered by the AUI.

The MAU shall be capable of operating from all possible voltage sources, including those current limited to 0.5 A, as supplied by the DTE or repeater through the resistance of all permissible AUI cables.

The MAU shall not introduce extraneous signals on the TD, CI, or DI circuits during normal power-up and power-down.

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14.4 Characteristics of the simplex link segment

Except where otherwise stated, the simplex link segment shall be tested with source and load impedances of 100 Ω.

14.4.1 Overview

The medium for 10BASE-T is twisted-pair wiring. A significant number of 10BASE-T networks are installed utilizing in-place unshielded telephone wiring and typical telephony installation practices, the end-to-end path including different types of wiring, cable connectors, and cross connects must be considered. Typically, a DTE connects to a wall outlet using a twisted-pair patch cord. Wall outlets connect through building wiring and a cross connect to the repeater MAU in a wiring closet.

The medium for 10BASE-Te is twisted-pair wire. The requirements of the 10BASE-Te simplex link segment (either pure 10BASE-Te or mixed 10BASE-T, 10BASE-Te) are equivalent to the requirements of the Class D channel specified by ISO/IEC 11801:1995. This requirement can also be met by Category 5 cable and components as specified in ANSI/TIA/EIA-568-A.

NOTE—ISO/IEC 11801:2002 provides a specification for media that exceeds the minimum requirements of this standard.

14.4.2 Transmission parameters

Each simplex link segment shall have the following characteristics. All characteristics specified apply to the total simplex link segment unless otherwise noted. These characteristics are generally met by 100 m of twisted-pair cable composed of 0.5 mm [24 AWG] twisted pairs.

14.4.2.1 Insertion loss

The insertion loss of a simplex link segment shall be no more than 11.5 dB at all frequencies between 5.0 MHz and 10 MHz for a 10BASE-T MAU that is not a 10BASE-Te MAU. For a 10BASE-Te MAU, the insertion loss of a simplex link segment shall be no more than 8.5 dB at all frequencies between 5.0 MHz and 10 MHz. This consists of the attenuation of the twisted pairs, connector losses, and reflection losses due to impedance mismatches between the various components of the simplex link segment. The insertion loss specification shall be met when the simplex link segment is terminated in source and load impedances that satisfy 14.3.1.2.2 and 14.3.1.3.4.

NOTE—Multipair PVC-insulated 0.5 mm [24 AWG] cable typically exhibits an attenuation of 8 dB to 10 dB/100 m at 20 °C. The loss of PVC-insulated cable exhibits significant temperature dependence. At temperatures greater than 40 °C, it may be necessary to use a less temperature-dependent cable, such as most plenum-rated cables.

14.4.2.2 Differential characteristic impedance

The magnitude of the differential characteristic impedance of a 3 m length of twisted pair used in a simplex link segment shall be between 85 Ω and 111 Ω for all frequencies between 5.0 MHz and 10 MHz. Since characteristic impedance tends to decrease with increasing frequency, the above requirement is generally implied by the condition that the magnitude of the characteristic impedance over the frequency band 1 MHz to 16 MHz is 100 Ω ± 15 Ω. Also, the magnitude of the input impedance averaged over the 5.0 MHz to 10 MHz frequency band of a simplex link segment terminated in 100 Ω shall be between 85 Ω and 111 Ω.

14.4.2.3 Medium timing jitter

Intersymbol interference and reflections due to impedance mismatches between tandem twisted pairs of a twisted-pair link segment and effects of connection devices can introduce jitter to the CD1 and CD0 signals

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received on the RD circuit. No more than ±5.0 ns of jitter shall be introduced to a test signal by a simplex link segment. The test signal shall have a peak amplitude of 3.0 V and 10% to 90% rise and fall times of 12 ns. The content of the test signal shall be a Manchester-encoded pseudo-random sequence with a minimum repetition period of 511 bits.

NOTE—Branches off a twisted pair (often referred to as "bridged taps" or "stubs") will generally cause excessive jitter and so should be avoided.

14.4.2.4 Delay

The maximum propagation delay of twisted pair shall be 5.7 ns/m (minimum velocity of $0.585 \times c$). The maximum propagation delay of a link segment shall not exceed 1000 ns.

14.4.3 Coupling parameters

To avoid excessive coupling of signals between twisted pairs of a twisted-pair cable, the crosstalk must be limited. Crosstalk loss is specified for the twisted pairs in a twisted-pair cable or twisted-pair cable binder group that are used as 10BASE-T twisted-pair links. Crosstalk loss is specified with the far ends of both the disturbed and the disturbing pairs and the near end of the disturbed pair terminated in 100 Ω. Drivers of disturbing pairs shall have a source impedance of 100 Ω.

14.4.3.1 Differential near-end crosstalk (NEXT) loss

The NEXT loss between any two twisted pairs of a twisted-pair cable is dependent upon the geometry of the twisted-pair cable. Since the proximity of any two twisted pairs is influenced by the size of the twisted-pair cable, the NEXT loss is affected by twisted-pair cable size.

14.4.3.1.1 Twenty-five-pair cable and twenty-five-pair binder groups

The NEXT loss between any two twisted pairs in a twenty-five-pair twisted-pair cable or binder group used for 10BASE-T applications shall be at least $30 - 15 \log_{10}(f/10)$ dB (where f is the frequency in MHz) over the frequency range 5.0 MHz and 10 MHz.

14.4.3.1.2 Four-pair cable

The NEXT loss between any two twisted pairs in a four-pair twisted-pair cable used for 10BASE-T applications shall be at least $26 - 15 \log_{10}(f/10)$ dB (where f is the frequency in MHz) over the frequency range 5.0 MHz and 10 MHz.

14.4.3.1.3 Other cables

The NEXT loss requirement for all other twisted-pair cables shall be the multiple-disturber NEXT loss of 14.4.3.2.

14.4.3.2 Multiple-disturber NEXT (MDNEXT) loss

When a twisted-pair cable or twisted-pair cable binder group contains twisted pairs from multiple 10BASE-T twisted-pair link segments, the multiple-disturber crosstalk loss is dependent upon the specific selection of disturbing and disturbed pairs. For each 10BASE-T receive pair, MDNEXT is measured by having the remaining near-end transmit pairs (excluding the transmit pair associated with the receive pair under test) driven with identical and synchronized sine wave signals. MDNEXT may then be determined from the signal level observed on the receive pair under test. By examining all pair combinations with a fixed number of disturbers, a cumulative distribution of MDNEXT is obtained at each frequency of interest. The one percentile of this cumulative distribution shall be at least $23 - 15 \log_{10}(f/10)$ (where f is the frequency in

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MHz) at 5.0 MHz, 7.5 MHz, and 10 MHz. When the number of possible combinations allowed by a cable is fewer than 100, the MDNEXT loss for all combinations shall be at least $23-15\log_{10}(f/10)$ (where f is the frequency in MHz) at 5.0 MHz, 7.5 MHz, and 10 MHz. Refer to 12.7.3.2 and B.3 for a tutorial and method for estimating the MDNEXT loss for a complete n-pair cable.

14.4.4 Noise environment

The noise level on the link segments shall be such that the objective error ratio is met. The noise environment consists generally of two primary contributors: crosstalk from other 10BASE-T circuits; and externally induced impulse noise, typically from telephone ringing and dialing signals, and other office and building equipment.

14.4.4.1 Impulse noise

The average rate of occurrence of impulses greater than 264 mV shall be less than or equal to 0.2/s as measured at the output of the following specified filter. Following the start of any particular impulse that is counted, any additional impulse shall be ignored for a period of 1 µs. The simplex link segment shall be terminated at the far end in 100 Ω. The filter is a 3-pole Butterworth low-pass with a 3 dB cutoff at 15 MHz (refer to B.4.2).

NOTE—Typically, the impulse noise occurrence rate changes inversely by one decade for each 5 dB to 9 dB change in the threshold voltage. If a count rate of N counts/s is measured on a specific twisted pair and filter at the specified voltage threshold, the media noise margin is approximately $7\log_{10}(0.2/N)$ dB. Impulse noise may be a burst phenomenon and should be measured over an extended period of time.

14.4.4.2 Crosstalk noise

The level of crosstalk noise on a simplex link segment depends on the level of the disturbing signal(s) and the crosstalk loss between the pair(s) carrying the signal(s) and the disturbed pair. With the maximum transmit level (14.3.1.2), the sinusoidal crosstalk loss (14.4.3.2), and multiple, random Manchester-encoded disturbers, the peak self-crosstalk noise levels as measured at the output of the following specified filter shall be less than or equal to 264 mV. The filter is a 3-pole Butterworth low-pass with a 3 dB cutoff at 15 MHz (refer to B.4.2).

14.5 MDI specification

This subclause defines the MDI for the twisted-pair link segment. The link topology requires a crossover function between PMAs. Implementation and location of this crossover is also defined in this clause.

14.5.1 MDI connectors

Eight-pin connectors meeting the requirements of Clause 3 and Figures 1 through 5 of IEC 60603-7 shall be used as the mechanical interface to the twisted-pair link segment. The plug connector shall be used on the

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twisted-pair link segment and the jack on the MAU. These connectors are depicted (for informational use only) in Figure 14–21 and Figure 14–22. The following table shows the assignment of signals to connector contacts.

Contact	MDI signal
1	TD+
2	TD–
3	RD+
4	Not used by 10BASE-T
5	Not used by 10BASE-T
6	RD–
7	Not used by 10BASE-T
8	Not used by 10BASE-T

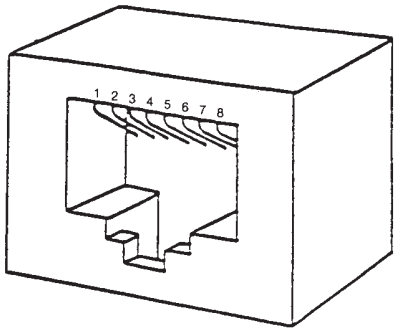

Figure 14–21—MAU MDI connect

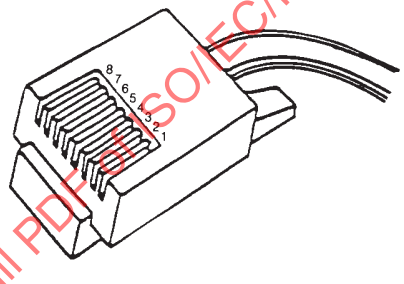

Figure 14–22—Twisted-pair link segment connector

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14.5.2 Crossover function

A crossover function shall be implemented in every twisted-pair link. The crossover function connects the transmitter of one MAU to the receiver of the MAU at the other end of the twisted-pair link. Crossover functions may be implemented internally to a MAU or elsewhere in the twisted-pair link. For MAUs that do not implement the crossover function, the signal names of 14.5.1 refer to their own internal circuits. For MAUs that do implement the crossover function, the signal names refer to the remote MAU of the twisted-pair link. Additionally, the MDI connector for a MAU that implements a fixed crossover function shall be marked with the graphical symbol “X”. Internal and external crossover functions are shown in Figure 14–23.

When a twisted-pair link connects a DTE to a repeater, it is recommended that the crossover be implemented in the MAU local to the repeater. If both MAUs of a twisted-pair link contain internal crossover functions, an additional external crossover is necessary. It is recommended that the crossover be visible to an installer from one of the MAUs. When both MAUs contain internal crossovers, it is further recommended in networks in which the topology identifies either a central backbone segment or a central hub that the MAU furthest from the central element be assigned the external crossover to maintain consistency.

Implicit implementation of the crossover function within a twisted-pair cable, or at a wiring panel, while not expressly forbidden, is beyond the scope of this standard.

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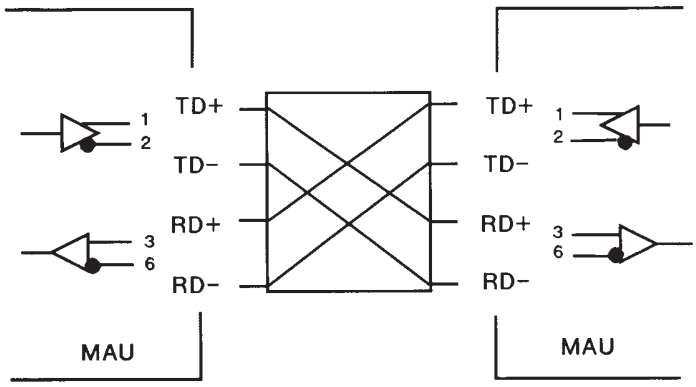
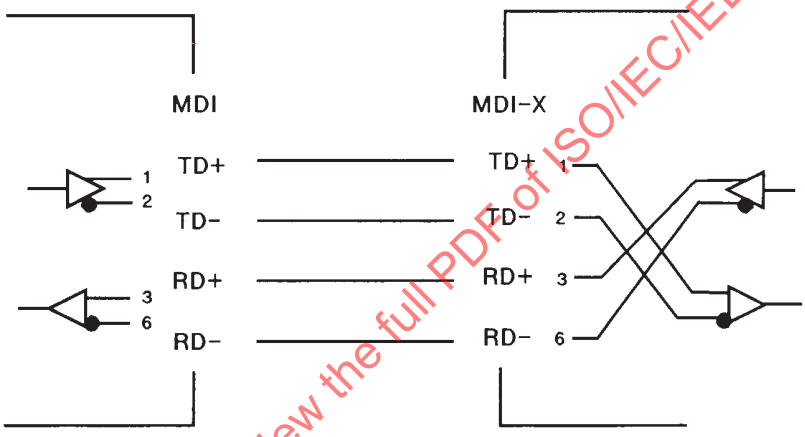


a) External Crossover function



b) MAU-Embedded Crossover function

Figure 14–23—Crossover function

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14.6 System considerations

The repeater unit specified in Clause 9 forms the central unit for interconnecting 10BASE-T twisted-pair links in networks of more than two nodes. It also provides the means for connecting 10BASE-T twisted-pair links to other 10 Mb/s baseband segments. The proper operation of a CSMA/CD network requires network size to be limited to control round-trip propagation delay to meet the requirements of 4.2.3.2.3 and 4.4.2, and the number of repeaters between any two DTEs to be limited in order to limit the shrinkage of the interpacket gap as it travels through the network. Configuration rules, which ensure that these limits are not exceeded, are given in Clause 13.

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14.7 Environmental specifications

14.7.1 General safety

All equipment meeting this standard shall conform to IEC 60950-1.

14.7.2 Network safety

This subclause sets forth a number of recommendations and guidelines related to safety concerns; the list is neither complete nor does it address all possible safety issues. The designer is urged to consult the relevant local, national, and international safety regulations to ensure compliance with the appropriate requirements.

LAN cable systems described in this subclause are subject to at least four direct electrical safety hazards during their installation and use. These hazards are as follows:

a) Direct contact between LAN components and power, lighting, or communications circuits.
b) Static charge buildup on LAN cables and components.
c) High-energy transients coupled onto the LAN cable system.
d) Voltage potential differences between safety grounds to which various LAN components are connected.

Such electrical safety hazards must be avoided or appropriately protected against for proper network installation and performance. In addition to provisions for proper handling of these conditions in an operational system, special measures must be taken to ensure that the intended safety features are not negated during installation of a new network or during modification or maintenance of an existing network. Isolation requirements are defined in 14.3.1.1.

14.7.2.1 Installation

Sound installation practice, as defined by applicable local codes and regulations, shall be followed in every instance in which such practice is applicable.

14.7.2.2 Grounding

Any safety grounding path for the MAU shall be provided through the circuit PG of the AUI connection.

WARNING

It is assumed that the equipment to which the MAU is attached is properly earthed, and not left floating nor serviced by a "doubly insulated ac power distribution system." The use of floating or insulated equipment, and the consequent implications for safety are beyond the scope of this standard.

14.7.2.3 Installation and maintenance guidelines

During installation and maintenance of the cable plant, care shall be taken to ensure that uninsulated network cable conductors do not make electrical contact with unintended conductors or ground.

14.7.2.4 Telephony voltages

The use of building wiring brings with it the possibility of wiring errors that may connect telephony voltages to 10BASE-T equipment. Other than voice signals (which are low voltage), the primary voltages that may be encountered are the "battery" and ringing voltages. Although there is no universal standard, the following maximums generally apply.

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Battery voltage to a telephone line is generally 56 Vdc applied to the line through a balanced 400 Ω source impedance.

Ringing voltage is a composite signal consisting of an ac component and a dc component. The ac component is up to 175 V peak at 20 Hz to 60 Hz with a 100 Ω source resistance. The dc component is 56 Vdc with a 300 Ω to 600 Ω source resistance. Large reactive transients can occur at the start and end of each ring interval.

Although 10BASE-T equipment is not required to survive such wiring hazards without damage, application of any of the above voltages shall not result in any safety hazard.

NOTE—Wiring errors may impose telephony voltages differentially across 10BASE-T transmitters or receivers. Because the termination resistance likely to be present across a receiver's input is of substantially lower impedance than an off-hook telephone instrument, receivers will generally appear to the telephone system as off-hook telephones. Therefore, full-ring voltages will be applied for only short periods. Transmitters that are coupled using transformers will similarly appear like off-hook telephones (though perhaps a bit more slowly) due to the low resistance of the transformer coil.

14.7.3 Environment

14.7.3.1 Electromagnetic emission

The twisted-pair link shall comply with applicable local and national codes for the limitation of electromagnetic interference.

14.7.3.2 Temperature and humidity

The twisted-pair link is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

It is recommended that manufacturers indicate in the literature associated with the MAU the operating environmental conditions to facilitate selection, installation, and maintenance.

It is recommended that manufacturers indicate, in the literature associated with the components of the twisted-pair link segment, the distance and operating environmental conditions over which the specifications of 14.4 will be met.

14.8 MAU labeling

It is recommended that each MAU (and supporting documentation) be labeled in a manner visible to the user with at least these parameters:

a) Data rate capability in Mb/s,
b) Power level in terms of maximum current drain (for external MAUs),
c) Any applicable safety warnings,
d) Duplex capabilities, and
e) Which of the two specifications is implemented, i.e., 10BASE-T or 10BASE-Te (not both).

See also 14.5.2.

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14.9 Timing summary

Table 14–2 summarizes the timing requirements for the 10BASE-T twisted-pair link. This table is a summary; for complete descriptions of the timing requirements, refer to the referenced subclauses.

Table 14–2—Maximum timing parameters

Symbol	Function	Bit loss[a]	Invalid bits[b]	Steady-state propagation delay[b]	Start-up delay[b]		Specified in
					Maximum	Variability	
M1	*RD_input* to *input* on DI	5.0	1.0	2.0	8.0	2.0	14.2.1.2
M2	*output* on DO to *TD_output*	2.0	1.0	2.0	5.0	2.0	14.2.1.1
M3	*RD_input* * *output* to *signal_quality_error*	—	—	—	9.0	—	14.2.1.4
M4	*RD_idle* + *output_idle* (end of collision) to *mau_available*	—	—	—	9.0	—	14.2.1.4
M5	*RD_input* * *output* to *input* on DI from circuit RD	—	—	—	9.0	—	14.2.1.4
M6	*RD_idle* * *output* to *input* on DI from circuit DO	—	—	—	9.0	—	14.2.1.4
M7	*output_idle* on DO to *signal_quality_error*	—	—	—	6 < x < 16	—	14.2.1.5
M8	*signal_quality_error* duration for SQE test	—	—	—	5 < x < 15	—	14.2.1.5
M9	*output* on DO to *input* on DI	5.0	1.0	1.0	7.0	—	14.2.1.3
T1	twisted-pair propagation	0	0	10.00	10.00	—	14.4.2.4
A1	AUI cable propagation (50 m)	0	0	2.57	2.57	—	7.4.3.7

[a]All time in BT.
[b]For an explanation of the meaning of variability, see 14.2.1.1 and 14.2.1.2.

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14.10 Protocol implementation conformance statement (PICS) proforma for Clause 14, Twisted-pair medium attachment unit (MAU) and baseband medium, type 10BASE-T and type 10BASE-Te[37]

14.10.1 Introduction

To evaluate conformance of a particular implementation, it is necessary to state which capabilities and options have been implemented for a given OSI protocol. Such a statement is called a protocol implementation conformance statement (PICS).

This PICS proforma defines conformance requirements for type 10BASE-T MAU implementations. When the supplier completes this proforma, this document becomes the PICS for the specified implementation. The PICS is then used to perform a static conformance review of the implementation to determine that all mandatory features are implemented and that all conditional features are correctly supported dependent on the options claimed to be implemented. The PICS is used also as an aid in test-case selection and result analysis during the dynamic conformance testing.

Separate MAU and link segment implementations are expected; submissions of either for testing do not require submission of the other. Furthermore, there is no current intention to produce an Abstract Test Suite from the subclause of the PICS proforma that discusses the link segment.

14.10.1.1 Scope

This subclause provides the PICS proforma for type 10BASE-T MAU specifications in accordance with the relevant guidance given in ISO/IEC 9646-2.

14.10.1.2 Reference

Type 10BASE-T MAU requirements referenced in this PICS proforma are found in 14.2 through 14.8 and in 7.3 through 7.6 of this standard. Subclauses 7.3 through 7.6 and 14.2 through 14.8 take precedence over 14.10 in case of any conflict.

The use and the requirements for PICS proforma are defined in ISO/IEC 9646-1 and ISO/IEC 9646-2.

14.10.1.3 Definitions

This document uses the following terms defined in ISO/IEC 9646-1:

PICS proforma
protocol implementation conformance statement (PICS)
static conformance review
dynamic conformance testing

14.10.1.4 Conformance

The supplier of a MAU that is claimed to conform to type 10BASE-T MAU specifications shall complete a copy of the PICS proforma provided in this document and shall provide the information necessary to identify both the supplier and the implementation.

[37] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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14.10.2 Identification of implementation

The MAU supplier shall complete the relevant fields in this subclause to identify the supplier and the particular MAU.

14.10.2.1 Supplier information

The MAU supplier shall complete the relevant fields in this subclause to identify the supplier and the particular MAU.

Company name:	
Representative name:	
Address:	
Phone:	
Fax:	
E-mail:	

14.10.2.2 Implementation information

Implementation name:	
Implementation identifier (including version/release):	

14.10.3 Identification of the protocol

The supplier will complete this subclause to identify the precise protocol implemented.

Check Y [ ] if the MAU identified in the previous subclause implements the following protocol standard; check N [ ] if otherwise and attach an explanation.

IEEE Std 802.3-2015,Clause 14, Twisted-pair medium attachment unit (MAU) and baseband medium, type 10BASE-T except type 10BASE-Te	Y [ ]	N [ ]
IEEE Std 802.3-2015, Clause 14, Twisted-pair medium attachment unit (MAU) and baseband medium, type 10BASE-Te	Y [ ]	N [ ]

List any other addenda or amendment documents implemented.

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14.10.4 PICS proforma for 10BASE-T

14.10.4.1 Abbreviations

The following abbreviations are used in the PICS proforma tables:

Req=Requirement. This column indicates whether the conformance requirement of a particular clause in the standard is mandatory, optional, or conditional.
Imp=Implementation. This column is filled in for a particular implementation with a "Y" or an "N" to indicate claimed conformance.
M=Mandatory. Conformance cannot be met unless the parameter is implemented as specified.
O=Optional. The parameter may be implemented or not but, if implemented, it must be as stated in the standard.
C=Conditional. If an associated major option is implemented, this parameter must be implemented.

NOTE—Recommendations in the standard become "Optional" parameters in the context of a PICS proforma.

14.10.4.2 PICS Completion instructions and implementation statement

A supplier wishing to submit a 10BASE-T MAU for conformance testing against this standard must fill in the column headed "Imp" in the PICS proforma tables and submit the resulting PICS with the equipment for test. This column must be filled in either with a "Y" for yes, indicating that the implementation is intended to meet the particular mandatory or optional requirement, or "N" for no, indicating that the option has not been implemented (or enabled where switchable) or that the requirement is not met. It should be noted that any instances of "N" entered against a mandatory requirement will result in the implementation failing the static conformance test. In addition, the supplier must indicate below whether or not the implementation implements all the mandatory requirements.

This implementation implements all mandatory requirements	Y [ ]	N [ ]

14.10.4.3 Additional information

Any additional information that is needed to ensure that the MAU or link segment submitted for test is configured as a 10BASE-T MAU or link segment should be entered into the PIXIT (Protocol Implementation eXtra Information for Testing) document supplied by the conformance testing organization. Relevant information on 10BASE-T MAUs or link segments includes the following:

a) Enable/disable mechanisms for SQE Test
b) Enable/disable mechanisms for features that allow compatibility with nonstandard implementations
c) Operational instructions for DTEs or repeaters in cases where the MAU is embedded
d) Environmental conditions
e) Input voltage range for implementations with embedded MAUs

The above list is illustrative and is not intended to be either mandatory or exhaustive.

14.10.4.4 References

ISO/IEC 9646-2 requires that all PICS proforma clauses be individually identified. Tables have subclause headings and numbered clauses in order to meet this requirement.

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14.10.4.5 PICS proforma tables for MAU

14.10.4.5.1 MAU functions

	Parameter	Subclause	Req	Imp	Value/Comment
	MAU functions:	14.2.1			
MF1	Transmit		M		
MF2	Receive		M		
MF3	Loopback		C		Function performed by MAUs attached to half duplex mode DTEs and repeaters, not performed by MAUs attached to full duplex mode DTEs.
MF4	Collision Presence		C		Function performed by MAUs attached to half duplex mode DTEs and repeaters, optionally performed by MAUs attached to full duplex mode DTEs that fully support this option as described in 14.2.1.
MF5	Jabber		M		
MF6	Link Integrity Test		M		
MF7	SQE Test		C		Function performed by MAUs attached to half duplex DTEs, optionally performed by MAUs attached to full duplex DTEs that fully support this option as described in 14.2.1, not performed by MAUs attached to repeaters.
MF8	Auto-Negotiation		C		Function provided by MAUs implementing the Auto-Negotiation algorithm, as defined in Clause 28.

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14.10.4.5.2 Transmit function

	Parameter	Subclause	Req	Imp	Value/Comment
TF1	Transmit path	14.2.1.1	M		DO circuit to TD circuit
TF2	Transmit signal polarity	14.2.1.1	M		DO A positive relative to DO B causes TD+ positive relative to TD–
TF3	Start-up bit loss (DO to TD circuits)	14.2.1.1	M		2 bits max
TF4	Transmit settling time	14.2.1.1	M		Second and following bits meet amplitude and jitter specifications
TF5	Transmit steady-state delay	14.2.1.1	M		2 bit times max
TF6	Transmit delay variability	14.2.1.1	M		2 bit times max
TF7	TP_IDL	14.2.1.1	M		Start of idle followed by a repeating sequence of silence and link test pulse
TF8	Silence duration	14.2.1.1	M		16 ms ± 8 ms, ≤ ±50 mV
TF9	TP_IDL termination with respect to start of packet	14.2.1.1	M		Normal start of packet requirements apply

14.10.4.5.3 Receive function

	Parameter	Subclause	Req	Imp	Value/Comment
RF1	Receive path	14.2.1.2	M		RD circuit to DI circuit
RF2	Receive signal polarity	14.2.1.2	M		RD+ positive relative to RD– causes DI A positive relative to DI B
RF3	Start-up bit loss (RD to DI circuits)	14.2.1.2	M		5 bits max
RF4	Receive settling time	14.2.1.2	M		Second and following bits meet jitter specifications
RF5	Receive steady-state delay	14.2.1.2	M		2 bit times max
RF6	Receive delay variability	14.2.1.2	M		2 bit times max

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14.10.4.5.4 Loopback function

The following are conditional based on whether the Loopback function is to be performed (14.10.4.5.1, item MF3).

	Parameter	Subclause	Req	Imp	Value/Comment
BF1	Loopback function requirements when RD = idle and DO = active	14.2.1.3	C		DO signals to DI circuit
BF2	Loopback bit loss (DO to DI circuits)	14.2.1.3	C		5 bits max
BF3	Loopback settling time	14.2.1.3	C		Second and following bits meet jitter specifications
BF4	Loopback steady-state delay	14.2.1.3	C		1 bit time max

14.10.4.5.5 Collision Detect function

The following are conditional based on whether the Collision Presence function is to be performed (14.10.4.5.1, item MF4).

	Parameter	Subclause	Req	Imp	Value/Comment
CF1	Collision Presence function requirements	14.2.1.4	C		CS0 on CI circuit if DO=active, RD=active and in Link Test Pass state
CF2	Collision indication delay	14.2.1.4	C		9 bit times max
CF3	Collision indicate de-assert delay	14.2.1.4	C		9 bit times max
CF4	CI circuit with no collision, SQE Test, or jabber	14.2.1.4	C		IDL signal
CF5	DI circuit source switch delay from CS0 assert	14.2.1.4	C		9 bit times max
CF6	DI circuit source switch delay from CS0 de-assert	14.2.1.4	C		9 bit times max

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14.10.4.5.6 *signal_quality_error* Message Test function

The following are conditional based on whether the *signal_quality_error* Message Test is to be performed (14.10.4.5.1, item MF7).

	Parameter	Subclause	Req	Imp	Value/Comment
SF1	SQE Test induced TD or DI circuit signals	14.2.1.5	C		No extraneous signals permitted
SF2	SQE_test _wait timer range	14.2.1.5	C		0.6 to 1.6 µs
SF3	SQE_test timer range	14.2.1.5	C		5 to 15 bit times
SF4	CI circuit during SQE Test	14.2.1.5	C		CS0 signal
SF5	SQE Test in Link Fail state	14.2.1.5	C		CS0 must not be sent

14.10.4.5.7 Jabber function

	Parameter	Subclause	Req	Imp	Value/Comment
JF1	Jabber Function implementation	14.2.1.6	M		Self-interrupt of transmit and loopback
JF2	Xmit_max timer range	14.2.1.6	M		20 ms min, 150 ms max
JF3	CI circuit during jabber	14.2.1.6	M		CS0 signal
JF4	Unjab timer range	14.2.1.6	M		0.5 s ± 0.25 s
JF5	MAU Jabber Lockup Protection	14.2.1.6	M		Jabber not activated by the longest permitted output specified in 9.6.5

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14.10.4.5.8 Link Integrity Test function

	Parameter	Subclause	Req	Imp	Value/Comment
LF1	Link_loss timer	14.2.1.7	M		50 ms min, 150 ms max
	Signals during detected failure:	14.2.1.7			
LF2	TD circuit		M		TP_IDL
LF3	DI circuit		M		IDL
LF4	CI circuit		M		IDL (except when jabber condition is also present)
LF5	Link Test Fail state exit conditions	14.2.1.7	M		RD = active or consecutive link test pulses = 2 min, 10 max
LF6	Link_test_min timer range	14.2.1.7	M		2 to 7 ms
LF7	Link_test_max timer range	14.2.1.7	M		25 to 150 ms
	Pulses outside acceptance window:	14.2.1.7			
LF8	Early while in Link Test Pass state		M		Ignore
LF9	Early or late while not in Link Test Pass state		M		Reset link test pulse counter
	Link fail effect on MAU functions:	14.2.1.7			
LF10	Transmit		M		Disable
LF11	Receive		M		Disable
LF12	Loopback		M		Disable
LF13	Collision Presence		M		Disable
LF14	SQE Test		M		Disable
LF15	Link Test Fail Extend state exit condition	14.2.1.7	M		Deferred until RD = idle and DO = idle
LF16	Power-on state	14.2.1.7	O		Link Test Fail Reset
LF17	Pulse/data discrimination	14.2.1.7	M		Link test pulse not detected as data

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14.10.4.5.9 MAU state diagram requirements

	Parameter	Subclause	Req	Imp	Value/Comment
SD1	Transmit, Receive, Loopback, and Collision Presence Functions state diagram	14.2.3	C		Meets requirements of Figure 14–3. Conditional on whether or not the function is to be performed (14.10.4.5.1/MF3 and 14.10.4.5.1/MF4).
SD2	MAU Transmit and Receive Functions state diagram (full duplex mode)	14.2.3	C		Conditional on whether or not the function is to be performed (14.10.4.5.1/MF3 and 14.10.4.5.1/MF4).
SD3	*signal_quality_error* Message Test Function state diagram	14.2.3	C		Meets requirements of Figure 14–4. Conditional on whether or not the function is to be performed (14.10.4.5.1/MF7).
SD4	Jabber Function state diagram	14.2.3	M		Meets requirements of Figure 14–5.
SD5	Link Integrity Test Function state diagram	14.2.3	M		Meets requirements of Figure 14–6.

14.10.4.5.10 AUI requirements

	Parameter	Subclause	Req	Imp	Value/Comment
AR1	AUI implementation	14.3	O		If implemented, refer to 14.10.4.6.
AR2	AUI messages	14.2.2	M		Comply to 7.2.1.

14.10.4.5.11 Isolation requirements

	Parameter	Subclause	Req	Imp	Value/Comment
IR1a	Isolation, MDI leads to DTE Physical Layer circuits	14.3.1.1	C		Any one of three tests listed in 14.3.1.1 Function provided by MAUs that do not encompass the PI of a PD within their MDI.
IR1b	Isolation, MDI leads to all external conductors	14.3.1.1	C		Any of the three tests listed in 14.3.1.1. Function provided by MAUs that encompass the PI of a PD within their MDI.
IR2	Resistance after breakdown test	14.3.1.1	M		≥ 2 MΩ at 500 Vdc

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14.10.4.5.12 Transmitter specification

	Parameter	Subclause	Req	Imp	Value/Comment
TS1	Peak differential output voltage on TD circuit for a type 10BASE-T MAU that is not a type 10BASE-Te MAU	14.3.1.2.1	C		Conditional on whether it is a type 10BASE-T MAU that is not a type 10BASE-Te MAU, 2.2 to 2.8 V
TS2	Peak differential output voltage on TD circuit for a type 10BASE-Te MAU	14.3.1.2.1	C		Conditional on whether it is a type 10BASE-Te MAU, 1.54 to 1.96 V
TS3	Harmonic content, all-ones signal	14.3.1.2.1	M		All harmonics ≥ 27 dB below fundamental
TS4	Output waveform, with scaling of voltage template	14.3.1.2.1	M		Within Figure 14–10 template
TS5	Start of TP_IDL waveform, with each specified load, with and without twisted-pair model	14.3.1.2.1	M		Within Figure 14–11 template, overshoot ≤ +50 mV after excursion below –50 mV
TS6	Link test pulse waveform, with each specified load, with and without twisted-pair model	14.3.1.2.1	M		Within Figure 14–11 template, overshoot ≤ +50 mV after excursion below –50 mV
TS7	TD circuit differential output impedance	14.3.1.2.2	M		Reflection ≥ 15 dB below incident, any simplex link segment
	Transmitter added timing jitter:	14.3.1.2.3			
TS8	Into 100 Ω through twisted-pair model		M		±3.5 ns max
TS9	Into 100 Ω		M		±8 ns max
TS10	Common-mode to differential-mode conversion	14.3.1.2.4	M		≥ 29 – 17 $\log_{10}(f/10)$ dB, f=1–20 MHz, f in MHz
TS11	TD circuit common-mode output voltage	14.3.1.2.5	M		< 50 mV peak
TS12	TD circuit common-mode rejection, 15 V peak 10.1 MHz sinusoid	14.3.1.2.6	M		≤ 100 mV differential and ≤ 1 ns jitter
TS13	TD circuit fault tolerance	14.3.1.2.7	M		No damage from a short circuit
TS14	TD circuit short-circuit current	14.3.1.2.7	M		300 mA max
TS15	TD circuit common-mode voltage withstand	14.3.1.2.7	M		1000 V min, applied per Figure 14–16
TS16	Power cycle behavior	14.3.2.3	M		No extraneous signals on the TD circuit

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14.10.4.5.13 Receiver specification

	Parameter	Subclause	Req	Imp	Value/Comment
RS1	RD circuit signal acceptance	14.3.1.3.1	M		Figures 14–17, 14–18, template
RS2	Received signal jitter accept	14.3.1.3.1	M		At least ±13.5 ns
RS3	Receiver added jitter	14.3.1.3.1	M		≤ ±1.5 ns, RD to DI circuits
RS4	RD circuit link test pulse acceptance	14.3.1.3.2	M		Figure 14–13 template
	RD circuit differential noise rejection:	14.3.1.3.2			
RS5	Signal (1)		M		≤ 300 mV peak
RS6	Signal (2)		M		≤ 6.2 V peak-to-peak, ≤ 2 MHz
RS7	Signal (3)		M		Single cycle ≤ 6.2 V, either phase, 2–15 MHz
RS8	Idle detection, RD circuit	14.3.1.3.3	M		Within 2.3 bit times
RS9	RD circuit differential input impedance	14.3.1.3.4	M		Reflected signal ≥ 15 dB below incident, any simplex link segment
RS10	RD circuit common-mode rejection	14.3.1.3.5	M		25 V peak-to-peak square wave to add ≤ 2.5 ns jitter
	RD circuit fault tolerance:	14.3.1.3.6			
RS11	Short circuit		M		Indefinite short circuit
RS12	Common-mode voltage		M		1000 V impulse, applied per Figure 14–20

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14.10.4.5.14 MDI requirements

	Parameter	Subclause	Req	Imp	Value/Comment
MR1	MDI connector	14.5.1	M		IEC 60603-7 jack
	MDI connector contact assignment:	14.5.1			
MR2	1		M		TD+
MR3	2		M		TD–
MR4	3		M		RD+
MR5	6		M		RD–
MR6	Crossover function implemented	14.5.2	O		Remote MAU from DTE (recommended)
MR7	Crossover function indication	14.5.2	C		X symbol on MDI connector. Conditional on crossover function implementation. Refer to response to 14.10.4.5.14/MR6
	MDI-X connector contact assignment:	14.5.2			
MR8	1		C		RD+
MR9	2		C		RD–
MR10	3		C		TD+
MR11	6		C		TD–
					Conditional on crossover function implementation. Refer to response to 14.10.4.5.14/MR6.

14.10.4.5.15 Safety requirements

	Parameter	Subclause	Req	Imp	Value/Comment
SR1	Safety grounding path	14.7.2.2	C		Must be via PG circuit. Conditional on AUI implementation. Refer to response for 14.10.4.5.10/AR1 or PIXIT
SR2	MAU labeling	14.8	O		Data rate, current, any applicable safety warnings (recommended)
SR3	General safety	14.7.1	M		Conforms to IEC 60950:1991
SR4	Application of telephony voltages	14.7.2.4	M		Creates no safety hazard

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14.10.4.6 PICS proforma tables for MAU AUI characteristics

The whole of 14.10.4.6 is conditional on the AUI being implemented and accessible for testing. Refer to response for Clause 14.10.4.5.10/AR1 or PIXIT.

14.10.4.6.1 Signal characteristics

	Parameter	Subclause	Req	Imp	Value/Comment
SC1	Signaling rate (stated on label)	7.3.2	C		10 Mb/s
SC2	CS0 signal frequency (on CI)	7.3.1.2	C		10 MHz ± 15%
SC3	CS0 signal duty cycle	7.3.1.2	C		60:40 worst case

14.10.4.6.2 DI and CI driver characteristics

	Parameter	Subclause	Req	Imp	Value/Comment
	Differential output voltage:	7.4.1.1			
DC1	Loaded		C		Figure 7–11
DC2	Idle state		C		≤ 40 mV into test load
DC3	Start of idle		C		Figure 7–12
DC4	Current into test load while idle	7.4.1.1	C		4 mA max after 80 BT
DC5	Requirements after idle	7.4.1.2	C		First bit to Figure 7–11
DC6	Common-mode output voltage, ac	7.4.1.3	C		≤ 40 mV peak. Figure 7–13
DC7	Differential output voltage, open circuit	7.4.1.4	C		13 V peak max
DC8	Common-mode output voltage, dc	7.4.1.5	C		≤ 5.5 V. Figure 7–13
DC9	Fault tolerance	7.4.1.6	C		Figure 7–14
DC10	Fault current	7.4.1.6	C		≤ 150 mA, any Figure 7–14 state

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14.10.4.6.3 DO receiver characteristics

	Parameter	Subclause	Req	Imp	Value/Comment
DO1	Unsquelched threshold	7.4.2.1	C		160 mV max differential
DO2	Squelch	14.3.2.1	C		Reject signals ≤ 160 mV magnitude
DO3	High-to-idle transition on DO circuit	7.4.1.1	C		Must not cause output
DO4	Differential input impedance at 10 MHz	7.4.2.2	C		Real part: 77.83 Ω ± 6%, 0 ≤ phase angle in degrees ≤ real part × 0.0338
DO5	Common-mode range, ac	7.4.2.3	C		3 V min 30 Hz to 40 kHz, 100 mV min 40 kHz to 10 MHz
DO6	Total common-mode range	7.4.2.4	C		Magnitude of 0 to 5.5 V ac + dc
DO7	Common-mode current limit	7.4.2.4	C		≤ 1 mA
DO8	IDL detection	7.3.1.1	C		≤ 1.6 bit times
DO9	Requirements after idle	7.4.2.5	C		Receiver in specification after start-up delay
DO10	Receiver fault tolerance	7.4.2.6	C		Figure 7–15
DO11	Input fault current	7.4.2.6	C		3 mA max for Figure 7–15

14.10.4.6.4 Power consumption

	Parameter	Subclause	Req	Imp	Value/Comment
PC1	Power surge limitation	14.3.2.3	C		≤2×10^{-3} A·s
PC2	Power surge duration	14.3.2.3	C		100 ms max
PC3	Steady-state current drawn	14.3.2.3	C		≤ 500 mA
	Power-up capability:				
PC4	Current limited sources	14.3.2.3	C		500 mA limited
PC5	Voltage sources	7.5.2.5	C		11.28 to 15.75 V, any permissible AUI cable
PC6	Power cycle behavior	14.3.2.3	C		No extraneous signals on CI nor DI circuits
PC7	Low VP circuit behavior	7.5.2.5	C		No disruption of media

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14.10.4.6.5 Circuit termination

	Parameter	Subclause	Req	Imp	Value/Comment
CT1	Common-mode termination	7.5.2.6	C		If used must be to VC
CT2	Pins 1,4,11,14 impedance to VC circuit	7.5.2.8	C		≤ 5 Ω at 5 MHz
CT3	Pins 1,4,11,14 coupling to VC circuit	7.5.2.8	C		Capacitive

14.10.4.6.6 Mechanical characteristics

	Parameter	Subclause	Req	Imp	Value/Comment
MC1	D-type connector dimensions	7.6.2	C		IEC 60807-2:1992 15-pole male
MC2	Shell plating material	7.6.2	C		Conductive
MC3	Shell multiple contact points	7.6.2	O		Number not defined (recommended)
MC4	Shell life expectancy	7.6.2	C		≤5 mΩ / 500 matings
MC5	Locking posts and mounting	7.6.1	C		Figures 7–17, 7–19
	Pin connections:	7.6.3			Circuit
MC6	3		C		Data out A
MC7	10		C		Data out B
MC8	11		C		Capacitor to VC
MC9	5		C		Data in A
MC10	12		C		Data in B
MC11	4		C		Capacitor to VC
MC12	7		C		No connection
MC13	15		C		No connection
MC14	8		C		Capacitor to VC
MC15	2		C		Control in A
MC16	9		C		Control in B
MC17	1		C		Capacitor to VC
MC18	6		C		Voltage common
MC19	13		O		Voltage plus
MC20	14		C		Capacitor to VC
MC21	Shell		C		Protective Ground (Conductive Shell)

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14.10.4.7 PICS proforma tables for 10BASE-T link segment

14.10.4.7.1 10BASE-T link segment characteristics

	Parameter	Subclause	Req	Imp	Value/Comment
	Cable size:				Cable size affects NEXT limits
LS1	25-pair cable or binder groups	14.4.3.1.1	O		
LS2	4-pair cable	14.4.3.1.2	O		
LS3	Other	14.4.3.1.3	O		
LS4	Insertion loss, 5.0 MHz to 10 MHz for a type 10BASE-T MAU that is not a type 10BASE-Te MAU	14.4.2.1	C		Conditional on whether it is a type 10BASE-T MAU that is not a type 10BASE-Te MAU, ≤ 11.5 dB
LS5	Insertion loss, 5.0 MHz to 10 MHz for a type 10BASE-Te MAU	14.4.2.1	C		Conditional on whether it is a type 10BASE-Te MAU, ≤ 8.5 dB
LS6	Differential characteristic impedance of a 3 m cable section, 5.0 MHz to 10 MHz	14.4.2.2	M		85 to 111 Ω
LS7	Input impedance averaged, 5.0 MHz to 10 MHz	14.4.2.2	M		85 to 111 Ω
LS8	Medium timing jitter (for defined test signal)	14.4.2.4	M		±5.0 ns max
	Delay:				
LS9	Per meter		M		≤ 5.7 ns/m
LS10	Link segment		M		≤ 1000 ns
	NEXT loss, pair-to-pair, 5.0 MHz to 10 MHz:				
LS11	25-pair cable and binder groups	14.4.3.1.1	C		≥ 30 – 15 $\log_{10}(f/10)$ dB
LS12	4-pair cable	14.4.3.1.2	C		≥ 26 – 15 $\log_{10}(f/10)$ dB These requirements are conditional on the responses in clauses 14.10.4.7.1/LS1 and 14.10.4.7.1/LS2, f in MHz
LS13	MDNEXT at 5.0, 7.5, and 10 MHz	14.4.3.2	M		≥ 23 – 15 $\log_{10}(f/10)$ dB, f in MHz
	Noise environment:				
LS14	Impulse noise (into defined circuit)	14.4.4.1	M		Fewer than 0.2 impulses/s of ≥ 264 mV
LS15	Crosstalk noise	14.4.4.2	M		≤ 264 mV
LS16	Connectors	14.5.1	M		IEC 60603-7 plug
LS17	Literature indicates the distance and environmental conditions over which 14.4 specifications are met	14.7.3.2	O		

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14.10.4.8 PICS proforma tables for Auto-Negotiation able MAUs

The following are conditional on whether the Auto-Negotiation algorithm is provided (Clause 28).

	Parameter	Subclause	Req	Imp	Value/Comment
AN1	TP_IDL	14.2.1.1	C		Defined in 28.2.1
AN2	Link Integrity Test Function State Diagram power-on default	14.2.1.7	C		Power-on in Link Test Fail Reset state
AN3	Link Test Fail state exit conditions	14.2.1.7	C		autoneg_wait_timer expired and either RD = active or consecutive link test pulses = 3 min., 10 max
AN4	Technology Dependent Interface support	14.2.1.7	C		In the Link Integrity Test state diagram function "link_status=OK" is added to the LINK TEST PASS state and "link_status=FAIL" is added to the LINK TEST FAIL RESET state
AN5	Link test pulse waveform for FLP Burst with and without twisted-pair model	14.3.1.2.1	C		Within Figure 14–11 template for, all pulses in FLP Burst, overshoot ≤ +50 mV after excursion below –50 mV
AN6	MAU indicates full duplex mode capability during Auto-Negotiation	14.2.1.8	C		Function optionally performed by embedded MAUs, not performed by MAUs that implement an AUI connector.

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15. Fiber optic medium and common elements of medium attachment units and star, type 10BASE-F

15.1 Scope

15.1.1 Overview

Clause 15, Clause 16, Clause 17, and Clause 18 define the functional, electrical, optical, and mechanical characteristics of the type 10BASE-FP (Passive) MAU, the type 10BASE-FB Backbone (Synchronous Active) MAU, the type 10BASE-FL Link (Asynchronous Active) MAU, the type 10BASE-FP (Passive) Star, and one common medium for use with those MAUs and the star. The purpose of the MAUs is to provide a means of attaching full duplex DTEs (10BASE-FL only), half duplex DTEs (10BASE-FP and 10BASE-FL only), or repeaters to the local network medium. The purpose of the 10BASE-FP Star is to provide the means of interconnecting 10BASE-FP MAUs into a star topology segment. The IEEE 802.3 repeaters are used to interconnect the star segment to other 10 Mb/s baseband segments. Information on selecting segment types for various applications is provided in 15.1.3.4.

The 10BASE-F specification builds upon Clause 1 through Clause 7 and Clause 9 of this standard. The relationship of this clause to the OSI Reference Model is shown in Figure 15–1a), Figure 15-1b), and Figure 15-1c) for 10BASE-FP, 10BASE-FB, and 10BASE-FL, respectively.

10BASE-F is specifically intended to be interoperable and compliant with the requirements for attachment to DTEs and repeaters via the 10 Mb/s Attachment Unit Interface (AUI). The use of 10BASE-F in networks with other IEEE 802.3, 10 Mb/s baseband segments is governed by the system considerations detailed in Clause 13.

15.1.1.1 Fiber optic medium attachment units (MAUs)

The MAUs specified in this clause, Clause 16 (10BASE-FP), Clause 17 (10BASE-FB), and Clause 18 10BASE-FL) have the following general characteristics:

a) They provide a means of coupling the PLS through the AUI to the fiber optic segment by way of the MDI.
b) They support message traffic at a data rate of 10 Mb/s.
c) They provide for driving up to 1 km of fiber optic cable with a 10BASE-FP Star connected in the middle between two 10BASE-FP MAUs. Provide for driving up to 2 km of fiber optic cable between two repeaters that have embedded 10BASE-FB MAUs. Provide for driving up to 2 km of fiber optic cable between two 10BASE-FL MAUs. Provide backward compatibility for communicating between FOIRL MAUs and 10BASE-FL MAUs over up to 1 km of fiber optic cable.
d) They permit the DTE to test the MAU and the availability of the medium.
e) They support system configurations using the CSMA/CD access mechanism defined in this standard.
f) They provide uninterrupted carrier sense during collisions.
g) They support a star cabling topology.
h) They allow incorporation of the MAU within the physical bounds of a DTE or repeater. (See Clause 17 for 10BASE-FB restrictions.)

15.1.1.2 Fiber optic passive star

The 10BASE-FP Star is a passive optical device that receives optical signals from, and distributes them to, connected devices (see Figure 15–2b). The 10BASE-FP Star is not a repeater.

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15.1.1.3 Repeater unit

The repeater unit has the characteristics defined in Clause 9. Repeater units are used as a hub in a star topology network in which DTEs attach directly to link segments. Repeater units are also used to extend the physical system topology of mixing segments by connecting 10BASE-FP or coaxial cable segments to other segments. Repeater units are used to connect 10BASE-F segments of any type to other 10BASE-F segments, and to any other 10 Mb/s baseband media types. 10BASE-FB segments connect only 10BASE-FB ports on repeaters.

NOTE—While 9.6.6 autopartitioning is not required as a mandatory feature on 10BASE-FB ports, it should be recognized that it could be of benefit where there is a high probability of misconnections of incompatible ports, e.g., patch panels shared between 10BASE-FB and other fiber optic communication technologies.

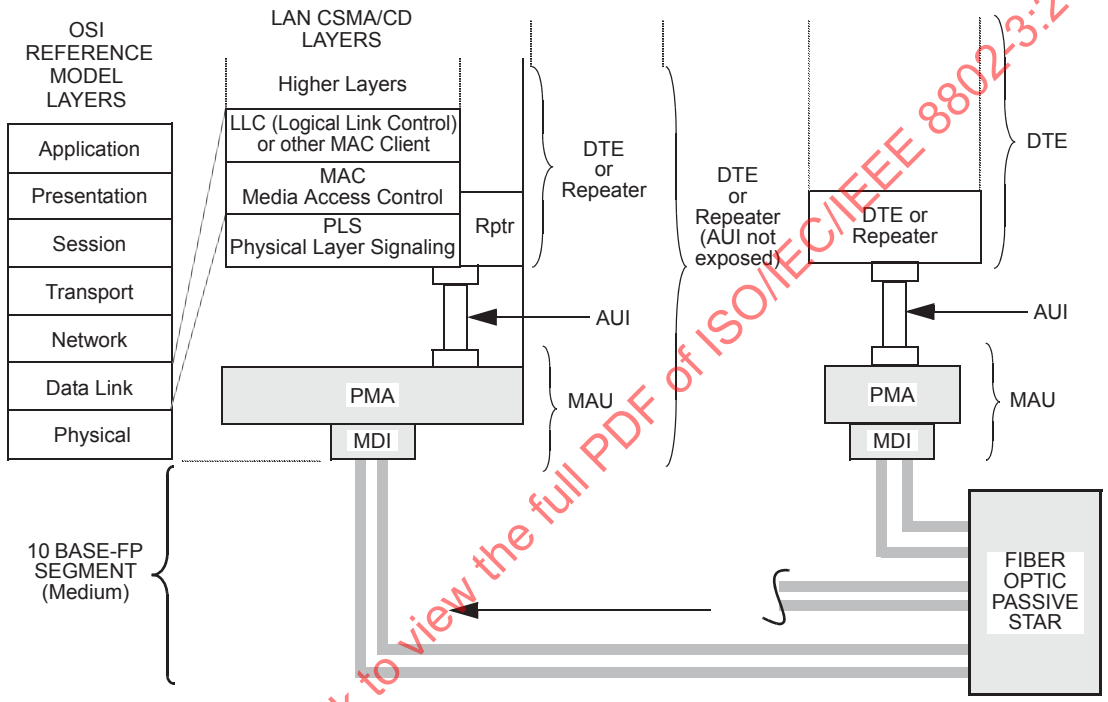
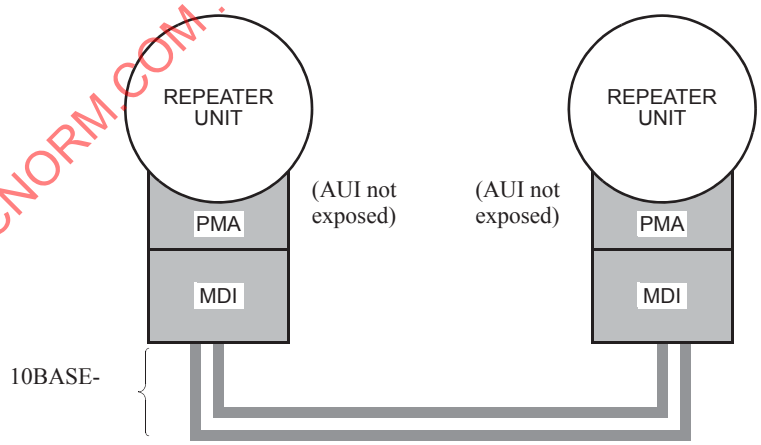


Figure 15–1—10BASE-F relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model



b) 10BASE-FB relationship to CSMA/CD LAN

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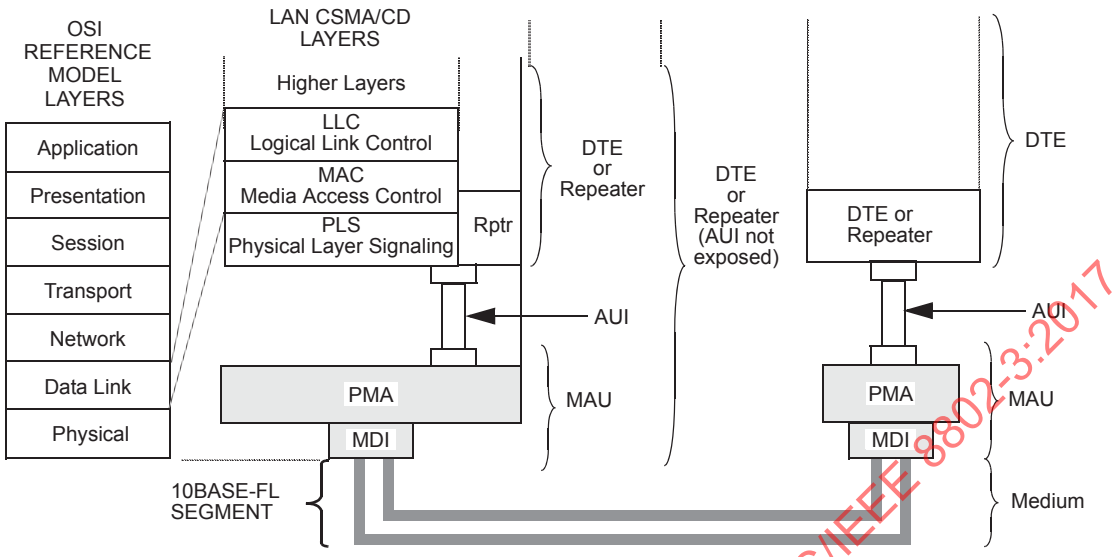

c) 10BASE-FL relationship to OSI and CSMA/CD LAN

Figure 15-1—(*Continued*)
10BASE-FL relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the ISO/IEC CSMA/CD LAN model

15.1.2 Definitions

See 1.4.

15.1.3 Applications perspective: MAUs, stars, and fiber optic medium

This clause states the broad objectives and assumptions underlying the specifications defined in Clause 15, Clause 16, Clause 17, and Clause 18.

15.1.3.1 Objectives

a) To provide a physical means for communication between LAN data link entities using fiber optic media connected in a star topology.
b) To ensure compatibility of independently developed physical, electrical, and optical interfaces.
c) To provide a communication channel capable of high bandwidth and low bit-error ratio performance. The resultant mean bit-error ratio, between AUIs over a fiber segment, should be less than one part in 10^9.
d) To provide for ease of installation and service.
e) To ensure that fairness of DTE access is not compromised.

15.1.3.2 Compatibility considerations

All implementations of 10BASE-FP, 10BASE-FB, and 10BASE-FL fiber optic systems shall be compatible at their respective MDIs when used in accordance with the restrictions of Clause 9 and 16.5 where appropriate. When FOIRL segments are used, all 10BASE-FL MAUs shall be compatible with the FOIRL MDI specified in 9.9 except for the media connector, which shall be as specified in 15.3.2.

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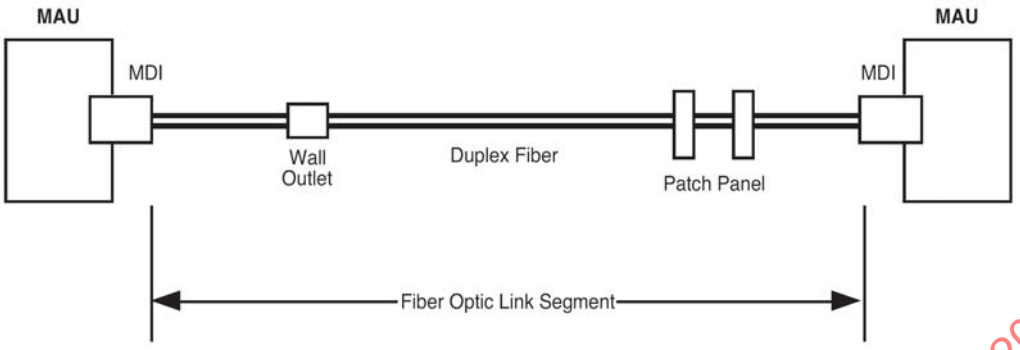
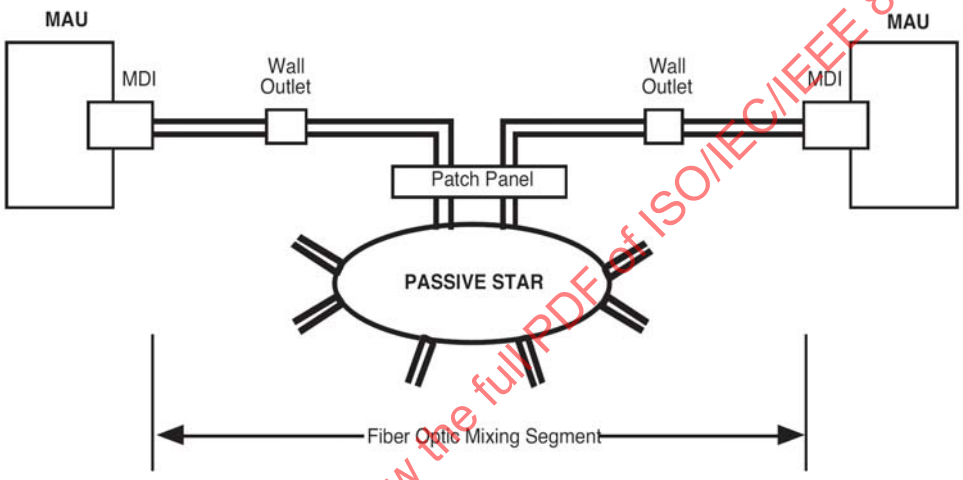


a) Example fiber optic link segment, 10BASE-FB and 10BASE-FL



b) Example fiber optic mixing segment, 10BASE-FP

Figure 15–2—Fiber optic link and mixing segments

Implementations of 10BASE-F of any one type are not compatible with 10BASE-F of any other type at the MDI.

Clause 15 provides medium specifications for interconnection of the fiber optic MAUs and star defined in Clause 16, Clause 17, and Clause 18. The star specified in 16.5 completes the specification of the media for a 10BASE-FP segment. The medium itself, the functional capability of the 10BASE-FP, 10BASE-FB, and 10BASE-FL MAUs, and the AUI are defined to provide the highest possible level of compatibility among devices designed by different manufacturers. Designers are free to implement circuitry within the MAU in an application-dependent manner provided that the MDI and AUI specifications are satisfied. The provision of the physical and mechanical implementation of the AUI is optional for Clause 16 and Clause 18 MAUs, and is not applicable for Clause 17 MAUs.

15.1.3.3 Relationship to PLS and AUI

Clause 15, together with Clause 16, Clause 17, or Clause 18, defines the portion of the Physical Layer and medium for the LAN necessary to couple a DTE or repeater message path to and from the medium.

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A close relationship exists between Clause 7 and the 10BASE-FP, 10BASE-FB, and 10BASE-FL MAUs defined in Clause 16, Clause 17, and Clause 18, respectively. Clause 15 specifies the physical medium parameters, and Clause 16, Clause 17, and Clause 18 the PMA logical functions residing in the physical MAU. The MAU provides services to the PLS defined in Clause 7 by means of the AUI. 10BASE-F MAUs support a subset of the AUI services specified in Clause 7. 10BASE-F MAUs do not support the optional *isolate* function, the optional CO circuit, or the optional CS1 signal on the CI circuit.

The design of an external MAU component requires the use of Clause 15, Clause 16 or Clause 18, and Clause 7 for the PLS and AUI specifications.

The figures and numerous textual references throughout Clause 15, Clause 16, Clause 17, and Clause 18 refer to terminology associated with the AUI (that is, DO, DI, and CI). Since an embodiment of the 10BASE-FP, 10BASE-FB, or 10BASE-FL MAU does not require implementation of an AUI, the DO, DI, and CI circuits may not physically exist. However, they are logically present, and MAU operation is defined in terms of their messages.

15.1.3.4 Guidelines for implementation of systems

The fiber optic systems defined herein cover a wide range of LAN applications in which the advantages of fiber optics are paramount. These advantages include noise immunity, low attenuation, bandwidth upgradeability, data security, and use in environments where the use of electric circuits would be hazardous. These systems allow construction of complex networks according to the system topology rules in Clause 13. Choice of system approach may be aided by the following guidelines:

— 10BASE-FP, Clause 16: A passive-star system for interconnecting repeaters or DTEs with up to 1 km per segment, useful where central power is unavailable or not sufficiently reliable for the intended application.
— 10BASE-FB, Clause 17: A system for interconnecting repeaters with up to 2 km per segment and for backbone applications where a large number of repeaters must be cascaded.
— 10BASE-FL, Clause 18: A system for interconnecting repeaters or DTEs with up to 2 km per segment and where backward compatibility with 9.9 (FOIRL) (up to 1 km per segment) is desirable. This system also supports full duplex operation (see 1.1.2).

Repeaters (Clause 9) must be used to connect other media to the above fiber optic segments. Repeaters also must be used to interconnect FOIRL, 10BASE-FB, 10BASE-FP, and 10BASE-FL segments. 10BASE-FB segments can be used only between 10BASE-FB ports on repeaters.

15.1.3.5 Modes of operation

10BASE-F MAUs are capable of operating in normal mode only (see 7.1.4). They shall not operate in monitor mode. A MAU attached to a repeater shall not be in full duplex mode.

The operation of a 10BASE-FL MAU differs depending on whether the attached DTE is operating in the half duplex or full duplex mode (see 1.1.2). In the full duplex mode, functions relating to the loopback of transmitted data (DO) onto the receive path (DI) are disabled (see 18.3.1.3, 18.3.1.6).

The requirements specified in clauses of this standard labeled “half duplex mode only” do not apply to a MAU used with a DTE configured for full duplex operation. It is the responsibility of the designer and/or user of equipment operating in full duplex mode to ensure that the 10BASE-FL MAU used or incorporated is properly configured for full duplex operation.

10BASE-FP and 10BASE-FB MAUs are capable of operating in half duplex mode only.

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15.2 MDI optical characteristics

The transmit and receive optical parameters for the 10BASE-FP, 10BASE-FB, and 10BASE-FL fiber optic systems are summarized in Table 15–1. Optical measurements shall be made with the MDI terminated with the optical connector specified in 15.3.2 and the optical fiber specified in 15.3.1. Fiber length shall be sufficient to attenuate cladding mode distribution.

NOTE—Transmit and receive optical parameters refer to optical power in the core of the respective fiber (15.3.1). Fibers currently available typically require 1 m to 5 m to remove optical power from the cladding.

15.2.1 Transmit optical parameters

15.2.1.1 Center wavelength

The center wavelength of the optical source emission shall be as specified in Table 15–1.

15.2.1.2 Spectral width

The full width half maximum (FWHM) spectral width of the optical source shall be as specified in Table 15–1.

15.2.1.3 Optical modulation extinction ratio

The optical modulation method is on-off keying of the optical power source. The minimum extinction ratio shall be as specified in Table 15–1, measured at the normalization points (15.2.1.11).

15.2.1.4 Optical Idle Signal amplitude

The optical Idle Signal shall be as specified in Table 15–1.

15.2.1.5 Optical transmit pulse logic polarity

LO on the AUI DO circuit shall be represented at the MDI as LO and as the higher optical power level transmitted at the MDI. HI on the AUI DO circuit shall be represented at the MDI as HI and as the lower optical power level transmitted at the MDI (see 7.4.2.1). A 10BASE-FP Star by its nature is noninverting from any input to any output.

15.2.1.6 Optical transmit pulse rise and fall times

The optical rise and fall times at the MDI transmitter shall be measured from the 10% to 90% levels. The rise and fall times and their difference shall be as specified in Table 15–1.

15.2.1.7 Optical transmit pulse overshoot and undershoot

The maximum optical overshoot and undershoot shall be as specified in Table 15–1.

15.2.1.8 Optical transmit pulse edge jitter

The total transmitted edge jitter measured at the MDI shall be as specified in Table 15–1 for a transmitted waveform consisting of a Manchester-encoded pseudo-random sequence with a minimum repetition period of 511 bits. The jitter at the MDI shall be measured at the power level median of the optical waveform's upper and lower power levels (as determined from the previous 16 or more transitions in any valid optical bit stream). This does not include any effects from variations of Optical Transmit Pulse Duty Cycle (15.2.1.9).

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Table 15–1—MDI parameters

Subclause	Parameter	Units	10BASE-FP	10BASE-FB	10BASE-FL
15.2.1	TRANSMIT OPTICAL PARAMETERS				
15.2.1.1	Center wavelength —min. —max.	 nm nm	 800 910	 800 910	 800 910
15.2.1.2	Spectral width (FWHM)	nm	<75	<75	<75
15.2.1.3	Optical modulation extinction ratio	dB	≤13	≤13	≤13
15.2.1.4	Optical idle signal amplitude	dBm	≤57	see 15.2.1.10	see 15.2.1.10
15.2.1.6	Optical transmit pulse rise and fall times —max. (data) —min. (data) —max. difference (data) —max. (idle) —min. (idle) —max. difference (idle)	 ns ns ns ns ns ns	 10 2 3 N/A N/A N/A	 10 0 3 10 0 3	 10 0 3 25 0 25
15.2.1.7	Optical transmit pulse —overshoot —undershoot	 % %	 5 5	 25 10	 25 10
15.2.1.8	Optical transmit pulse edge jitter —added, DO circuit to MDI —total at MDI (data) —total at MDI (idle)	 ns ns ns	 N/A ±1 N/A	 N/A ±2 ±2	 ±2 ±4 N/A
15.2.1.9	Optical transmit pulse Duty cycle distortion —data —idle	 ns ns	 ±1 N/A	 ±2.5 ±2.5	 ±2.5 ±50.0
15.2.1.10	Optical transmit average power range —min. —max.	 dBm dBm	 –15 –11	 –20 –12	 –20 –12
15.2.2	RECEIVE OPTICAL PARAMETERS				
15.2.2.1	Optical receive average power range —min. —max.	 dBm dBm	 –41 –27	 –32.5 –12.0	 –32.5 –12.0
15.2.2.2	MAU optical receive edge jitter (data) —received at MDI —added, MDI to DI circuit —total at DI circuit (MAU end of AUI)	 ns ns ns	 ±4.5 N/A N/A	 ±2.0 N/A ±6.5	 ±6.5 ±8.5 ±15.0
15.2.2.4	Optical receive pulse rise and fall times —max. (data) —min. (data) —max. difference (data) —max. (idle) —min. (idle) —max. difference (idle)	 ns ns ns ns ns ns	 18.5 2.0 3.0 N/A N/A N/A	 31.5 0.0 3.0 31.5 0.0 3.0	 31.5 0.0 3.0 41.0 0.0 25.0

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15.2.1.9 Optical transmit pulse duty cycle distortion

The optical pulse duty cycle shall be as specified in Table 15–1. The duty cycle distortion measured at the output of the electro-optic source shall be measured at the power level median of the optical waveform's upper and lower power levels (as determined in 15.2.1.10).

15.2.1.10 Optical transmit average power range

The optical transmit average power coupled into the core of the fiber shall be in the range specified in Table 15–1 at the MDI.

To meet the 10BASE-FP power range, the use of one or more techniques such as emitters with a focused radiation pattern, optical power setting, or temperature compensation may be necessary.

NOTE—The optical power ranges shown in Table 15–1 can be met by the following:

10BASE-FB and 10BASE-FL MDI
- Nominal average power, beginning of life–15 dBm
- Transmit power tolerance*±3 dB
- Transmit power degradation, end of life–2 dB

10BASE-FP MDI
- Nominal average power, beginning of life–12.5 dBm
- Transmit power tolerance*±1.5 dB
- Transmit power degradation, end of life–1 dB

* Transmit power tolerance includes emitter, optical connector, and optical fiber tolerances.

15.2.1.11 Optical transmit signal templates

The transmitted optical waveforms for the 10BASE-FP MAU, 10BASE-FB MAU, and 10BASE-FL MAU shall fall within the templates shown in Figure 15–3, Figure 15–4, and Figure 15–5, respectively, when normalized. Normalization is achieved by linearly scaling and shifting the waveform amplitude and shifting the waveform timebase so that it intersects the two normalization points indicated by the black dots on the templates. These templates show a graphical representation of the transmit parameters described in 15.2.1.3, 15.2.1.6, 15.2.1.8, and 15.2.1.9. Table 15–1 lists the appropriate numerical values for these parameters. If any conflict exists between the templates and Table 15–1, the table shall take precedence.

The definition of "normalized optical power" is indicated on Figure 15–3, Figure 15–4, and Figure 15–5. The measured optical power is scaled and shifted so that the definition of "0" optical power and "1" optical power is determined by the average signal value at the points indicated by the black dots on the figures.

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15.2.1.11.1 10BASE-FP optical transmit signal template

The points of inflection for the template of Figure 15–3 are defined by the coordinate pairs contained in Table 15–2.

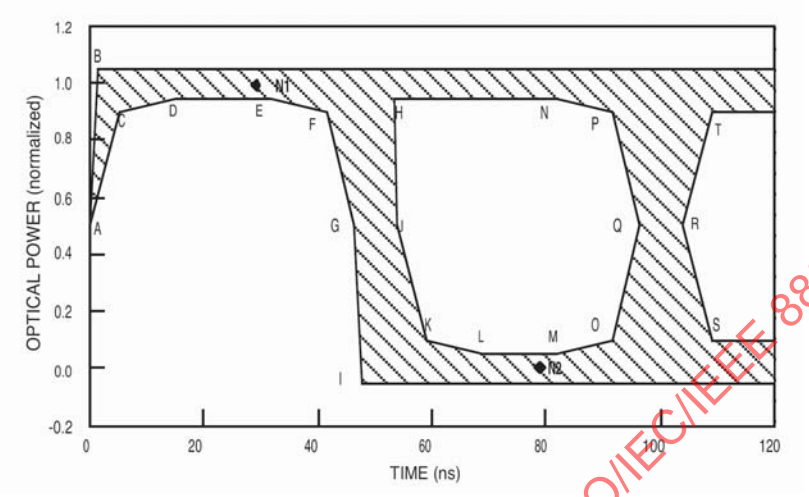

Figure 15–3—10BASE-FP MAU transmit waveform template

Table 15–2—Transmitted optical waveform values for Figure 15–3

Reference	Time (ns)	Optical power (normalized)
A	0.0	0.5
B	1.375	1.05
C	5.0	0.9
D	15.0	0.95
E	31.0	0.95
F	41.0	0.9
G	46.0	0.5
H	52.875	0.95
I	47.375	–0.05
J	54.0	0.50
K	59.0	0.10
L	69.0	0.05

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Table 15–2—Transmitted optical waveform values for Figure 15–3 *(continued)*

Reference	Time (ns)	Optical power (normalized)
M	81.0	0.05
N	81.0	0.95
O	91.0	0.10
P	91.0	0.90
Q	96.0	0.50
R	104.0	0.50
S	109.0	0.10
T	109.0	0.90
N1	29.0	1.00
N2	79.0	0.00

15.2.1.11.2 10BASE-FB optical transmit signal template

The points of inflection for the template of Figure 15–4 are defined by the coordinate pairs contained in Table 15–3.

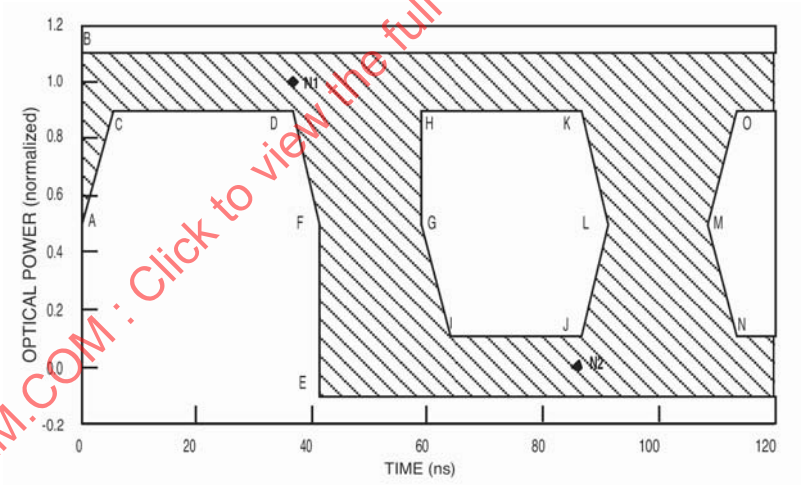

Figure 15–4—10BASE-FB MAU transmit waveform template

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Table 15–3—Transmitted optical waveform for Figure 15–4

Reference	Time (ns)	Optical power (normalized)
A	0.0	0.5
B	0.0	1.1
C	5.0	0.9
D	36.0	0.9
E	41.0	–0.1
F	41.0	0.5
G	59.0	0.5
H	59.0	0.9
I	64.0	0.1
J	86.0	0.1
K	86.0	0.9
L	91.0	0.5
M	109.0	0.5
N	114.0	0.1
O	114.0	0.9
N1	36.0	1.00
N2	86.0	0.00

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15.2.1.11.3 10BASE-FL Optical transmit signal template

The points of inflection for the template of Figure 15–5 are defined by the coordinate pairs contained in Table 15–4. This template is for data only.

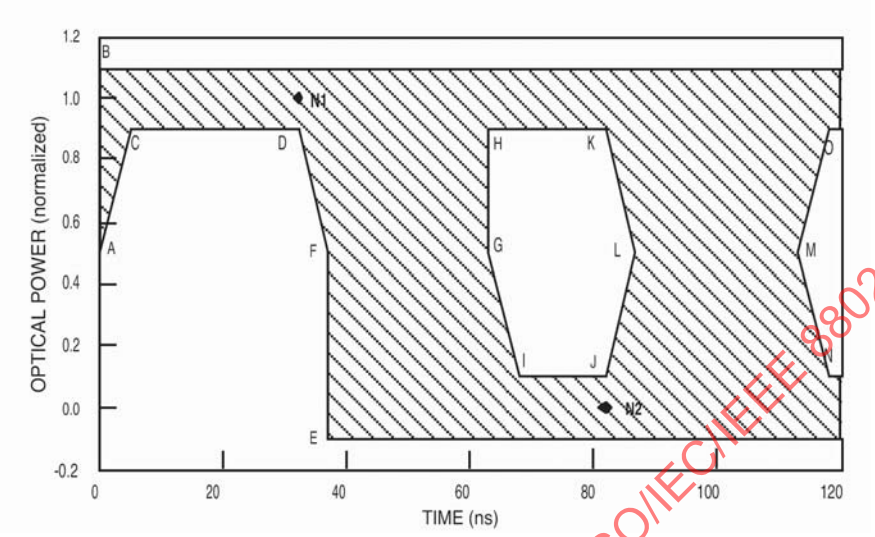

Figure 15–5—10BASE-FL MAU transmit waveform template (data only)

Table 15–4—Transmitted optical waveform values for Figure 15–5

Reference	Time (ns)	Optical power (normalized)
A	0.0	0.5
B	0.0	1.1
C	5.0	0.9
D	32.0	0.9
E	37.0	–0.1
F	37.0	0.5
G	63.0	0.5

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Table 15–4—Transmitted optical waveform values for Figure 15–5 *(continued)*

Reference	Time (ns)	Optical power (normalized)
H	63.0	0.9
I	68.0	0.1
J	82.0	0.1
K	82.0	0.9
L	87.0	0.5
M	113.0	0.5
N	118.0	0.1
O	118.0	0.9
N1	32.0	1.00
N2	82.0	0.00

15.2.2 Receive optical parameters

The bit-error ratio (BER) shall be less than one part in 10^9, when measured between two AUIs attached to a single 10BASE-FP, 10BASE-FB, or 10BASE-FL segment for all combinations of valid optical receive parameters specified in the following subclauses and valid optical transmit pulse duty cycle distortion (15.2.1.9). For the case of integrated MAUs this measurement must be made by inference.

15.2.2.1 Optical receive average power range

The optical receive average power shall be in the range specified in Table 15–1 at the MDI when a single transmitter is transmitting on the medium.

15.2.2.2 Optical receive pulse edge jitter

The received edge jitter shall be as specified for a received waveform consisting of a Manchester-encoded pseudo-random sequence with a minimum repetition period of 511 bits. The jitter at the input MDI shall be measured at the power level median of the optical waveform's upper and lower power levels (as determined from the previous 16 or more transitions in any valid bit stream). The jitter measured at the output of the DI circuit driver shall be measured at the zero crossing points (as determined from the previous 16 or more transitions in any valid bit stream).

NOTE—For the transmit optical parameters of Table 15–1 and the fiber parameters of 15.3.1, the contribution to jitter for a 2 km long fiber is less than 10 ps (.01 ns). For purposes of calculation and specifications, no jitter contribution is allocated to the fiber optic segment (including any 10BASE-FP Star).

Optical signals at the input of the MDI receiver shall be received and sent to the DI circuit if they have total received jitter of no more than that specified in Table 15–1.

The maximum additional edge jitter introduced at a MAU from the input of the MDI receiver to the output of the DI circuit driver shall be as specified in Table 15–1.

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The total edge jitter at the output of the DI circuit driver shall be no more than that given by the sum of the worst-case edge jitter components specified in Table 15–1.

15.2.2.3 Optical receive pulse logic polarity

The higher optical power level received at the MDI shall be represented by LO at both the MDI and the AUI DI circuit. The lower optical power level received at the MDI shall be represented by HI at both the MDI and the AUI DI circuit (see 7.4.2.1).

15.2.2.4 Optical receive pulse rise and fall times

The optical rise and fall times at the MDI receiver shall be measured from the 10% to 90% levels. The rise and fall times and their maximum difference shall be as specified in Table 15–1 at the MDI.

15.3 Characteristics of the fiber optic medium

The fiber optic transmission medium consists of one or more sections of fiber optic cables with any intermediate connectors required to connect sections together and terminated at each end in the optical connector plug as specified in 15.3.2. The fiber optic medium spans from one MDI to another MDI.

15.3.1 Optical fiber and cable

The optical medium requirements are satisfied by the 62.5/125 μm nominal diameter fiber specified in IEC 60793-2:1992, type A1b with the exceptions noted in 15.3.1.1 to 15.3.1.3. For links under 5 m in length it may be necessary to use techniques such as attenuators or mode-stripping filters to attenuate optical power coupled into the cladding in order to meet the requirements of 15.2.2.1. The system can operate, subject to certain restrictions, with a variety of optical fibers. Information on other fiber sizes is contained in D.4. However, conformance to this standard and interoperability between different vendors' equipment is assured only through the use of the optical fiber specified in this subclause.

15.3.1.1 Attenuation

This standard was developed on the basis of cabled optical fiber with an attenuation value of less than or equal to 3.75 dB/km, when measured at a wavelength of 850 nm. Higher loss fiber may be used for shorter fiber pair lengths as long as the requirements in 15.3.3 are met.

NOTE—This value of attenuation is a relaxation of the standard IEC 60793-2:1992, type A1b, category ≤3.5 dB/km and ISO/IEC 11801:2002.

15.3.1.2 Modal bandwidth

Each optical fiber shall have a modal bandwidth-length product of not less than 160 MHz·km at a wavelength of 850 nm.

NOTE—This value of modal bandwidth is a relaxation of the standard IEC 60793-2:1992, type A1b, category >200 MHz·km and ISO/IEC 11801:2002.

15.3.1.3 Propagation delay

The propagation delay shall be ≤5 μs/km. (This is equivalent to a velocity of propagation of 0.67c.)

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15.3.2 Optical medium connector plug and socket

Each end of the fiber optic cable that is to be connected to a 10BASE-FP, 10BASE-FB, or 10BASE-FL MAU or a 10BASE-FP Star shall be terminated in the BFOC/2.5 connector plug shown in Figure 15–6 (for informational use only) (one per fiber), as specified in IEC 60874-10:1992. The corresponding mating connector sockets shown in Figure 15–7 (for informational use only) shall be used on all network elements covered by this specification (10BASE-FP MAU, 10BASE-FB MAU, 10BASE-FL MAU, and 10BASE-FP Star) to which the fiber optic cable attaches. In-line or patch panel connectors may be of other types, but must meet the requirements of 15.3.2.1 and 15.3.2.2.

NOTE—It is good practice to cap unused connectors to protect the system from ambient light and the connector interface from contamination.

15.3.2.1 Optical connector insertion loss

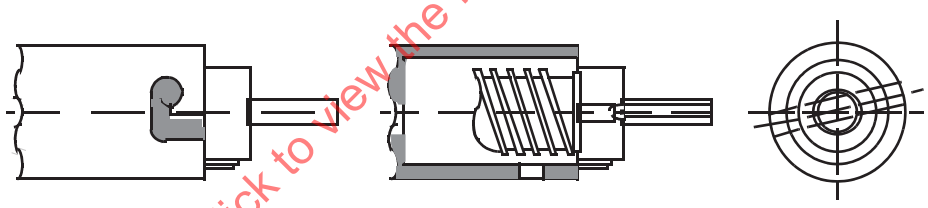
This standard was developed on the basis of a maximum insertion loss of 1.0 dB (see note below). Connectors with different loss characteristics may be used as long as the requirements in 15.3.2.2 and either 15.3.3.1 or 15.3.3.2 are met. Use of connectors with greater than 1.0 dB insertion loss is likely to reduce achievable transmission distances below those mentioned in 15.1.3.4.

NOTE—Per test method ANSI/EIA/TIA 455-34-1985 [B5], Method A, or ANSI/EIA/TIA 455-59-1989 [B8]. (No ISO/IEC test method was available at the time this standard was developed.)

15.3.2.2 Optical connector return loss

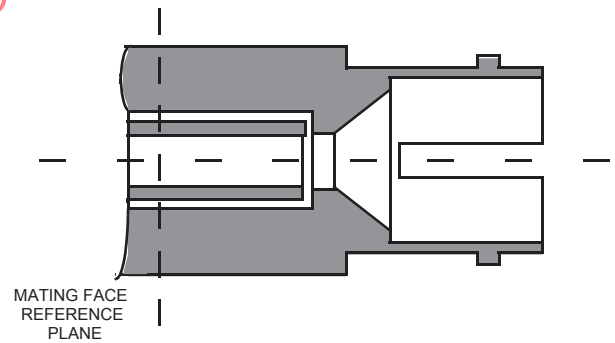
The return loss of optical connectors for 10BASE-FP segments shall be greater than 25 dB.

NOTE—The number of intermediate connectors in a fiber path may have system implications because of return loss considerations (see B.5.2).



(informative only)

Figure 15–6—BFOC/2.5 connector plug



(informative only)

Figure 15–7—BFOC/2.5 connector socket

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15.3.3 Fiber optic medium insertion loss

The optical insertion loss may be allocated between the elements of the fiber optic cable plant in any manner as long as the requirements of 15.3.3.1 and 15.3.3.2 are met. The optical insertion loss shall be measured in accordance with ANSI/EIA/TIA 526-14-1990 [B11], Method A, Two Reference Jumpers.

NOTE—No ISO/IEC test method was available at the time this standard was developed.

15.3.3.1 10BASE-FP segment insertion loss

The optical insertion loss of the 10BASE-FP segment including 10BASE-FP Star shall be between 16 dB and 26 B, measured using an optical signal source with a center wavelength of 850 nm and spectral width of 75 nm. The range of measured insertion losses across the 10BASE-FP segment shall be less than 6 dB for any given star output port with respect to all input ports (see note in 16.5.2.2). See B.5.2 for examples of system implementation.

15.3.3.2 10BASE-FB and 10BASE-FL segment insertion loss

The optical insertion loss of the 10BASE-FB and 10BASE-FL segment shall be less than 12.5 dB, measured using an optical signal source with a center wavelength of 850 nm and spectral width of 75 nm.

15.3.4 Electrical isolation

Electrical isolation shall be provided between MDIs attached to the fiber optic cable. There shall be no conducting path between the optical medium connector plug and any conducting element within the fiber optic cable. This isolation shall withstand at least one of the following electrical strength tests:

a) 1500 V rms at 50 Hz to 60 Hz for 60 s, applied as specified in 5.3.2 of IEC 60950:1991.
b) 2250 Vdc for 60 s, applied as specified in 5.3.2 of IEC 60950:1991.
c) A sequence of ten 2400 V impulses of alternating polarity, applied at intervals of not less than 1 s. The shape of the impulses shall be 1.2/50 µm (1.2 µm virtual front time, 50 µm virtual time of half value) as defined in IEC 60060.

There shall be no isolation breakdown, as defined in 5.3.2 of IEC 60950:1991, during the test. The resistance after the test shall be at least 2 MΩ measured at 500 Vdc.

15.4 MAU reliability

The MAU shall be designed to have a Mean Time Before Failure (MTBF) of at least 10 million hours of continuous operation without causing communication failure among other stations attached to the network. Component failures within the MAU electronics should not prevent communication among other MAUs on the network.

15.5 MAU–AUI specification

When a MAU contains a physical AUI connector, the following specifications shall be met.

15.5.1 MAU–AUI electrical characteristics

The electrical characteristics for the driver and receiver components within the MAU that are connected to the AUI shall be identical to those specified in 7.4 and 7.5. Additionally, the AUI DO receiver shall reject an input waveform of less than ± 160 mV differential.

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15.5.2 MAU–AUI mechanical connections

The MAU shall be provided with a 15-pin male connector as specified in 7.6.

15.5.3 Power consumption

Following power on, the surge current drawn by the MAU through the AUI shall be such that $I_p \times T_w$ is less than or equal to 2×10^{-3} Ampere-seconds, where I_p is the peak surge current and T_w is the time during which the current exceeds the larger of 0.5 A or $0.5 \times I_p$. After 100 ms following power on, the current drawn by the MAU shall not exceed 0.5 A when powered by the AUI.

The MAU shall be capable of operating from all possible AUI voltage sources, including those current-limited to 0.5 A, as supplied by the DTE or repeater through the resistance of all permissible AUI cables.

It is permissible, as an option, to provide a separate power source for the MAU. If a separate power source is implemented, provision shall be made to assure that under no circumstances power can be sourced on pin 13 (Circuit VP) of the AUI. The separate power source if implemented shall withstand at least one of the tests of 15.3.4.

The MAU shall be labeled externally to identify the maximum value of power supply current required by the device when the AUI is implemented.

The MAU shall not introduce at the MDI or onto the DI or CI circuits of the AUI any extraneous signals on power-up or power-down.

15.5.4 MAU–AUI messages

The messages between the PLS in the DTE and the PMA in the MAU shall comply with 7.2.1. These messages also are used in repeater unit to PMA communications.

15.5.4.1 PLS to PMA messages

The following messages are sent by the PLS in the DTE or repeater to the PMA in the MAU (see 7.2.1.1):

Message	Circuit*	Signal	Meaning
output	DO	CD1, CD0	Output information
output_idle	DO	IDL	No data to be output
* Or virtual equivalent for an embedded MAU.			

15.5.4.2 PMA to PLS messages

The following messages are sent by the PMA in the MAU to the PLS in the DTE or repeater (see 7.2.1.2):

15.5.4.2.1 *signal_quality_error* message

The *signal_quality_error* (SQE) message shall operate in the following fashion:

a) The SQE message shall be sent whenever a collision exists, as described in 16.3.4, 17.3.3 or 18.3.1.4.

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Message	Circuit*	Signal	Meaning
input	DI	CD1, CD0	Input information
input_idle	DI	IDL	No input information
signal_quality_error	CI	CS0	Collision or error detected by MAU
mau_available	CI	IDL	MAU is available for output
* Or virtual equivalent for an embedded MAU.			

b) The SQE message shall be sent whenever a jabber condition exists, as described in 16.3.6 or 18.3.1.6.
c) The SQE message shall be sent as a result of SQE Test, as described in 16.3.5 or 18.3.1.5. SQE Test shall not be performed by MAUs connected to repeaters.
d) Under all other conditions, the MAU shall send the *mau_available* message.

The MAU is required to assert the SQE message at the appropriate times, as described in a) through c) above, whenever the MAU is powered.

15.6 Environmental specifications

15.6.1 Safety requirements

An application of the equipment specified herein is for interconnecting equipment in different buildings. This may present hazards beyond the range of protection assured by 15.3.4. Installation practice shall be consistent with this application and provide adequate personnel and equipment safety from earth faults and lightning strike hazards.

Installation practice shall be in accordance with local and national regulations.

NOTE—While optical fibers are nonconducting, some fiber optic cables do contain metallic strength members or sheathing that must be considered during installation. However, since grounding of these metallic members does not involve the signal path, it is beyond the scope of this standard.

15.6.2 Electromagnetic environment

Sources of interference from the environment include electromagnetic fields, electrostatic discharge, and transient voltages between earth connections. The MAUs shall meet their specifications when operating in an ambient plane wave field of 2 V/m from 10 kHz through 30 MHz, and 5 V/m from 30 MHz through 1 GHz.

NOTE—These are levels typically found 1 km from radio broadcast stations.

The MAUs, stars, and associated connector/cable systems shall comply with applicable local and national codes, such as FCC Docket 20780-1980 [B29] in the USA. Equipment shall comply with local and national requirements for limitation of electromagnetic interference and susceptibility. Where no local or national requirements exist, equipment shall comply with CISPR 22: 1993.

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15.6.3 Other environmental requirements

The MAUs, stars, and associated connector/cable systems are expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling such as shock and vibration. Specific requirements and values for these parameters are considered to be beyond the scope of this standard. Manufacturers should indicate in the literature associated with a unit (and on the unit if possible) the operating environment specifications to facilitate selection, installation, and maintenance of these components. It is further recommended that such specifications be stated in standard terms, as specified in IEC 60068, IEC 60874-10:1992, IEC 60793-1:1992, and IEC 60794-1:1993.

15.7 MAU labeling

It is recommended that each MAU (and supporting documentation) be labeled in a manner visible to the user with at least these parameters:

a) Whether 10BASE-FP MAU, 10BASE-FB MAU, or 10BASE-FL MAU
b) Data rate capability in Mb/s
c) Power level in terms of maximum current drain (for external MAUs as required by 15.5.3)
d) Any applicable safety warnings
e) Which connector is input and which is output
f) For 10BASE-FP MAUs, the Manufacturer ID and the MAU ID in two separate fields (see 16.3.1.1.3)
g) For 10BASE-FL MAUs, if capable of full duplex operation

15.7.1 10BASE-FP star labeling

It is recommended that each 10BASE-FP Star (and supporting documentation) be labeled in a manner visible to the user with at least these parameters:

a) Label as 10BASE-FP Star
b) Label input/output connectors

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15.8 Protocol implementation conformance statement (PICS) proforma for Clause 15, Fiber optic medium and common elements of medium attachment units and star, type 10BASE-F[38]

15.8.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 15, Fiber optic medium and common elements of medium attachment units and star, type 10BASE-F, shall complete the following PICS proforma.

A completed PICS proforma is the PICS for the implementation in question. The PICS is a statement of which capabilities and options of the protocol have been implemented. The PICS can be used for a variety of purposes by various parties, including the following:

— As a checklist by the protocol implementer, to reduce the risk of failure to conform to the standard through oversight;
— As a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard PICS proforma, by the supplier and acquirer, or potential acquirer, of the implementation;
— As a basis for initially checking the possibility of interworking with another implementation by the user, or potential user, of the implementation (note that, while interworking can never be guaranteed, failure to interwork can often be predicted from incompatible PICs);
— As the basis for selecting appropriate tests against which to assess the claim for conformance of the implementation, by a protocol tester.

15.8.2 Abbreviations and special symbols

15.8.2.1 Status symbols

The following symbols are used in the PICS proforma:

M is mandatory field/function
O is optional field/function
O.<n> is optional field/function, but at least one of the group of options labeled by the same numeral <n> is required
O/<n> is optional field/function, but one and only one of the group of options labeled by the same numeral <n> is required
X is prohibited field/function
<item> is simple predicate condition, dependent on the support marked for <item>

15.8.2.2 Abbreviations

N/A Not applicable

15.8.3 Instructions for completing the pics proforma

15.8.3.1 General structure of the PICS proforma

The first part of the PICS proforma, Implementation Identification and Protocol Summary, is to be completed as indicated with the information necessary to identify fully both the supplier and the implementation.

[38] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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The main part of the PICS proforma is a fixed-format questionnaire divided into subclauses, each containing a group of items. Answers to the questionnaire items are to be provided in the right-most column, either by simply marking an answer to indicate a restricted choice (usually Yes, No, or Not Applicable), or by entering a value or a set or range of values. (Note that there are some items where two or more choices from a set of possible answers can apply; all relevant choices are to be marked.)

Each item is identified by an item reference in the first column; the second column contains the question to be answered; the third column contains the reference or references to the material that specifies the item in the main body of the standard; the fourth column contains values and/or comments pertaining to the question to be answered. The remaining columns record the status of the item—whether the support is mandatory, optional, or conditional—and provide the space for the answers; see also 15.8.3.4.

The supplier may also provide, or be required to provide, further information, categorized as either Additional Information or Exception Information. When present, each kind of further information is to be provided in a further subclause of items labeled A<i> or X<i>, respectively, for cross-referencing purposes, where <i> is any unambiguous identification for the item (e.g., simply a numeral); there are no other restrictions on its format or presentation.

A completed PICS proforma, including any Additional Information and Exception Information, is the protocol implementation conformance statement for the implementation in question.

Note that where an implementation is capable of being configured in more than one way, according to the items listed under 15.8.5, Major Capabilities/Options, a single PICS may be able to describe all such configurations. However, the supplier has the choice of providing more than one PICS, each covering some subset of the implementation's configuration capabilities, if that would make presentation of the information easier and clearer.

15.8.3.2 Additional information

Items of Additional Information allow a supplier to provide further information intended to assist the interpretation of the PICS. It is not intended or expected that a large quantity will be supplied, and the PICS can be considered complete without any such information. Examples might be an outline of the ways in which a (single) implementation can be set up to operate in a variety of environments and configurations; or a brief rationale, based perhaps upon specific application needs, for the exclusion of features which, although optional, are nonetheless commonly present in implementations of the 10BASE-F protocol.

References to items of Additional Information may be entered next to any answer in the questionnaire, and may be included in items of Exception Information.

15.8.3.3 Exception information

It may occasionally happen that a supplier will wish to answer an item with mandatory or prohibited status (after any conditions have been applied) in a way that conflicts with the indicated requirement. No preprinted answer will be found in the Support column for this; instead, the supplier is required to write into the Support column an X<i> reference to an item of Exception Information, and to provide the appropriate rationale in the Exception item itself.

An implementation for which an Exception item is required in this way does not conform to this standard.

Note that a possible reason for the situation described above is that a defect in the standard has been reported, a correction for which is expected to change the requirement not met by the implementation.

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15.8.3.4 Conditional items

The PICS proforma contains a number of conditional items. These are items for which both the applicability of the item itself, and its status if it does apply—mandatory, optional, or prohibited—are dependent upon whether or not certain other items are supported.

Individual conditional items are indicated by a conditional symbol of the form "<item>:<s>" in the Status column, where "<item>" is an item reference that appears in the first column of the table for some other item, and "<s>" is a status symbol, M, O, or X.

If the item referred to by the conditional symbol is marked as supported, the conditional item is applicable, and its status is given by "<s>"; the support column is to be completed in the usual way. Otherwise, the conditional item is not relevant and the Not Applicable (N/A) answer is to be marked.

Each item whose reference is used in a conditional symbol is indicated by an asterisk in the Item column.

15.8.4 Identification

15.8.4.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation name(s) and version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

15.8.4.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 15, 10 Mb/s Fiber Optic Medium Attachment Unit (MAU) and Medium Specification, type 10BASE-F
Identification of amendments and corrigenda to this PICS proforma which have been completed as part of this PICS	
Have any Exception items been required?No [ ]Yes [ ] (See 15.8.3.3; The answer Yes means that the implementation does not conform to IEEE 802.3-2015.)	

Date of statement	

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15.8.5 Major capabilities/options

Item	Feature	Reference	Value/Comment	Status	Support
*FP	10BASE-FP Implementation	15.1.1	N/A	0.1	Yes[ ] No [ ]
*FB	10BASE-FB Implementation	15.1.1	N/A	0.1	Yes[ ] No [ ]
*FL	10BASE-FL Implementation	15.1.1	N/A	0.1	Yes[ ] No [ ]

In addition, the following predicate name is defined for use when different implementations from the set above have common parameters:

*FA: FB or FL

15.8.6 PICS Proforma for the fiber optic medium

15.8.6.1 Characteristics of the fiber optic medium

Item	Feature	Reference	Value/Comment	Status	Support
*M1	Fiber size	15.3.1	62.5/125 µm	O	Yes [ ]No [ ]
M2	Attenuation of cabled optical fiber	15.3.1.1	≤3.75 dB/km at 850 nm when 62.5/125 µm fiber is used	M1: M	N/A [ ]M: Yes [ ]
M3	Fiber modal bandwidth	15.3.1.2	≥160 MHz·km at 850 nm	M	Yes [ ]
M4	Velocity of propagation	15.3.1.3	≤ 5 µs/km	M	Yes [ ]

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15.8.6.2 Optical medium connector plug and socket

Item	Feature	Subclause	Value/Comment	Status	Support
MC1	Connector plug for termination of fiber	15.3.2	BFOC/2.5—see IEC 60874-10:1992	M	Yes [ ]
MC2	Optical connector loss	15.3.2.1	< 1.0 dB	O	Yes [ ]No [ ]
MC3	Optical connector return loss (10BASE-FP only)	15.3.2.2	> 25 dB	FP: M	N/A [ ]M: Yes [ ]

15.8.6.3 Fiber optic medium insertion loss

Item	Feature	Subclause	Value/Comment	Status	Support
	Fiber optic medium insertion loss		Measured as per ANSI/ EIA/TIA 526-14-1990 [B11], Method A, using optical signal with center wavelength of 850 nm and spectral width of 75 nm		
IL1	10BASE-FP segment insertion loss (including 10BASE-FP Star)	15.3.3.1	Between 16 dB and 26 dB	FP: M	N/A [ ] M: Yes [ ]
IL2	10BASE-FB and 10BASE-FL segment insertion loss	15.3.3.2	< 12.5 dB	FA: M	N/A [ ] M: Yes [ ]
IL3	Range of insertion losses measured across one 10BASE-FP segment or one star output port	15.3.3.1	< 6 dB	FP: M	N/A [ ] M: Yes [ ]

15.8.6.4 Electrical isolation requirements

Item	Feature	Subclause	Value/Comment	Status	Support
IR1	Electrical isolation, optical connector plug to any electrically conducting element in cable	15.3.4	Any one of three tests listed in 15.3.4	M	Yes [ ]
IR2	Resistance after breakdown test	15.3.4	> 2 MΩ measured at 500 Vdc	M	Yes [ ]

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16. Fiber optic passive star and medium attachment unit, type 10BASE-FP

NOTE—This MAU is not recommended for new installations. Since September 2003, maintenance changes are no longer being considered for this clause.

16.1 Scope

16.1.1 Overview

This clause, along with Clause 15, defines the functional, electrical, optical, and mechanical characteristics of a fiber optic passive-star system for interconnecting DTEs and repeaters. The relationship of this clause to the OSI Reference Model is shown in Figure 15–1a). This system, which may be interconnected to other 10 Mb/s baseband segments using repeaters, consists of the 10BASE-FP MAU (including a fiber optic MDI specified in 15.2), a 10BASE-FP fiber optic Star, and the fiber optic medium specified in 15.3. The 10BASE-FP MAU provides the means for attaching DTEs and repeaters to a 10BASE-FP Star LAN, and a 10BASE-FP Star provides the only means to interconnect 10BASE-FP MAUs via their MDIs.

16.1.1.1 10BASE-FP medium attachment unit

The 10BASE-FP MAU has the following general characteristics:

a) It supports a totally passive-star topology interconnection means.
b) It connects a DTE or repeater to a 10BASE-FP fiber optic segment.
c) It supports message traffic at a data rate of 10 Mb/s.
d) It permits up to 500 m of fiber optic cable, as specified in 15.3, between 10BASE-FP MAUs and a 10BASE-FP Star. (See B.5.2.)
e) It permits the DTE or repeater to confirm operation of the MAU and availability of the medium.
f) It permits the DTE to test the collision detection circuitry of the MAU.
g) It recodes the preamble prior to transmission at the MDI to allow passive-system collision detection and restores normal preamble to packets received at the MDI.
h) It transmits coded jam during collision for deterministic detection of end of collision.
i) It supports network configurations using the CSMA/CD access mechanism defined in this standard.

16.1.1.2 10BASE-FP Star

The star has the following general characteristics:

a) It supports a totally passive-star topology interconnection means.
b) It receives an optical signal from any 10BASE-FP MAU connected to the passive fiber optic segment and distributes the signal uniformly to all 10BASE-FP MAUs connected to the passive fiber optic segment, including the one from which the transmission originated.
c) It supports message traffic at a data rate of 10 Mb/s.
d) It permits segments of up to 500 m radius of fiber optic cable, as specified in 15.3, among MAUs and the star. (See B.5.2.)
e) It supports system configurations using the CSMA/CD access mechanism defined in this standard.

16.1.1.3 Repeater unit

The repeater unit (Clause 9), along with 10BASE-FP MAUs (making a repeater set), is used to interconnect 10BASE-FP segments to achieve the maximum 10BASE-FP connection path. The repeater is also used to extend the physical system topology by connecting 10BASE-FP segments to 10BASE-FB and 10BASE-FL segments as well as all other 10 Mb/s baseband media types.

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Multiple repeater units are permitted within a single collision domain to provide the maximum connection path length specified in Clause 13. The repeater is not a DTE and therefore has slightly different requirements for its attached MAUs as defined in 9.4.1. It is recommended that repeater sets with 10BASE-FP MAUs provide the auto partition/reconnection algorithm on those ports as specified in 9.6.6.2.

16.2 PMA interface messages

The messages between PLS in the DTE or the repeater and the PMA in the MAU shall comply with the PMA interface messages in 7.2.1 and 15.5.4. The messages between the PMAs over the MDI are summarized below.

16.2.1 PMA-to-MDI interface signal encodings

The following signals are used by the interface messages between the PMA and the MDI.

Code Rule Violation, CRV. See 15.1.2.

Manchester-Coded Data One, CD1. A clocked bit symbol in which the first half is LO and the second half is HI.

Manchester-Coded Data Zero, CD0. A clocked bit symbol in which the first half is HI and the second half is LO.

Manchester Code Violation Zero, MV0. A clocked bit symbol in which the symbol is LO for the bit duration.

Received Idle, RDARK. See 15.2.1.4 and 16.2.3.2.

Transmitted Idle, TDARK. See 15.2.1.4 and 16.2.2.2.

16.2.2 PMA-to-MDI OTD messages

The following messages can be sent by the MAU PMA to the MDI OTD (Optical Transmit Data) circuit:

Message	Circuit	Signal	Meaning
OTD_output	OTD	CD1, CD0	Output information
OTD_idle	OTD	TDARK	No data to be output
OTD_manch_violation	OTD	MV0	Manchester violation to be output

16.2.2.1 *OTD_output*

The PMA sublayer shall send the *OTD_output* message to the OTD circuit when the DTE or repeater outputs a bit of data, as modified by the Preamble Encoding function (see 16.3.1.1 and Figure 16–1), and neither link fault nor jabber has been detected. The physical realization of the *OTD_output* message shall be a CD0 or CD1 signal sent by the PMA.

16.2.2.2 *OTD_idle*

The PMA sublayer shall send the *OTD_idle* message to the OTD circuit when the DTE or repeater sends idle or if either link fault or jabber has been detected. The physical realization of the *OTD_idle* message shall be a TDARK signal sent by the PMA. TDARK shall be a signal with an optical level as specified in 15.2.1.4, Optical Idle Signal Amplitude, and shall have a duration of 1.5 bit times (BT) or greater.

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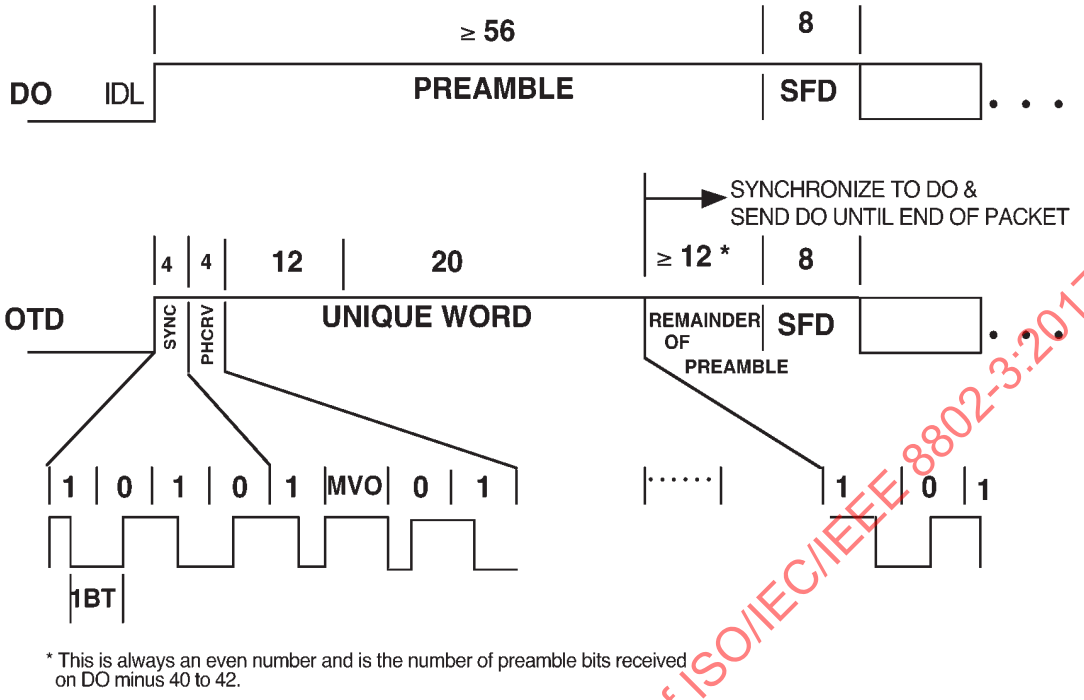

Figure 16–1—10BASE-FP MAU preamble encoding

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16.2.2.3 *OTD_manch_violation*

The PMA shall send the *OTD_manch_violation* message whenever the Preamble Encoding function (16.3.1.1) or the Collision Encoding function (16.3.1.3) requires it to do so. The physical realization of the *OTD_manch_violation* message shall be an MV0 signal sent by the PMA.

16.2.3 MDI ORD-to-PMA messages

The following messages can be received by the MAU PMA from the MDI ORD (Optical Receive Data) circuit:

Message	Circuit	Signal	Meaning
ORD_input	ORD	CD1, CD0	Input information
ORD_idle	ORD	RDARK	No information to input
ORD_crv	ORD	CRV	Detected Manchester violation

16.2.3.1 *ORD_input*

When the PMA sublayer receives the *ORD_input* message on its ORD circuit, it detects a bit of data. The physical realization of the *ORD_input* message shall be a CD0 or CD1 signal.

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16.2.3.2 *ORD_idle*

When the PMA sublayer receives the *ORD_idle* message on its ORD circuit, it detects idle. The physical realization of the *ORD_idle* message shall be an RDARK signal. RDARK shall be a signal with an optical level as specified in 15.2.1.4, Idle Signal Amplitude, and shall have a duration of 1.25 BT or greater.

16.2.3.3 *ORD_crv*

When the PMA sublayer receives the *ORD_crv* message on its ORD circuit, it detects a code rule violation. The physical realization of the *ORD_crv* message shall be a CRV signal. CRV is defined in 15.1.2.

16.3 10BASE-FP MAU functional specifications

The MAU component provides the means by which signals on the DO and DI circuits are coupled:

a) From the DTE or repeater to the MAU's transmit MDI, and
b) From the MAU's receive MDI to the DTE or repeater.

Further, simultaneous transmissions from two or more MAUs are reported as a collision on the CI circuit.

To achieve this basic objective, the MAU component shall contain the following functional capabilities to handle message flow between the DTE or repeater and the MDI:

— Transmit function: Provides the ability to transmit serial data bit streams from the attached device into the MAU's transmit MDI.
— Receive function: Provides the ability to receive serial data bit streams from the MAU's receive MDI and transmit them to the attached device.
— Loopback function: Provides the ability to transfer serial data bit streams from the DO to the DI circuit when the MAU is sending data to the OTD circuit.
— Collision Presence function: Provides the ability to detect, and report to the attached device, a collision.
— *signal_quality_error* Message (SQE) Test function: Provides the ability to indicate to the DTE that the Collision Presence function is operational and that the *signal_quality_error* message can be sent by the MAU.
— Jabber function: Provides the ability to detect abnormally long data streams on the DO circuit and inhibit Data Transmit and Receive, SQE Test, Data Loopback, and the Collision Presence function.
— Link Fault Detection and Low Light function: Provides the ability to detect faults in the 10BASE-FP fiber optic segment and inhibit Data Transmit and Receive, SQE Test, Data Loopback, and the Collision Presence function.

16.3.1 Transmit function requirements

The function of the MAU transmitter shall be to transmit the data received at the DO circuit of the AUI onto the MDI. The Transmit function has four purposes:

a) To convert the electrical signals to optical signals.
b) To recode the preamble to guarantee collision detection.
c) To generate a unique jam signal to facilitate deterministic end of collision detection.
d) To retime signals received on the DO circuit.

The levels and timing of the optical signal shall be as specified in 15.2.1. When a packet is received at the DO interface, transmission of encoded preamble at the MDI shall begin within 5.5 BT. The first bit transmit-

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ted onto the fiber from the MDI shall be a CD1 (see 16.3.1.1.1). The signaling rate at the MDI shall be 10 Mb/s ± 0.005%.

NOTE—The tolerance of ±0.005% simplifies the detection of data and collision in the MAU receiver. It may not be necessary to retime signals in an embedded MAU.

16.3.1.1 Preamble encoding

The Transmit function shall replace the first 40 bits of preamble with a pattern consisting of a 4-bit synchronization pattern, a 4-bit packet header Manchester-coding violation pattern (see 16.3.1.1.2), and a 32-bit unique word (see 16.3.1.1.3) as shown in Figure 16–1. Following the unique word, the remainder of the preamble received on the DO shall be transmitted as received subject to the following rules:

a) The encoded preamble shall be aligned with the preamble received from the DO circuit in such a way that the first bit of the remainder is a Manchester-encoded 1; i.e., the remainder of the preamble is CD1, CD0, CD1, CD0,….
b) The number of bits of preamble received from the DO circuit and sent to the MDI prior to the transmission of SFD shall be no less than the total number received from the DO circuit minus 42 bits and no greater than the total number received from the DO circuit minus 40 bits. The above ensures that the preamble transmitted on the OTD circuit is no more than 2 bits shorter than the preamble received from the DO circuit.

The purpose of preamble encoding is to provide synchronization and collision detection information to the Receive function. This unique encoding exists only on the medium and is removed by the receiving MAU.

16.3.1.1.1 Synchronization pattern

The synchronization pattern shall be a Manchester-encoded 1010 (SYNC=CD1 CD0 CD1 CD0). No other pattern, including 0101, is allowed.

16.3.1.1.2 Packet header code rule violation

The packet header code rule violation pattern shall be a fixed, 4-bit pattern that contains a single violation of the Manchester coding rules. The pattern consists of a CD1, MV0, CD0, CD1. The single Manchester violation in the pattern is the only violation allowed in a properly transmitted packet.

16.3.1.1.3 Unique word

The unique word shall be a 32-bit long Manchester-encoded data pattern that is used to guarantee that the preambles sent by any two 10BASE-FP MAUs are different. The word consists of a 12-bit Manufacturer ID assigned by the IEEE Registration Authority and a 20-bit 10BASE-FP MAU ID assigned by the manufacturer to ensure that the 32-bit word is unique. The nature of the Registration Authority and the procedure by which it administers these 12-bit manufacturer identifiers is beyond the scope of this standard. Each of the elements of the unique word shall be transmitted least significant bit first, starting with the Manufacturer ID followed by the MAU ID.

16.3.1.2 Data transmit

The Data Transmit function shall receive the data signals on the DO circuit and send them on the MDI following the encoded preamble.

The steady-state delay between the DO circuit and transmission on the MDI at the time of the start bit in the SFD, shall be no more than 3.5 BT. The difference between start-of-packet propagation delay for any two packets that are separated by 9.6 µs or less shall not exceed 3 BT.

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16.3.1.3 Collision encoding (unique word jam)

After the start of collision (see 16.3.4.2), the Transmit function shall, within 3.5 BT, cease to send the encoded preamble or data from the DO circuit and shall send a repeating, unique, 33-bit pattern. This pattern shall consist of MV0 followed by the 32-bit unique word. In the presence of a collision, a MAU will detect at least two *ORD_crv* within 33 BT and can thereby guarantee accurate detection of end of collision. This pattern shall be repeatedly transmitted at the MDI OTD until the MAU ceases to receive data on the DO circuit. When this occurs, the MAU shall begin sending *OTD_idle* at the MDI within 3.5 BT of the last bit on the DO circuit.

16.3.2 Receive function requirements

The function of the MAU Receive function is to transmit the data received on the MDI ORD circuit into the DI circuit. The Receive function has three purposes:

a) To convert optical signals to electrical signals.
b) To replace the coded preamble with normal preamble as specified in 4.2.5.
c) To provide uninterrupted carrier sense during collision presence.

The optical-to-electrical conversion shall be as specified in 15.2.2.3.

16.3.2.1 Preamble reconstruction and alignment

When a packet is received on the MDI ORD circuit, transmission of the reconstructed preamble to the DI circuit shall begin within 2.5 BT. The difference between start-of-packet propagation delay for any two packets that are separated by 9.6 µs or less shall not exceed 1 BT.

The reconstructed preamble shall consist of exactly 40 bits of standard preamble (CD1, CD0, CD1,…CD0) followed by the preamble remainder received on the ORD circuit. The Receive function shall align the preamble remainder such that the 41st bit transmitted on the DI circuit is a Manchester-encoded 1 (CD1).

16.3.2.2 Data receive

The Data Receive function shall receive data signals on the MDI ORD circuit and send them into the DI circuit following the reconstructed preamble.

At the start of SFD reception at the MDI ORD circuit, the steady-state delay between the MDI ORD circuit and the DI circuit shall not exceed 2.5 BT.

16.3.2.3 Signal presence during collision

When a collision is detected (see 16.3.4.2), the Receive function shall transmit Manchester Fill, a sequence of Manchester-encoded alternating CD1s and CD0s on the DI circuit. This Manchester sequence shall be sent on the DI circuit for the duration of activity on the MDI ORD circuit and shall be deasserted within 3 BT from the start of RDARK on the MDI ORD circuit. In addition, the data being sent to the DI circuit shall be monitored and altered to be a valid Manchester sequence if any sequence besides a valid Manchester sequence or RDARK is seen, in the absence of collision yet being signaled.

16.3.3 Loopback function requirements

The MAU shall transmit the bit stream received from the DO circuit into the DI circuit. At the start-of-packet transmission, no more than 2 bits of information shall be received from the DO circuit and not transmitted into the DI circuit. It is permissible for the first bit sent to contain encoded phase violations or invalid data. All successive bits shall be transmitted into the DI circuit and shall exhibit no more edge jitter than that

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specified for signals transmitted into the DI circuit by the Receive function, as specified in 15.2.2.2. The steady-state propagation delay between the DO circuit receiver input and the DI circuit driver output for such signals shall not exceed 1 BT. The MAU's DI circuit driver shall comply with the specification for AUI drivers in 7.4.1. There shall be no logical signal inversions between the DO circuit and the DI circuit during collision-free transmission.

16.3.4 Collision presence function requirements

16.3.4.1 CI Circuit signaling

CI circuit signaling and timing shall meet the requirements of 7.3.1.2, as modified by 15.1.3.3, and 15.5.4.1.

16.3.4.2 Collision detection

The MAU shall detect as a collision the following two cases (see Figure 16–6)

a) DO becoming active while ORD is active, except for the instance where ORD is still active from a previous transmission's loopback from the star.
b) The detection of a second *ORD_crv* without an intervening *ORD_idle*.

The start of collision is measured from the time DO becomes active in case a) above and from the occurrence of the second *ORD_crv* for case b) above.

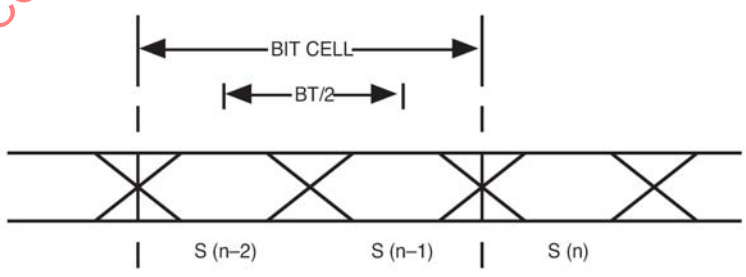
The MAU shall detect *ORD_crv*'s over the received optical power ranges specified in 15.2.2.1. In addition, *ORD_crv* detection shall occur over a differential power range of 8.0 dB.

While a collision is occurring, a CS0 (7.3.1.2) signal shall be sent on the CI circuit. The signal shall be presented to the CI circuit no more than 3.5 BT after start of collision.

If two or more packets arrive simultaneously at the MDI, then the MAU will receive the packet header *ORD_crv* and at least one additional *ORD_crv* during reception of the overlapping unique word patterns. Otherwise the MAU will receive the multiple packet header *ORD_crv*'s from the interfering packet(s).

In order to meet the performance requirements, *ORD_crv* detection needs to be performed in the analog portion of the receiver, as the amplitude information that is essential for *ORD_crv* detection is lost after converting the analog signal into a digital (binary) waveform.

One possible way to detect *ORD_crv* is to compare the amplitudes of three consecutive samples separated by one half BT. The samples are obtained by using a recovered 20 MHz receive clock as shown below.



The differences d1 = | S(n) – S(n-1) | and d2 = | S(n) – S(n-2) | are produced. The computation must be done once per bit cell, with S(n) being the sample from the first half of the bit cell. In a valid Manchester-encoded sequence, one of these differences must be zero. Thus, if both differences are above a certain threshold, a Manchester code rule violation (*ORD_crv* message) is detected. The actual value of the threshold is imple-

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mentation dependent but needs to be such that the probability of obtaining an *ORD_crv* when two or more MAUs are sending simultaneously is 100% (also see 15.2.2). Also, at least one of S(n), S(n–1), or S(n–2) must be HI.

The approach described above may not be the only approach that may meet the requirements for reliable collision detection through *ORD_crv*. The implementer may choose any approach that satisfies the requirements.

NOTE—Implementers are cautioned that optical waveforms received during collisions are the superpositions of multiple transmitted waveforms and that any receive clock synchronization may then be undefined. Under these conditions, collisions will continue to be detected and indicated correctly.

16.3.4.3 End of collision

After detection of a collision (16.3.4.2), CI shall send CS0 until (see Figure 16–2 and Figure 16–6[39])

a) Either DO becomes inactive,
b) ORD becomes idle, or,
c) After waiting for a delay of 54 BT for the unique word jam to loop back from the star, 33 BT have passed with no more than one *ORD_crv*.

The CS0 signal shall be deasserted within 3 BT after any of the above conditions has occurred (see Figure 16–6).

The signal presented on the CI circuit in the absence of collision, SQE Test, or Jabber shall be the IDL signal.

NOTE—The Transmit function (16.3.1) encodes the signal transmitted to guarantee that
a)All transmissions received without collision contain one and only one *ORD_crv*.
b)All transmissions received with collision contain more than one *ORD_crv*.
c)During a collision, spacing between *ORD_crv* events is no more than 32 BT (UWJ has an MV0 every 33 BT).

If a collision is in progress, either the MV0s are in alignment and at least one additional *ORD_crv* will occur during (and because of) the superposition of the unique words, or the MV0s are not in alignment and will be detected in each of the UWJs as *ORD_crv*.

16.3.5 *signal_quality_error* Message (SQE) Test function requirements

The SQE Test function shall be performed by MAUs connected to DTEs and shall not be performed by MAUs connected to repeaters. A capability may be provided in the MAU to activate or inhibit the SQE Test function. It is not required that a MAU determine that it is connected to either a DTE or a repeater and automatically activate or inhibit the SQE Test function. When the SQE test is performed, the MAU shall send CS0 on the CI circuit for a time "SQE_test" beginning a time "SQE_test_wait" after the last positive transition of a packet on the DO circuit. The value of "SQE_test" shall be 10 BT + 5 BT and the value of SQE_test_wait shall be between 0.6 µs and 1.6 µs. This function should use as much of the normal collision detection and signaling circuitry as possible without introducing extraneous signals on the OTD circuit or DI circuit.

16.3.6 Jabber function requirements

The MAU shall contain a self-interrupting capability to prevent an illegally long transmission by the DTE from permanently disrupting transmission on the network (see Figure 16–5). If the transmission exceeds time "xmit_max", then Jabber shall be detected. The value of "xmit_max" shall be in the range of 20 ms to 150 ms.

Upon detection of the Jabber condition, the MAU shall perform the following:

a) Disable Data Transmit,

[39]The MAU state diagrams, Figures 16–2 through 16–6, follow 16.3.4.3.

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b) Send the CS0 signal on the CI circuit, and
c) Disable the Loopback function (16.3.1.3) from the DO circuit to the DI circuit.

The MAU shall reset the Jabber function after a continuous period of IDL on the DO circuit of time "unjab". The value of "unjab" shall be 0.5 s ± 0.25 s.

The MAU shall not activate its Jabber function when the repeater's MAU Jabber Lockup Protection function operates at its longest permitted time as specified in 9.6.5.

NOTE—It is recommended that the Jabber function be activated when the OTD circuit transmitter is sending *OTD_output* messages for longer than the value of "xmit_max_timer".

16.3.7 Link fault detection and low light function requirements

The MAU shall have the capability, as defined in Figure 16–4, to detect faults in the passive fiber optic segment that may affect the reliable carrier sense required by the CSMA/CD access method. The Link Fault Detection and Low Light function ascertains the integrity of the link, during packet transmission, by detecting the presence, at the MDI ORD circuit, of an optical signal that meets the requirements of 15.2.2.1 returned from the star. The MAU shall detect a Link Fault if, after the start of a packet onto the OTD circuit, time "link_test" elapses with no optical signal having been received on the ORD circuit. The value of "link_test" shall be 10 µs ± 2.5 µs. A Link Fault shall also be detected if the optical power of a received optical signal is not sufficient to maintain a BER of one part in 10^7.

On detection of the Link Fault condition, the MAU shall perform the following:

a) Disable its Data Transmit,
b) Disable its Data Receive, and
c) Disable the Loopback (16.3.1.3) from the DO circuit to the DI circuit.

The MAU shall reset the Link Fault function after time "link_heal", followed by the presence of an optical signal on the ORD circuit having sufficient optical power to maintain a BER of one part in 10^7, and then followed by DO circuit and ORD circuit becoming idle. The value of "link_heal" shall be 0.5 s ± 0.25 s.

The Link Fault state diagram (Figure 16–4) controls the measurement of optical loopback time. The value for link_test has been chosen to ensure that a correctly operating 10BASE-FP MAU attached to a 10BASE-FP Star via an unbroken fiber pair 500 m long will always exit the START LINK TEST state before link_test_ timer_done is asserted.

When not transmitting, and not receiving idle, if the optical power of the received optical signal is not sufficient to maintain a BER of one part in 10^7, the MAU shall set CRV to *true* and send the *ORD_crv* message.

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16.3.8 Interface message time references

Delay and bit loss specifications are measured from the occurrence of messages at the MDI and MAU AUI. A “positive-going” transition is from LO to HI. The following describes the point where each message starts:

Message	Reference
output	leading bit cell boundary (BCB) of first valid CD1 or CD0
output_idle	last positive-going transition prior to start of IDL
input	leading BCB of first valid CD1 or CD0
input_idle	last positive-going transition prior to start of IDL.
signal_quality_error	first transition of valid amplitude
mau_available	last positive-going transition prior to start of IDl
OTD_output	leading BCB of first (valid) CD1 or CD0
OTD_idle	last positive-going transition prior to start of TDARK
OTD_manch_violation	leading BCB of valid MV0
ORD_input	leading BCB of first (valid) CD1 or CD0
ORD_idle	last positive-going transition prior to start of RDARK
ORD_crv	leading BCB of a Manchester code rule violated bit

16.3.9 MAU state diagram

The state diagrams, Figure 16–2 through Figure 16–6, depict the full set of allowed MAU state functions relative to the circuits of the AUI and MDI.

The notation used in the state diagrams follows the conventions in 1.2.1. The variables, timers, and counters used in the state diagrams are defined in the following subclauses.

16.3.9.1 MAU state diagram variables

Variables are used in the state diagrams to indicate the status of MAU inputs and outputs, to control MAU operation, and to pass state information between functions.

In the variable definitions, the name of the variable is followed by a brief description of the variable and a list of values the variable may take. For those variables that are state diagram outputs, one value will be identified as the default. The variable has the default value when no active state contains a term assigning a different value.

The variables used in the state diagrams are as follows:

begin

The interprocess flag controlling state diagram initialization values.
Values: false (default).
true.

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DI

Controls the signal sent by the MAU on the DI circuit.
Values: idle; MAU sends *input_idle*, IDL (default)
DO; MAU sends the signal received on the DO circuit.
Manchester fill; (16.3.2.3).
ORD; MAU sends the Manchester-encoded data received on the ORD circuit.
STANDARD PREAMBLE; MAU sends CD1 CD0 CD1 CD0 etc., preamble as defined in 4.2.5 and described in 16.3.2.1.

CI

Controls the signal sent by the MAU on the CI circuit.
Values: idle; MAU sends *mau_available*, IDL (default).
SQE; MAU sends *signal_quality_error*, CS0.

DO

Status of the signal received by the MAU on the DO circuit.
Values: idle; MAU receives *output_idle*, IDL.
active; MAU receives output, CD0 or CD1.

OTD

Controls the signal sent by the MAU on the OTD circuit.
Values: idle; MAU sends TDARK (default).
MP; MAU sends MODIFIED PREAMBLE (16.3.1.1).
DO; MAU sends the Manchester-encoded data received on the DO circuit.
UWJ; MAU sends UNIQUE WORD JAM (16.3.1.3).

ORD

Status of the signal received by the MAU on the ORD circuit.
Values: idle; MAU receives RDARK.
active; MAU receives CD0, CD1 or CRV.

jab

Interprocess variable that indicates whether a jabber has been detected.
Values: not_detect; jabber not detected (default).
detect; jabber detected.

link_status

Interprocess variable that indicates whether a link fault has been detected.
Values: good; no link fault detected (default).
bad; link fault detected.

col_status

Interprocess variable that indicates whether a CRV *(ORD_crv)* was received near the beginning of a received packet.
Values: good; no CRV fault detected (default).
fault; CRV fault detected.

status

Interprocess variable that indicates if a CRV fault, link fault or a jabber is detected.
Values: ok; link_status=good * jab=not_detect * col_status=good.
fault; link_status=bad + jab=detect + col_status=fault.

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collision

Status of the Collision Detect function.
Values: false; no collision detected (default).
true; collision detected (16.3.4.2).

E_col

Status indicating that a collision was detected in the electrical domain.
Values: false; no electrical collision detected (default).
true; electrical collision detected.

CRV

Status of the code rule violation detector.
Values: false; no code rule violation.
true; a code rule violation has occurred.

SQE_test

A capability may be provided in the MAU to activate or inhibit the SQE Test function. It is not required that a MAU determine that it is connected to either a DTE or a repeater and automatically activate or inhibit the SQE Test function.
Values: false; MAU is connected to a repeater.
true; MAU is connected to a DTE.

MPT

Status indicator for transmission of Modified Preamble.
Values: not done; Modified Preamble being transmitted.
done; transmission of Modified Preamble complete.

MPR

Status indicator for reception of Modified Preamble.
Values: not done; Modified Preamble being received.
done; reception of Modified Preamble complete.

low_light

Status indicator for low light detection.
Values: false; low_light not detected (16.3.7).
true; low_light detected (16.3.7).

16.3.9.2 MAU state diagram timers

All timers operate in the same fashion. A timer is reset and starts counting upon entering a state where “start x_timer” is asserted. At time “x” after the timer has been started, “x_timer_done” is asserted and remains asserted until the timer is reset. At all other times “x_timer_not_done” is asserted.

When entering a state where “start x_timer” is asserted, the timer is reset and restarted even if the entered state is the same as the exited state.

The timers used in the MAU state diagrams are defined as follows:

link_test_timer. The timer for longest time between start of DO and start of ORD before Link Fault state is entered (16.3.7).

link_heal_timer. The timer that defines the time delay from Link Fault detection to start of qualification procedure that resets link_fault (16.3.7 and Figure 16–4).

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SQE_test_timer. The timer for the duration of the Signal Quality Error test signal (16.3.5).

SQE_test_wait_timer. The timer for the delay from end of packet to the start of the SQE test signal (16.3.5).

xmit_max_timer. The timer for excessively long transmit time (16.3.6).

unjab_timer. The timer for the length of time the DO circuit must be continuously idle to allow transmission to be re-enabled (16.3.6).

16.3.9.3 MAU state diagram counters

All counters operate in the same fashion. A counter is reset (set to zero) upon entering a state where "start_x_cntr" is asserted. The counter then increments each time the associated event occurs until the counter reaches its maximum value.

The counters used in the MAU state diagrams are defined as follows:

CRV_cntr. Counts the number of CRVs. Used to differentiate between collision and UWJ. *Values:* Integers between and including 0 and 2.

EOC_cntr. Counts the number of BTs since last CRV. Used to identify end of collision (when EOC_cntr = 33). *Values:* Integers between and including 0 and 33.

DELAY_cntr. Counts BTs. Used to control the state transition after receiving MV0 in the preamble as a CRV. *Values:* Integers between and including 0 and 108.

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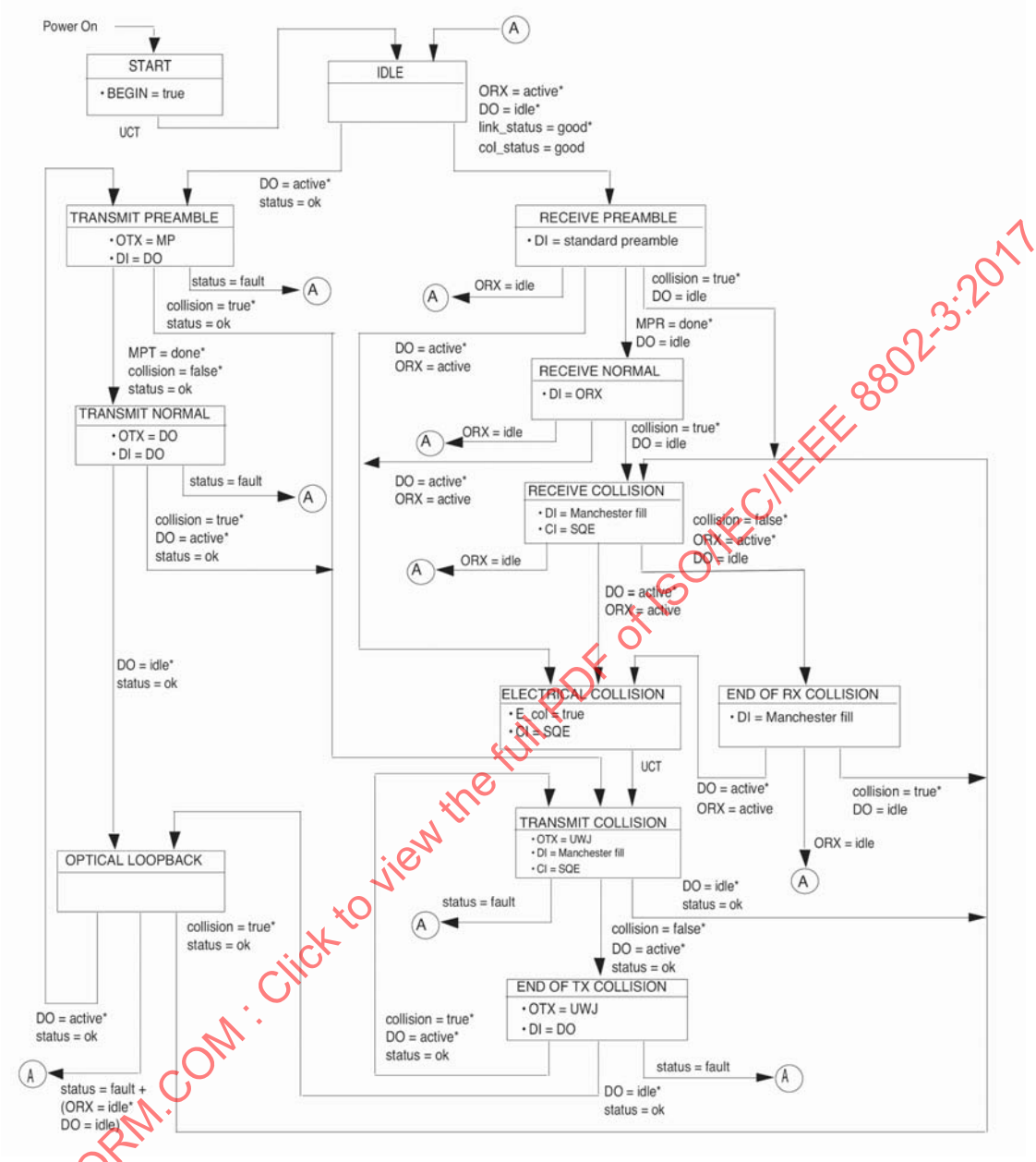

Figure 16–2—Transmit and Receive function state diagram

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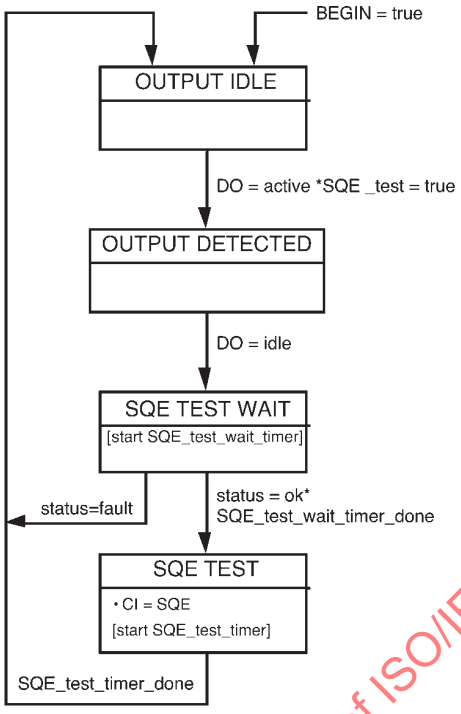

Figure 16–3—*signal_quality_error* Message Test function state diagram

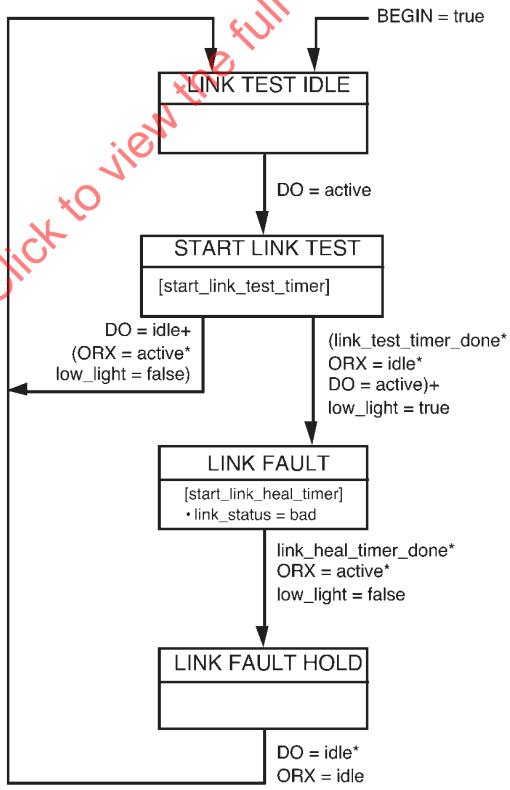

Figure 16–4—Link fault state diagram

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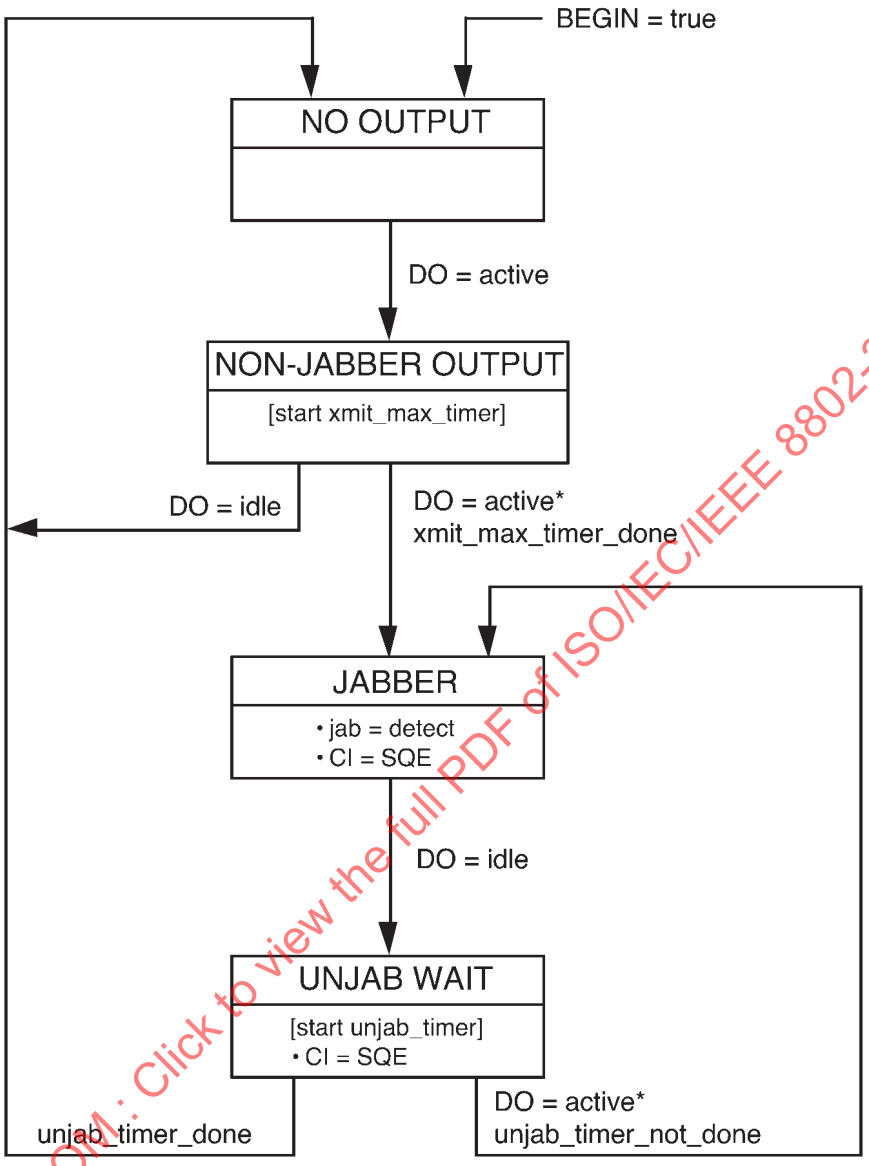

Figure 16–5—Jabber function state diagram

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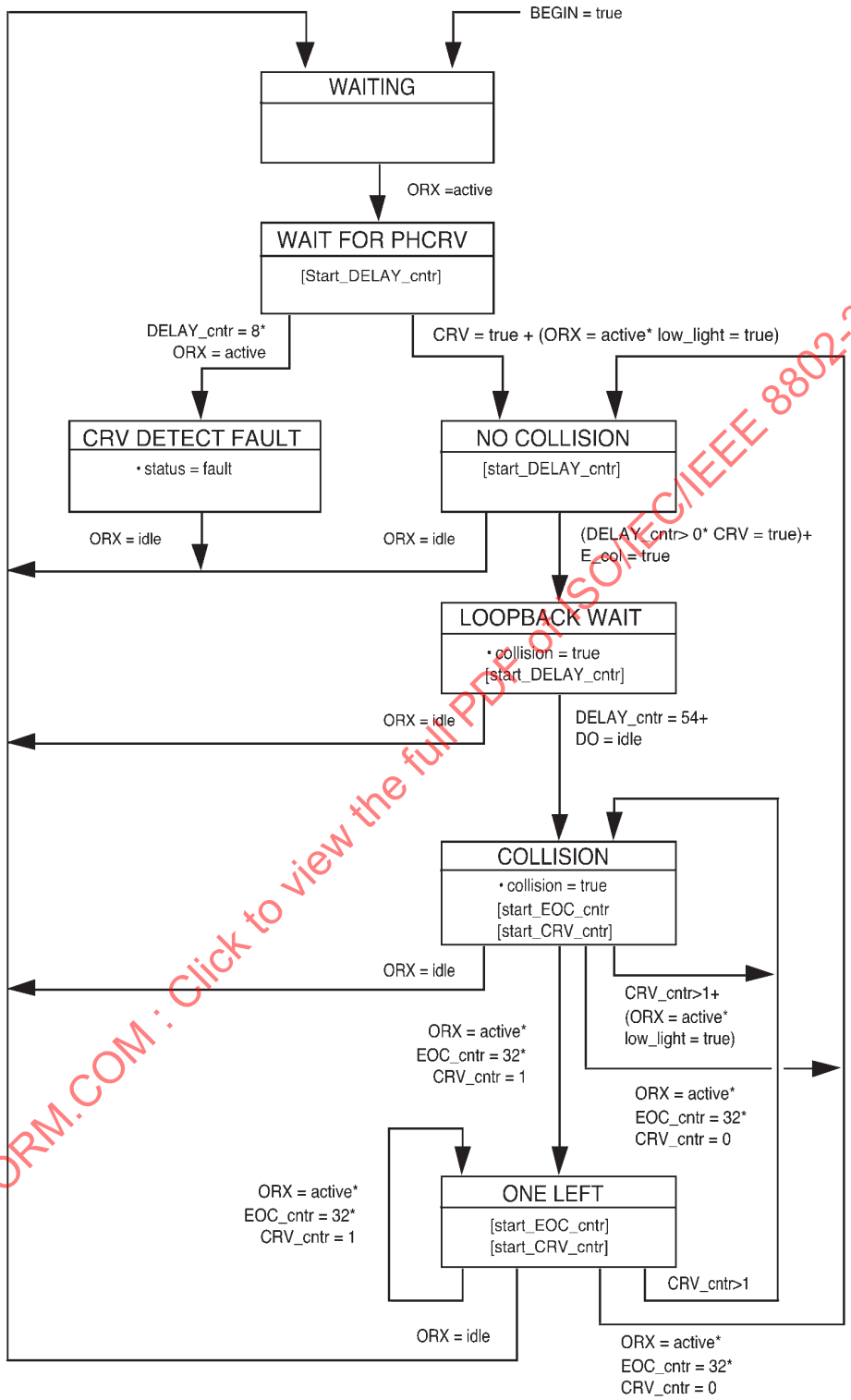

Figure 16–6—Collision detect state diagram

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16.4 Timing summary

Table 16–1 summarizes the timing requirements for 10BASE-FP. This table is a summary; for complete descriptions of the timing to the referenced subclauses. All times are in bit times (BT).

Table 16–1—Maximum timing parameters

Symbol	Function	Bit loss	Invalid bits	Steady-state prop. delay	Start-up delay		
					Max.	Var.	Specified in
M1	*ORD_input* to *input* on DI	0.0	0.0	2.5	2.5	1.0	16.3.2
M2	*output* on DO to *OTD_output*	2.0	0.0	3.5	5.5	3.0	16.3.1
M3	non-looped-back *ORD_input*, and then *output* on DO, to *signal_quality_error* or two *ORD_ crv*, without intervening *ORD_idle*, to *signal_quality_error*				3.5		16.3.4.2
M4a	33 BT with only one *ORD_crv* to *mau_available*			3.0			16.3.4.3
M4b	non-looped-back *ORD_input*, and then *output* on DO, to UWJ as *OTD_output*				3.5		16.3.1.3
M5	while transmitting: two *ORD_crv*, without intervening *ORD_idle*, to UWJ as *OTD_output*			3.5			16.3.1.3
M6	while UWJ as *OTD_output*: *output_idle* to *OTD_idle*			3.5			16.3.1.3
M7	*output_idle* on DO to *signal_quality_error*			6 to 16			16.3.5
M8	*signal_quality_error* duration for SQE test			5 to 15			16.3.5
M9	*output* on DO to *input* on DI	2.0	1.0	1.0	4.0		16.3.3
F1	Fiber Optic Cable Propagation (1000 m)	0	0	50	50		15.3.1.3
A1	AUI Cable Propagation (50 m)	0	0	2.57	2.57		7.4.3.7

16.5 10BASE-FP Star functional specifications

The 10BASE-FP Star provides a means by which the optical signal output from any 10BASE-FP MAU is coupled to the inputs of all 10BASE-FP MAUs attached to the same 10BASE-FP fiber optic segment.

16.5.1 Star functions

16.5.1.1 Number of ports

A star may contain any number of input/output optical interfaces as long as the requirements of 16.5.2 are met.

16.5.1.2 Optical power division

A star shall divide optical power incident on an input port uniformly (within the limits defined in 16.5.2.2) among all output ports without any amplification of the input optical signal.

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16.5.1.3 Configuration

A 10BASE-FP fiber optic segment is configured by attaching a fiber pair between each MAU MDI and a star optical interface. Each MAU OTD circuit shall be connected to an input port of the star, and each MAU ORD circuit shall be connected to an output port. It is recommended for media management purposes to use each output port of the star with its corresponding input port.

16.5.1.4 Reliability

The star shall be designed to provide an MTBF of at least 10 million hours of continuous operation without causing a communication failure among stations attached to the network medium.

16.5.2 Star optical characteristics

16.5.2.1 Star insertion loss

The insertion loss between each input/output optical interface (including the loss of one connector pair) shall be in the range 16 dB to 20 dB, when measured in accordance with ANSI/EIA/TIA 455-180-1990 [B10] using the optical fiber, wavelength, and connector specifications of 15.2.1.1, 15.2.1.2, 15.3.1, and 15.3.2. This insertion loss can generally be met by a star with 33 or fewer input/output optical interfaces. Small-port-count stars may need attenuation in addition to that of the star coupler in order to meet this requirement. A star with more than 33 input/output optical interfaces is not precluded as long as the insertion loss, uniformity, and directivity requirements of this subclause, 16.5.2.2, and 16.5.2.3 are met.

NOTE—The mixing segment insertion loss specified in 15.3.3.1 is generally met by a 33-port star coupler constructed from optical fiber (15.3.1) with connectors (15.3.2) and up to 500 m of optical fiber (15.3.1) on each port. Different sizes and grades of fiber and star coupler may also meet this insertion loss and, while not prohibited, are beyond the scope of this standard.

16.5.2.2 Star single output port uniformity

Single output port uniformity is defined to be the difference between the maximum and minimum insertion loss values (measured according to 16.5.2.1) of any given output port and all input ports. Star single output port uniformity for each output port shall be less than 2.5 dB.

NOTE—Optical uniformity of a star refers to the variation in insertion loss of all input/output port combinations. In the 10BASE-FP system, the uniformity requirement is determined by the receiver. The variation between any given output port and all the input ports needs to be specified. Therefore, it is recommended that each output port connection remain constant during the insertion loss measurements involving that output port. This single output port uniformity is typically better than the overall uniformity of the star.

16.5.2.3 Star directivity

Directivity is the portion of light which is incident on an input port that appears as light emitted from another input port. For the star, directivity for all input optical interface combinations shall be greater than 35 dB. Directivity is measured in accordance with ANSI/EIA/TIA 455-180-1990 [B10] using the optical fiber and wavelength specifications of 15.2.1.1, 15.2.1.2, and 15.3.1.

NOTE—Although passive-star couplers are bidirectional (i.e., light can be transmitted in both directions on one fiber simultaneously), a 10BASE-FP Star cannot use this attribute to support two LANs simultaneously.

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16.6 Protocol implementation conformance statement (PICS) proforma for Clause 16, Fiber optic passive star and medium attachment unit, type 10BASE-FP[40]

16.6.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 16, Fiber optic passive star and medium attachment unit, type 10BASE-FP, shall complete the following protocol implementation conformance statement (PICS) proforma.

A completed PICS proforma is the PICS for the implementation in question. The PICS is a statement of which capabilities and options of the protocol have been implemented. The PICS can be used for a variety of purposes by various parties, including the following:

— As a checklist by the protocol implementer, to reduce the risk of failure to conform to the standard through oversight;
— As a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard PICS proforma, by the supplier and acquirer, or potential acquirer, of the implementation;
— As a basis for initially checking the possibility of interworking with another implementation by the user, or potential user, of the implementation (note that, while interworking can never be guaranteed, failure to interwork can often be predicted from incompatible PICs);
— As the basis for selecting appropriate tests against which to assess the claim for conformance of the implementation, by a protocol tester.

16.6.2 Abbreviations and special symbols

16.6.2.1 Status symbols

The following symbols are used in the PICS proforma:

M	mandatory field/function
O	optional field/function
O.<n>	is optional field/function, but at least one of the group of options labeled by the same numeral <n> is required
O/<n>	is optional field/function, but one and only one of the group of options labeled by the same numeral <n> is required
X	is prohibited field/function
<item>:	is simple-predicate condition, dependent on the support marked for <item>

16.6.2.2 Abbreviations

N/A	not applicable

16.6.3 Instructions for completing the PICS proforma

16.6.3.1 General structure of the PICS proforma

The first part of the PICS proforma, Implementation Identification and Protocol Summary, is to be completed as indicated with the information necessary to identify fully both the supplier and the implementation.

[40] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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The main part of the PICS proforma is a fixed-format questionnaire divided into subclauses, each containing a group of items. Answers to the questionnaire items are to be provided in the right-most column, either by simply marking an answer to indicate a restricted choice (usually Yes, No, or Not Applicable), or by entering a value or a set or range of values. (Note that there are some items where two or more choices from a set of possible answers can apply; all relevant choices are to be marked.)

Each item is identified by an item reference in the first column; the second column contains the question to be answered; the third column contains the reference or references to the material that specifies the item in the main body of the standard; the fourth column contains values and/or comments pertaining to the question to be answered. The remaining columns record the status of the item—whether the support is mandatory, optional, or conditional—and provide the space for the answers; see also 16.6.3.4 below.

The supplier may also provide, or be required to provide, further information, categorized as either Additional Information or Exception Information. When present, each kind of further information is to be provided in a further subclause of items labeled A<i> or X<i>, respectively, for cross-referencing purposes, where <i> is any unambiguous identification for the item (e.g., simply a numeral); there are no other restrictions on its format or presentation.

A completed PICS proforma, including any Additional Information and Exception Information, is the protocol implementation conformance statement for the implementation in question.

Note that where an implementation is capable of being configured in more than one way, according to the items listed under 16.6.5, Major Capabilities/Options, a single PICS may be able to describe all such configurations. However, the supplier has the choice of providing more than one PICS, each covering some subset of the implementation's configuration capabilities, if that would make presentation of the information easier and clearer.

16.6.3.2 Additional information

Items of Additional Information allow a supplier to provide further information intended to assist the interpretation of the PICS. It is not intended or expected that a large quantity will be supplied, and the PICS can be considered complete without any such information. Examples might be an outline of the ways in which a (single) implementation can be set up to operate in a variety of environments and configurations; or a brief rationale, based perhaps upon specific application needs, for the exclusion of features which, although optional, are nonetheless commonly present in implementations of the 10BASE-FP protocol.

References to items of Additional Information may be entered next to any answer in the questionnaire, and may be included in items of Exception Information.

16.6.3.3 Exception information

It may occasionally happen that a supplier will wish to answer an item with mandatory or prohibited status (after any conditions have been applied) in a way that conflicts with the indicated requirement. No preprinted answer will be found in the Support column for this; instead, the supplier is required to write into the Support column an X<i> reference to an item of Exception Information, and to provide the appropriate rationale in the Exception item itself.

An implementation for which an Exception item is required in this way does not conform to this standard.

Note that a possible reason for the situation described above is that a defect in the standard has been reported, a correction for which is expected to change the requirement not met by the implementation.

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16.6.3.4 Conditional items

The PICS proforma contains a number of conditional items. These are items for which both the applicability of the item itself, and its status if it does apply—mandatory, optional, or prohibited—are dependent upon whether or not certain other items are supported.

Individual conditional items are indicated by a conditional symbol of the form "<item>:<s>" in the Status column, where "<item>" is an item reference that appears in the first column of the table for some other item, and "<s>" is a status symbol, M, O, or X.

If the item referred to by the conditional symbol is marked as supported, the conditional item is applicable, and its status is given by "<s>"; the support column is to be completed in the usual way. Otherwise, the conditional item is not relevant and the Not Applicable (N/A) answer is to be marked.

Each item whose reference is used in a conditional symbol is indicated by an asterisk in the Item column.

16.6.4 Identification

16.6.4.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

16.6.4.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 16, Fiber optic passive star and medium attachment unit, type 10BASE-FP
Identification of amendments and corrigenda to this PICS proforma which have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See 17.5.3.3; The answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	

Date of statement	

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16.6.5 Major capabilities/options

Item	Feature	Reference	Value/Comment	Status	Support
*DTE	MAU supports DTE connections	15.1.1	N/A	O.1	Yes [ ] No [ ]
*RPT	MAU supports repeater connections	15.1.1	N/A	O.1	Yes [ ] No [ ]
*AUI	AUI connection physically exists and is accessible for test	15.1.3.2	N/A	O	Yes [ ] No [ ]

16.6.6 PICS proforma for the type 10BASE-FP MAU

16.6.6.1 Compatibility considerations

Item	Feature	Subclause	Value/Comment	Status	Support
CC1	Compatibility Considerations: 10BASE-FP Systems compatible at 10BASE-FP MDI	15.1.3.2		M	Yes [ ]
CC2	Mode of operation	15.1.3.5	normal mode only	M	Yes [ ]

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16.6.6.2 Optical transmit parameters

Item	Feature	Subclause	Value/Comment	Status	Support
OT1	Center Wavelength	15.2.1.1	min 800 nm max 910 nm	M	Yes [ ]
OT2	Spectral Width (FWHM)	15.2.1.2	< 75 nm	M	Yes [ ]
OT3	Optical Modulation Extinction Ratio	15.2.1.3	< –13 dB	M	Yes [ ]
OT4	Optical Idle Signal Amplitude	15.2.1.4	< 57 dBm	M	Yes [ ]
OT5	Optical Transmit Pulse Logic Polarity	15.2.1.5	High Optical Power = LO on AUI DO and MDI. Low Optical Power = HI on AUI DO and MDI.	M	Yes [ ]
	Optical Transmit Pulse Rise and Fall times	15.2.1.6	Measured from 10% to 90% level		
OT6	Max. (Data)		10.0 ns	M	Yes [ ]
OT7	Min. (Data)		2.0 ns	M	Yes [ ]
OT8	Max. Difference (Data)		3.0 ns	M	Yes [ ]
OT9	Optical Transmit Pulse Over-shoot	15.2.1.7	< 5%	M	Yes [ ]
OT10	Optical Transmit Pulse Under-shoot	15.2.1.7	< 5%	M	Yes [ ]
OT11	Optical Transmit Pulse Edge Jitter, Total at MDI (Data)	15.2.1.8	± 1.0 ns Measured as in 15.2.1.8	M	Yes [ ]
OT12	Optical Transmit Pulse Duty Cycle Distortion (Data)	15.2.1.9	± 1.0 ns max Measured at median power level	M	Yes [ ]
	Optical Transmit Average Power	15.2.1.10			
OT13	Min.		–15 dBm	M	Yes [ ]
OT14	Max.		–11 dBm	M	Yes [ ]
OT15	Transmit signal template	Figure 15–3	Optical signal within template	M	Yes [ ]

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16.6.6.3 Optical receive parameters

Item	Feature	Subclause	Value/Comment	Status	Support
OR1	BER between two AUIs attached to a single segment	15.2.2	< one part in 10^9	M	Yes [ ]
 OR2 OR3	Optical Receive Average Power Min. Max.	15.2.2.1	When a single transmitter transmits on the medium –41.0 dBm –27.0 dBm	 M M	 Yes [ ] Yes [ ]
OR4	MAU optical receive Edge Jitter (Data) Received at MDI	15.2.2.2	± 4.5 ns at median power. Measured as in 15.2.2.2.	M	Yes [ ]
OR5	Optical Receive Pulse Logic Polarity	15.2.2.3	High Optical Power = LO on AUI DI and MDI. Low Optical Power = HI on AUI DI and MDI.	M	Yes [ ]
 OR6 OR7	Optical Receive Pulse Rise and Fall Times: Max. (Data) Min. (Data)	15.2.2.4	Measured from 10% to 90% level 18.5 ns 2.0 ns	 M M	 Yes [ ] Yes [ ]

16.6.6.4 Optical medium connector plug and socket

Item	Feature	Subclause	Value/Comment	Status	Support
CS1	Connector Socket	15.3.2	BFOC/2.5—see IEC 60874-10:1992	M	Yes [ ]

16.6.6.5 MAU functions

Item	Feature	Subclause	Value/Comment	Status	Support
MF1	Transmit	16.3.1		M	Yes [ ]
MF2	Data Loopback	16.3.3		M	Yes [ ]
MF3	Receive	16.3.2		M	Yes [ ]
MF4	Collision Presence	16.3.4		M	Yes [ ]
MF5	Jabber	16.3.6		M	Yes [ ]
MF6	Link Fault Detection	16.3.7		M	Yes [ ]
MF7	Low Light Detection	16.3.7		M	Yes [ ]
MF8	SQE Test	16.3.5		DTE: M	N/A [ ] M: Yes [ ]
				RPT: X	N/A [ ] X: Yes [ ]

16.6.6.6 PMA interface messages

Item	Feature	Subclause	Value/Comment	Status	Support
PIM1	Messages between DTE or repeater PLS and MAU PMA	16.2	As in 7.2.1 and 15.5.4	M	Yes [ ]

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16.6.6.7 PMA to MDI OTD messages

Item	Feature	Subclause	Value/ Comment	Status	Support
OTD1	Signal sent on OTD corresponding to *OTD_output* message	16.2.2.1	CD1,CD0	M	Yes [ ]
OTD2	Signal sent on OTD corresponding to *OTD_idle* message	16.2.2.2	TDARK	M	Yes [ ]
OTD3	TDARK optical level	16.2.2.2	As in 15.2.1.4	M	Yes [ ]
OTD4	TDARK duration	16.2.2.2	≥ 1.5 BT	M	Yes [ ]
OTD5	Signal sent on OTD to ensure detection of collisions: *OTD_manch_violation* message	16.2.2.3	MV0	M	Yes [ ]

16.6.6.8 MDI ORD to PMA messages

Item	Feature	Subclause	Value/ Comment	Status	Support
OTD1	Signal received on ORD corresponding to *ORD_input* message	16.2.3.1	CD1,CD0	M	Yes [ ]
OTD2	Signal received on ORD corresponding to *ORD_idle* message	16.2.3.2	RDARK	M	Yes [ ]
OTD3	RDARK Optical Level	16.2.3.2	As in 15.2.1.4	M	Yes [ ]
OTD4	RDARK Duration	16.2.3.2	≥ 1.25 BT	M	Yes [ ]
OTD5	Signal received on ORD corresponding to *ORD_crv* message	16.2.3.3	CRV	M	Yes [ ]

16.6.6.9 Transmit functions

Item	Feature	Subclause	Value/Comment	Status	Support
XT1	Signaling rate	16.3.1	10 Mb/s ± 0.005%	M	Yes [ ]
XT2	Optical transmit levels and timing	16.3.1	As in 15.2.1	M	Yes [ ]
XT3	Transmit start-up delay	16.3.1	≤ 5.5 BT	M	Yes [ ]
XT4	First bit transmitted	16.3.1	CD1	M	Yes [ ]
XT5	Transmit path	16.3.1	DO circuit to transmit MDI	M	Yes [ ]
XT6	Preamble encoding	16.3.1.1	Replace first 40 bits of preamble with pattern as described	M	Yes [ ]
XT7	Remainder of preamble	16.3.1.1	Transmitted as received	M	Yes [ ]
XT8	Alignment of remainder of preamble	16.3.1.1	CD1,CD0,…	M	Yes [ ]

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16.6.6.9 Transmit functions *(continued)*

XT9	Number of preamble bits received from DO and sent to the transmit MDI prior to transmission of SFD	16.3.1.1	≥ total number received from DO minus 42 bits and ≤ total number received from DO minus 40 bits	M	Yes [ ]
XT10	Synchronization pattern	16.3.1.1.1	CD1,CD0,CD1,CD0	M	Yes [ ]
XT11	Packet header code rule violation	16.3.1.1.2	CD1,MV0,CD0,CD1	M	Yes [ ]
XT12	Unique Word	16.3.1.1.3	32 bit word as described	M	Yes [ ]
XT13	Unique Word order of transmission	16.3.1.1.3	Least significant bit first	M	Yes [ ]
XT14	Data transmit	16.3.1.2	Following preamble, all data received from DO is sent to transmit MDI	M	Yes [ ]
XT15	Transmit steady-state delay	16.3.1.2	3.5 BT max	M	Yes [ ]
XT16	Transmit delay variability	16.3.1.2	3 BT max for packets ≤ 9.6 µs apart	M	Yes [ ]

16.6.6.10 Collision Encoding (Unique Word Jam) function

Item	Feature	Subclause	Value/Comment	Status	Support
CE1	Collision detection to Unique Word Jam transmission delay	16.3.1.3	3.5 BT max	M	Yes [ ]
CE2	Unique Word Jam composition	16.3.1.3	MV0,Unique Word, MV0,Unique Word, MV0,Unique Word, etc.…	M	Yes [ ]
CE3	End of data on DO to end of Unique Word Jam transmission delay	16.3.1.3	3.5 BT max	M	Yes [ ]

16.6.6.11 Receive functions

Item	Feature	Subclause	Value/Comment	Status	Support
RCV1	Optical to Electrical conversion	16.3.2	As specified in 15.2.2.3	M	Yes [ ]

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16.6.6.12 Preamble reconstruction and alignment function

Item	Feature	Subclause	Value/Comment	Status	Support
PRA1	Start-up delay (receive MDI to DI)	16.3.2.1	2.5 BT max	M	Yes [ ]
PRA2	Receive delay variability	16.3.2.1	1 BT max for any two packets ≤ 9.6 µs apart	M	Yes [ ]
PRA3	Reconstructed preamble composition	16.3.2.1	40 bits of CD1,CD0,CD1,…,CD0 followed by remainder of preamble received on receive MDI	M	Yes [ ]
PRA4	Reconstructed preamble alignment	16.3.2.1	41st bit is CD1	M	Yes [ ]

16.6.6.13 Data receive function

Item	Feature	Subclause	Value/Comment	Status	Support
DR1	Receive path (following reconstructed preamble)	16.3.2.2	Receive MDI to DI circuit	M	Yes [ ]
DR2	Steady-state delay (receive MDI to DI)	16.3.2.2	2.5 BT max	M	Yes [ ]

16.6.6.14 Signal presence during collision

Item	Feature	Subclause	Value/Comment	Status	Support
SPC1	Signal transmitted on DI during Collision	16.3.2.3	Manchester Fill (CD1,CD0,CD1, etc.)	M	Yes [ ]
SPC2	Transmit valid Manchester during collision	16.3.2.3	For duration of activity on receive MDI	M	Yes [ ]
SPC3	RDARK to end of valid Manchester delay on DI	16.3.2.3	3 BT max	M	Yes [ ]
SPC4	Signal transmitted on DI during invalid data on receive MDI	16.3.2.3	Valid Manchester sequence	M	Yes [ ]

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16.6.6.15 Loopback function

Item	Feature	Subclause	Value/Comment	Status	Support
LP1	Data Loopback function	16.3.3	DO signals to DI circuit	M	Yes [ ]
LP2	Loopback bit loss (DO to DI)	16.3.3	2 bits max at start of packet	M	Yes [ ]
LP3	Loopback settling time	16.3.3	2nd and following bits shall meet jitter specifications in 15.2.2.2.1	M	Yes [ ]
LP4	Loopback steady-state delay	16.3.3	1 BT max	M	Yes [ ]
LP5	DI circuit driver	16.3.3	See 7.4.1	M	Yes [ ]
LP6	Loopback polarity	16.3.3	No signal inversion from DO to DI	M	Yes [ ]

16.6.6.16 Collision presence function

Item	Feature	Subclause	Value/Comment	Status	Support
CP1	CI signaling and timing	16.3.4.1	As specified in 7.3.1.2, and modified by 15.1.3.3 and 15.5.4.1	M	Yes [ ]
CP2	Collision Detection	16.3.4.2	CS0 on CI if DO = active and ORD = active (if IPG ≥ OTD to ORD loopback time) or two CRVs detected with no intervening *ORD_idle*	M	Yes [ ]
CP3	Collision indication delay	16.3.4.2	3.5 BT max after second CRV or 3.5 BT max after presence of DO = active and ORD = active	M	Yes [ ]
CP4	Received Power range for detection of CRV	16.3.4.2	As specified in 15.2.2.1	M	Yes [ ]
CP5	Received Differential Power Range for detection of CRV	16.3.4.2	8.0 dB	M	Yes [ ]
CP6	End of Collision determination	16.3.4.3	CS0 on CI until DO = inactive or ORD = idle; or after waiting 54 BT, 33 BT with no more than one CRV detected	M	Yes [ ]
CP7	End of Collision deassertion delay	16.3.4.3	3 BT max	M	Yes [ ]
CP8	CI circuit with no collision, SQE Test or jabber	16.3.4.3	IDL	M	Yes [ ]

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16.6.6.17 *signal_quality_error* Message (SQE) test function

Item	Feature	Subclause	Value/Comment	Status	Support
STF1	SQE Test induced OTD or DI signal	16.3.5	No extraneous signals permitted	DTE: M	N/A [ ] M: Yes [ ]
STF2	SQE Test timing (after last positive edge on DO) of CS0 on CI	16.3.5	Start 0.6 µs to 1.6 µs. Duration 5 bits to 15 bits	DTE: M	N/A [ ] M: Yes [ ]

16.6.6.18 Jabber function

Item	Feature	Subclause	Value/Comment	Status	Support
JAB1	Jabber function implementation	16.3.6	Self-interrupt of transmit and loopback	M	Yes [ ]
JAB2	Excessive frame timer for jabber detection	16.3.6	20 ms min., 150 ms max.	M	Yes [ ]
JAB3	CI circuit during jabber	16.3.6	CS0 signal	M	Yes [ ]
JAB4	MAU jabber reset delay	16.3.6	0.5 s ± 0.25 s	M	Yes [ ]
JAB5	State of Loopback function during jabber	16.3.6	Disabled	M	Yes [ ]
JAB6	State of Transmit function during jabber	16.3.6	Disabled	M	Yes [ ]
JAB7	Jabber inhibit	16.3.6	Jabber not activated by the longest permitted output specified in 9.6.5	M	Yes [ ]

16.6.6.19 Link Fault Detect function

Item	Feature	Subclause	Value/Comment	Status	Support
LF1	Link Test Timer	16.3.7	10 µs ± 2.5 µs	M	Yes [ ]
LF2 LF3 LF4	Actions during detected failure: Data Transmit function Data Receive function Loopback function	16.3.7	 Disabled Disabled Disabled	 M M M	 Yes [ ] Yes [ ] Yes [ ]
LF5	Link heal timer	16.3.7	0.5 s ± 0.25 s	M	Yes [ ]
LF6	Receive power level for link fault detect	16.3.7	Not sufficient to maintain BER < 10^{-7}	M	Yes [ ]
LF7	Action if receive power level not sufficient to maintain BER < 10^{-7}	16.3.7	CRV = true	M	Yes [ ]
LF8	Link fault reset	16.3.7	Expiration of link_heal_timer followed by optical signal of sufficient power to maintain BER ≤ 10^{-7}	M	Yes [ ]

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16.6.6.20 MAU state diagram requirements

Item	Feature	Subclause	Value/Comment	Status	Support
SD1	Transmit and Receive function state diagram	16.3.9	Meets requirements of Figure 16–2	M	Yes [ ]
SD2	SQE Message Test function state diagram	16.3.9	Meets requirements of Figure 16–3	DTE: M	N/A [ ] M: Yes [ ]
SD3	Link Fault state diagram	16.3.9	Meets requirements of Figure 16–4	M	Yes [ ]
SD4	Jabber function state diagram	16.3.9	Meets requirements of Figure 16–5	M	Yes [ ]
SD5	Collision Detect state diagram	16.3.9	Meets requirements of Figure 16–6	M	Yes [ ]

16.6.6.21 MAU-to-AUI signal characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
ASC1	Signaling rate (stated on label)	7.3.2	10 Mb/s	AUI: M	N/A [ ] M: Yes [ ]
ASC2	CS0 signal frequency (on CI)	7.3.1.2	10 MHz ± 15%	AUI: M	N/A [ ] M: Yes [ ]
ASC3	CS0 signal duty cycle	7.3.1.2	60:40 worst case	AUI: M	N/A [ ] M: Yes [ ]

16.6.6.22 MAU-to-AUI DI and CI driver characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
ADC1 ADC2	Differential output voltage: Idle state Start of idle	7.4.1.1	 ≤ 40 mV after 80 BT. Figure 7–12	 AUI: M AUI: M	 N/A [ ] M: Yes [ ] N/A [ ] M: Yes [ ]
ADC3	Current into test load while idle	7.4.1.1	4 mA max after 80 BT	AUI: M	N/A [ ] M: Yes [ ]
ADC4	Requirements after idle	7.4.1.2	1st bit to Figure 7–11	AUI: M	N/A [ ] M: Yes [ ]
ADC5	Common-mode output voltage, ac	7.4.1.3	≤ 2.5 V peak for 30 Hz to 40 kHz, ≤ 160 mV peak for 40 kHz to 10 MHz, Figure 7–13	AUI: M	N/A [ ] M: Yes [ ]
ADC6	Differential output voltage, open circuit	7.4.1.4	13 V peak max	AUI: M	N/A [ ] M: Yes [ ]
ADC7	Common-mode output voltage, dc	7.4.1.5	≤ 5.5 V, Figure 7–1	AUI: M	N/A [ ] M: Yes [ ]
ADC8	Fault tolerance	7.4.1.6	Figure 7–14	AUI: M	N/A [ ] M: Yes [ ]
ADC9	Fault current	7.4.1.6	≤ 150 mA, any state, Figure 7–14	AUI: M	N/A [ ] M: Yes [ ]

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16.6.6.23 AUI-to-MAU DO receiver characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
DO1	Unsquelched threshold	7.4.2.1	160 mV max diff	AUI: M	N/A [ ] M: Yes [ ]
DO2	Squelch	15.5.1	Reject signals < ±160 mV differential	AUI: M	N/A [ ] M: Yes [ ]
DO3	High to idle transition	7.4.1.1	Must not cause output	AUI: M	N/A [ ] M: Yes [ ]
DO4	Differential input impedance	7.4.2.2	Real part: 77.83 Ω ± 6%, 0 ≤ phase angle ≤ real part * 0.0338	AUI: M	N/A [ ] M: Yes [ ]
DO5	Common-mode range, ac	7.4.2.3	3 V min for 30 Hz to 40 kHz, 200 mV min for 40 kHz to 10 MHz	AUI: M	N/A [ ] M: Yes [ ]
DO6	Total common-mode range	7.4.2.4	Magnitude of 0 to 5.5 Vac+dc	AUI: M	N/A [ ] M: Yes [ ]
DO7	Common-mode current limit	7.4.2.4	≤ 1 mA	AUI: M	N/A [ ] M: Yes [ ]
DO8	IDL detection	7.3.1.1	≤ 1.6 BT	AUI: M	N/A [ ] M: Yes [ ]
DO9	Requirements after idle	7.4.2.5	Receiver in specification after start-up delay	AUI: M	N/A [ ] M: Yes [ ]
DO10	Receiver fault tolerance	7.4.2.6	Figure 7–16	AUI: M	N/A [ ] M: Yes [ ]
DO11	Input fault current	7.4.2.6	3 mA max for Figure 7–16	AUI: M	N/A [ ] M: Yes [ ]

16.6.6.24 MAU-to-AUI circuit termination

Item	Feature	Subclause	Value/Comment	Status	Support
ACT1	Common-mode termination	7.5.2.6	If used, must be to VC	AUI: M	N/A [ ] M: Yes [ ]
ACT2	Pins 1, 4, 8, 11, 14 impedance to VC circuit	7.5.2.8	≤ 5 Ω at 5 MHz	AUI: M	N/A [ ] M: Yes [ ]
ACT3	Pins 1, 4, 8, 11, 14 coupling to VC circuit	7.5.2.8	Capacitive	AUI: M	N/A [ ] M: Yes [ ]

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16.6.6.25 MAU-to-AUI mechanical connections

Item	Feature	Subclause	Value/Comment	Status	Support
AM1	D-type connector dimensions	7.6.2	IEC 60807-2:1992 15-pole male	AUI: M	N/A [ ] M: Yes [ ]
AM2	Shell plating material	7.6.2	Conductive	AUI: M	N/A [ ] M: Yes [ ]
AM3	Shell multiple contact points	7.6.2	Number not defined (recommended)	AUI: O	N/A [ ] O: Yes [ ] O: No [ ]
AM4	Shell life expectancy	7.6.2	≤ 5 mΩ after 500 matings	AUI: M	N/A [ ] M: Yes [ ]
AM5	Locking posts and mounting	7.6.1	Figures 7–18 and 7–20	AUI: M	N/A [ ] M: Yes [ ]
	Pin connections	7.6.3	Circuit		
AM6	3		Data Out A	AUI: M	N/A [ ] M: Yes [ ]
AM7	10		Data Out B	AUI: M	N/A [ ] M: Yes [ ]
AM8	11		Capacitor to VC	AUI: M	N/A [ ] M: Yes [ ]
AM9	5		Data In A	AUI: M	N/A [ ] M: Yes [ ]
AM10	12		Data In B	AUI: M	N/A [ ] M: Yes [ ]
AM11	4		Capacitor to VC	AUI: M	N/A [ ] M: Yes [ ]
AM12	7		No connection	AUI: M	N/A [ ] M: Yes [ ]
AM13	15		No connection	AUI: M	N/A [ ] M: Yes [ ]
AM14	8		Capacitor to VC	AUI: M	N/A [ ] M: Yes [ ]
AM15	2		Control In A	AUI: M	N/A [ ] M: Yes [ ]
AM16	9		Control In B	AUI: M	N/A [ ] M: Yes [ ]
AM17	1		Capacitor to VC	AUI: M	N/A [ ] M: Yes [ ]
AM18	6		Voltage common	AUI: M	N/A [ ] M: Yes [ ]
AM19	13		Voltage plus	AUI: M	N/A [ ] M: Yes [ ]
AM20	1		Capacitor to VC	AUI: M	N/A [ ] M: Yes [ ]
AM21	Shell		Isolated from all pins	AUI: M	N/A [ ] M: Yes [ ]

16.6.6.26 MAU reliability

Item	Feature	Subclause	Value/Comment	Status	Support
MR1	Mean Time Before Failure	15.4	> 10^7 hours without causing communications failure among other stations	M	Yes [ ]

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16.6.6.27 Power consumption

Item	Feature	Subclause	Value/Comment	Status	Support
PC1	Power surge limitation	15.5.3	$< 2 \times 10^{-3}$ A–s	APW: M	N/A [ ] M: Yes [ ]
PC2	Power surge duration	15.5.3	100 ms max	APW: M	N/A [ ] M: Yes [ ]
PC3	Steady-state current drawn	15.5.3	≤ 0.5 A	APW: M	N/A [ ] M: Yes [ ]
PC4 PC5	Power-up capability: Current-limited sources Voltage-limited sources	15.5.3 7.5.2.5	0.5 A limited. 11.28 to 15.75 V via any AUI cable	APW: M APW: M	N/A [ ] M: Yes [ ] N/A [ ] M: Yes [ ]
PC6	Labeling	15.5.3	As in 15.5.315.5.3	APW: M	N/A [ ] M: Yes [ ]
PC7	Power cycle behavior	15.5.3	No extraneous signals on MDI, DI, or CI	AUI: M	
PC8	Low VP behavior	7.5.2.5	No disruption of media	APW: M	N/A [ ] M: Yes [ ]
PC9	Power sourced on pin 13 of AUI	15.5.3	None if separate power source is implemented	SPW: X	N/A [ ] X: Yes [ ]
PC10	Optional power source isolation	15.5.3	If implemented, shall withstand one of 15.3.4 tests	SPW: M	N/A [ ] M: Yes [ ]

16.6.6.28 PLS–PMA requirements

Item	Feature	Subclause	Value/Comment	Status	Support
PMA1	Messages between PLS in DTE or Repeater and PMA	15.5.4	As in 7.2.1	M	Yes [ ]

16.6.6.29 *signal_quality_error* message (SQE)

Item	Feature	Subclause	Value/Comment	Status	Support
SQE1	Local MAU Transmitting and no Collision or Fault Detected	15.5.4.2.1	*MAU_available* sent on CI	M	Yes [ ]
SQE2	Whenever a Collision exists as described in 16.3.4	15.5.4.2.1	SQE sent	M	Yes [ ]
SQE3	SQE Test as described in 16.3.5	15.5.4.2.1	SQE sent	DTE: M RPT: X	N/A [ ] M: Yes [ ] N/A [ ] X: Yes [ ]
SQE4	Jabber Condition exists as described in 16.3.6	15.5.4.2.1	SQE sent	M	Yes [ ]
SQE5	Message sent in the absence of SQE	15.5.4.2.1	*MAU_available* message	M	Yes [ ]

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16.6.6.30 Environmental requirements

Item	Feature	Subclause	Value/Comment	Status	Support
E1	Ambient plane wave field in which MAU meets specification	15.6.2	2 V/m from 10 kHz to 30 MHz. 5 V/m from 30 MHz to 1 GHz	M	Yes [ ]
E2	Electromagnetic emissions and susceptibility	15.6.2	Comply with local and/or national requirements. If none exist, comply with CISPR 22: 1993.	M	Yes [ ]

16.6.6.31 MAU labeling

Item	Feature	Subclause	Value/Comment	Status	Support
LBL1	MAU Type	15.7	10BASE-FP	O	Yes [ ] No [ ]
LBL2	Data Rate	15.7	10 Mb/s	O	Yes [ ] No [ ]
LBL3	Power Level	15.7	Maximum current drain	O	Yes [ ] No [ ]
LBL4	Safety Warnings	15.7	Any applicable	O	Yes [ ] No [ ]
LBL5	Port Labeling	15.7	Input and output	O	Yes [ ] No [ ]
LBL6	Manufacturer ID and MAU ID	15.7	12-bit Manufacturer ID and 20-bit MAU ID in separate fields	O	Yes [ ] No [ ]

16.6.7 PICS proforma tables for 10BASE-FP stars

16.6.7.1 Star basic functions

Item	Feature	Subclause	Value/Comment	Status	Support
SB1	Optical power division	16.5.1.2	Divide optical power from an input among all outputs (as described in 16.5.2.2)	M	Yes [ ]
SB2	Configuration of 10BASE-FP Stars and MAUs	16.5.1.3	MAU OTD to star input port. MAU ORD to star output port.	M	Yes [ ]
SB3	MTBF without causing communications failure among attached stations	16.5.1.4	10^7 hours	M	Yes [ ]

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16.6.7.2 Star optical characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
SO1	Insertion loss	16.5.2.1	16 dB min 20 dB max	M	Yes [ ]
SO2	Single output port uniformity	16.5.2.2	2.5 dB max	M	Yes [ ]
SO3	Directivity	16.5.2.3	35 dB min	M	Yes [ ]
SO4	Connector socket	15.3.2	BFOC/2.5—see IEC 60874-10:1992	M	Yes [ ]
SO5	Optical connector loss	15.3.2.1	< 1.0 dB	O	Yes [ ] No [ ]
SO6	Optical connector return loss	15.3.2.2	> 25 dB	M	Yes [ ]

16.6.7.3 Star environmental requirements

Item	Feature	Subclause	Value/Comment	Status	Support
SE1	Ambient plane wave field in which star meets specification	15.6.2	2 V/m from 10 kHz to 30 MHz. 5 V/m from 30 MHz to 1 GHz	M	Yes [ ]
SE2	Electromagnetic emissions and susceptibility	15.6.2	Comply with local and/or national requirements. If none exist, comply with CISPR 22: 1993.	M	Yes [ ]

16.6.7.4 10BASE-FP star labeling

Item	Feature	Subclause	Value/Comment	Status	Support
SL1	Device type	15.7.1	10BASE-FP Star	O	Yes [ ] No [ ]
SL2	Port labeling	15.7.1	Input and output	O	Yes [ ] No [ ]

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17. Fiber optic medium attachment unit, type 10BASE-FB

NOTE—This MAU is not recommended for new installations. Since September 2011, maintenance changes are no longer being considered for this clause.

17.1 Scope

17.1.1 Overview

This clause, along with Clause 15, defines the functional, electrical, optical, and mechanical characteristics of an optimized fiber optic link for interconnecting repeaters. The relationship of this specification to the sublayers used within this standard is shown in Figure 15-1b). This fiber optic link may be used to interconnect repeaters in star topologies and consists of a new PMA specific to the repeater (including a fiber optic MDI specified in 15.2), and the fiber optic medium specified in 15.3. This clause defines a MAU that extends the link distances beyond MAUs specified in 9.9 and significantly increases the number of allowable repeaters in series. While this clause defines a MAU, the AUI shall exist only as a logical service interface.

17.1.1.1 Medium attachment unit

The 10BASE-FB MAU has the following general characteristics:

a) It enables coupling of the Physical Layer Signaling (PLS) messages to the baseband fiber optic link defined in Clause 15.
b) It supports message traffic at a data rate of 10 Mb/s.
c) It provides for operating over 0 to at least 2000 m of fiber optic cable specified in 15.3.
d) It transmits both data and idle signals synchronously with the bit clock and receives data without resynchronizing on each packet.
e) It connects a repeater to a fiber optic backbone link segment.
f) It provides point-to-point signaling of status via synchronous signaling as defined in 17.2.1.
g) It transmits synchronous signals as defined in 17.2.1.
h) It supports network configurations using the CSMA/CD access method defined in IEEE 802.3 with baseband signaling.
i) It supports a point-to-point interconnection between repeaters, and when used with repeaters having multiple ports, supports a star wiring topology.

17.1.1.2 Relationship to repeater

A close relationship exists between Clause 17 and Clause 9. Clause 17 specifies the PMA logical functions residing in the MAU that exist as an integrated MAU in the repeater. A logical interface using messages associated with the AUI is provided as the interface with the repeater. In addition, the Data Loopback function is provided to ensure proper operation of the Partition function defined in 9.6.6.

17.1.1.3 Remote diagnostic messages

The MAU implements remote status signaling during fault conditions. The MAU transmits status messages defined in 17.2.2 and detects the messages described in 17.2.3.

17.1.2 Relationship to AUI

There is no physical implementation of AUI associated with the MAU. Implementation of an AUI, while possible, is beyond the scope of the International Standard. Messages associated with the AUI, however, are used throughout this document as a means to interface with the repeater. Thus, the sole purpose of the use of

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the messages associated with the AUI is as a service interface. The PMA uses the variables In, Out, and Col and their associated messages to communicate with a port in the repeater.

17.2 PMA interface messages

The messages between a port in the repeater and the PMA in the MAU shall comply with the PMA interface messages in 17.2.1 and 15.5.4. The messages between the PMAs over the MDI are summarized below.

17.2.1 PMA-to-MDI interface signal encodings

The following signals are used by the interface messages between the PMA and the MDI:

Manchester-Encoded Data One, CD. A clocked bit symbol in which the first half is LO and the second half is HI.

Manchester-Encoded Data Zero, CD0. A clocked bit symbol in which the first half is HI and the second half is LO.

Manchester Code Violation One, MV1. A clocked bit symbol in which the symbol is HI for the bit duration.

Manchester Code Violation Zero, MV0. A clocked bit symbol in which the symbol is LO for the bit duration.

Synchronous Idle, SIDL. Control symbol series coded as the repeating sequence of MV1, MV1, MV0, MV0, starting with the first MV1, resulting in 2.5 MHz signal.

Remote Fault, RF. Control symbol series coded as the repeating sequence of MV1, MV1, MV1, MV0, MV0, MV0, starting with the first MV1, resulting in 1.667 MHz signal.

17.2.2 PMA-to-MDI OTD messages

The signals SIDL and RF shall be made up of sequences of the symbols MV1 and MV0 listed in the table and illustrated in Figure 17–1. All signals shall be transmitted synchronized to the local bit clock. SIDL and RF appear only between PMAs. The following messages can be sent by the MAU PMA to the MDI OTD (Optical Transmit Data) circuit:

Message	Circuit	Signal	Meaning
OTD_output	OTD	CD1, CD0	Output information
OTD_sync_idle	OTD	SIDL (MV1, MV1, MV0, MV0)	Synchronous idle
OTD_remote_fault	OTD	RF (MV1, MV1, MV1, MV0, MV0,MV0)	Jabber, Low Light, Invalid Data, or Lock Lost detected

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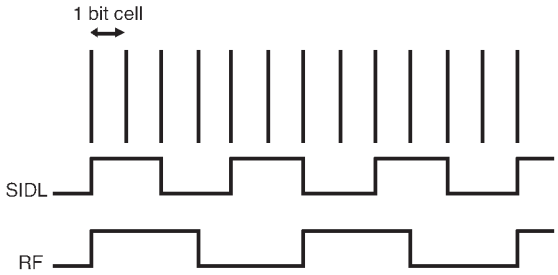

Figure 17–1—MDI status signaling messages

17.2.2.1 OTD_output

The PMA sublayer sends the *OTD_output* message to the OTD circuit when the repeater outputs a bit of data to the MDI's OTD circuit and the MDI's OTD circuit and the PMA is not sending the *OTD_remote_fault* message. The physical realization of the *OTD_output* message is a CD0 or CD1 signal sent by the PMA.

17.2.2.2 OTD_sync_idle

The PMA sublayer sends the *OTD_sync_idle* message to the OTD circuit when the repeater sends idle and the PMA is not sending *OTD_remote_fault* message. The physical realization of the *OTD_sync_idle* message is a repeating sequence of the SIDL signal sent by the PMA.

17.2.2.3 OTD_remote_fault

The PMA sublayer sends *OTD_remote_fault* message to the OTD circuit when receive jabber is detected, low light has been detected, invalid data has been detected, or continuous clock recovery condition per 17.3.8 is not met ("lock_lost" = true). The physical realization of the *OTD_remote_fault* message is a repeating sequence of the RF signal sent by the PMA. The *OTD_remote_fault* message may be sent when local faults other than the receive jabber, low light or invalid data are present on the ORD circuit. However, the partition condition of the repeater port shall not cause *OTD_remote_fault* to be sent.

17.2.3 MDI ORD-to-PMA messages

17.2.3.1 Status decoding

The following messages shall be received by the MAU PMA from the MDI ORD (Optical Receive Data) circuit.

17.2.3.2 ORD_input

When the PMA sublayer receives the *ORD_input* message on its ORD circuit, it detects a bit of data. The physical realization of the *ORD_input* message is the CD0 or CD1 signal.

17.2.3.3 ORD_sync_idle

When the PMA sublayer receives the *ORD_sync_idle* message on its ORD circuit, it detects idle. The physical realization of the *ORD_sync_idle* message is the SIDL signal.

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17.2.3.4 ORD_remote_fault

When the PMA sublayer receives the *ORD_remote_fault* message on its ORD circuit, it detects remote fault. The physical realization of the *ORD_remote_fault* message is the RF signal.

17.2.3.5 ORD_invalid_data

When the PMA sublayer receives signals other than CD0, CD1, SIDL, or RF while low light is not detected, or input signals that do not meet the requirements in 17.2.4 and 17.3.8, it detects invalid data. The physical realization of the *ORD_invalid_data* message is a signal not meeting the above allowed set.

Message	Circuit	Signal	Meaning
ORD_input	ORD	CD1, CD0	Input Information
ORD_sync_idle	ORD	SIDL (MV1, MV1, MV0, MV0)	Synchronous Idle
ORD_remote_fault	ORD	RF (MV1, MV1, MV1, MV0, MV0, MV0)	Jabber, Low Light, Invalid Data, or LockLost=true detected by the far-end MAU
ORD_invalid_data	ORD	Any signal other than CD0, CD1, SIDL or RF	Undefined or asynchronous signal

17.2.4 Transitions between signals

The SIDL to data (CD0 or CD1) transition shall occur at any bit cell boundary. SIDL shall begin with its first MV1 immediately following the last bit cell of a packet. When a fault is detected during data transmission, the RF signal shall be transmitted immediately following the next bit cell boundary, starting with the first MV1. When a signal that contains alternating MV0 and MV1, starting with a MV0, is detected during a data reception, it shall be interpreted as alternating CD0 and CD1 as long as the sequence persists. When a fault is detected during idle, the SIDL sequence shall be completed before sending RF. Other than defined above, any transition from one status signal to another status signal shall begin only after the previous signal has been sent in its entirety.

17.2.5 Signaling rate

The signaling rate shall conform to 7.3.2.

17.3 MAU functional specifications

The MAU provides the means by which repeaters can be connected for backbone applications by the use of synchronous signaling. In addition, the MAU provides the means by which status on one end of the link may be signaled to the other end to provide media diagnostics.

17.3.1 Transmit function requirements

The Transmit function shall transmit the output message received from the repeater unit onto the MDI. The Transmit function has three purposes:

a) To convert the electrical signals to optical signals.
b) To generate the SIDL signal when receiving the *output_idle* message from the repeater.
c) To generate the RF signal.

The levels and timing of the optical signal shall be as specified in 15.2.1, and any transition from one signal to another shall meet the requirements in 17.2.4.

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17.3.1.1 Data transmit

The Transmit function shall receive the output messages from the repeater unit and send them onto the MDI OTD circuit. When a packet is received at this interface, no bit of information shall be received from the repeater and not transmitted to the MDI. In addition, only the bits of information received from the repeater shall be transmitted to the MDI. The start-up and steady-state delay between output message and transmission on the MDI shall each be no more than 2 BT. If a fault is detected during data transmission, data transmission shall cease and the RF signal shall be transmitted as specified in 17.2.4 and 17.3.1.3.

17.3.1.2 Synchronous idle

Whenever the repeater unit sends the *idle* message, SIDL signal shall be sent on the OTD circuit of the MDI, when the PMA is not sending the *OTD_remote_fault* message.

17.3.1.3 Fault signaling

Upon detecting receive jabber as specified in 17.3.6, or low light as specified in 17.3.7, or unqualified input signal as specified in 17.3.8, the Transmit function shall output RF signal on the OTD circuit of the MDI.

17.3.2 Receive function requirements

The Receive function shall receive optical signals from the ORD circuit of the MDI and send *input* or *idle* messages to the repeater unit. The Receive function has two purposes:

a) To convert optical signals to electrical signals.
b) To detect and interpret CD0, CD1, SIDL, and RF.

The optical to electrical conversion shall be as specified in 15.2.2.3.

17.3.2.1 Data receive

The Receive function shall receive the CD0 or CD1 signals from the ORD circuit of the MDI and send *input* messages to the repeater unit. When a packet is received, all bits of information shall be received from the ORD circuit and sent to the repeater unit. In addition, only the bits of information received from the ORD circuit shall be sent to the repeater unit. Any transition of one signal to another not meeting the requirements in 17.2.4 shall be detected as *ORD_invalid_data* message. When *ORD_invalid _data* message is received, data transmission shall be prevented. The start-up and steady-state delay between reception on MDI to *input* message shall be no more than 2 BT.

17.3.2.2 Remote status message handling

The Receive function shall recognize the signals SIDL or RF at the MDI and send the *input_idle* message to the repeater unit. The reception of the RF signal at the MDI shall prevent data transmissions.

17.3.3 Collision function requirements

17.3.3.1 Collision detection

The MAU shall detect as a collision the simultaneous occurrence of *ORD_input* message on the ORD circuit and the *output* message from the repeater. When a collision has occurred, the *signal_quality_error* message shall be sent to the repeater within 3.5 BT.

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17.3.3.2 End of collision

The MAU shall detect as the end of collision either the *output_idle* message or messages other than *ORD_input* received from the ORD circuit. When the end of a collision occurs, the *mau_available* message shall be sent to the repeater within 5 BT and the *input_idle* message shall be sent to the repeater within 5 BT.

17.3.4 Loopback function requirements

The Loopback function is defined to provide the same service interface as other MAUs between the PMD and the repeater. Since this MAU does not have a physical AUI, this function is logically present but not necessarily physically implemented.

When the MAU is transmitting on the OTD circuit and is not receiving *ORD_input* messages on the ORD circuit, the MAU shall transmit either *output* messages as *input* messages or *output_idle* messages as *input_idle* messages. The steady-state propagation delay of this message transfer shall not exceed 2 BT.

17.3.5 Fault-handling function requirements

There are two types of faults that shall be detected: local and remote. The local faults are detection of low light, receive jabber, and invalid data conditions. The remote status signals consist of receptions of normal idle (indicated by the signal SIDL), and remote faults (indicated by the signal RF). Table 17–1 defines the signals that shall be sent onto the media at the port's MDI during fault conditions.

Table 17–1—MDI fault conditions and their states

Fault types	Signal at OTD MDI
Low Light detected	RF
Receive Jabber detected	RF
Invalid Data detected	RF
Receive RF	SIDL

During reception of RF, SIDL shall be transmitted at the MDI, unless there is a local fault.

17.3.6 Jabber function requirements

A MAU shall contain a self-interrupt capability, as described in Figure 17–3, to prevent an illegally long reception of data from reaching the Data-Handling function of the repeater. The MAU shall provide a window "rcv_max" during which the *input* messages may be sent to the repeater unit. The value of "rcv_max" shall be between 8 ms and 12 ms. If a reception exceeds this duration, the jabber condition shall be detected.

Upon detection of the jabber condition, the MAU shall perform the following:

a) Inhibit sending further *input* messages to the repeater unit,
b) Disable the *OTD_sync_idle* message (17.2.2.2) to the MDI, and
c) Send the *OTD_remote_fault* message (17.2.2.3) to the MDI.

The MAU shall reset the Jabber function and reassert *OTD_sync_idle* message when one of the following conditions is met:

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— On power-up reset, or
— After a continuous time “rcv_unjab” of not detecting jabber on the ORD circuit of the MAU (see Figure 17–3).

The value of “rcv_unjab” shall be 0.5 s ± 0.25 s.

17.3.7 Low light level detection function requirements

The MAU shall have the capability to interrupt a port’s reception at the MDI ORD circuit when reliable reception can no longer be assured at that port based on the incoming optical power level.

The MAU shall have a low light level detection capability as defined in Figure 17–2. It shall interrupt reception of any signals from the ORD circuit of the MDI when reliable detection can no longer be assured. This error condition shall not be detected if the average receive optical power level at the MDI exceeds –32.5 dBm in the frequency band between 0.5 MHz to 25 MHz. It shall also not be detected if the low light condition remains for less than 30 BT. It shall be detected before the average receive optical power level at the MDI has fallen to a level that is lower than the average receive optical power level that corresponds to a BER of one part in 10^{10} for the MAU for a duration of 2000 BT. The low light level detected condition shall cease to exist when the received optical power level exceeds the power level required to maintain a BER of one part in 10^{10} and the requirements in 17.3.8 are met.

On detection of the low light level detection condition at its MDI, the MAU shall perform the following:

a) Inhibit sending further input messages to the repeater unit,
b) Inhibit the Data Transmit function,
c) Disable the *OTD_sync_idle* message (17.2.2.2) to the MDI, and
d) Send the *OTD_remote_fault* message (17.2.2.3) to the MDI.

Once the low light condition continuously ceases to exist at the port for a time “low_light_heal” of 0.5 s ± 0.25 s, the MAU shall reset the Low Light function.

17.3.8 Synchronous qualification function requirements

The MAU shall have the capability in Figure 17–2 to interrupt reception at the MDI when reliable reception can no longer be assured based on the loss of clock recovery. The synchronous signaling condition shall be detected at a port if SIDL or RF is detected for the entire duration of the time “validation” of successful and continuous clock recovery. The value of time “validation” shall be between 64 BT and 128 BT. The clock recovery shall tolerate the jitter specified in 15.2.2.2 at the MDI and recover clocks with proper frequency and tolerances. The variable “lock_lost” shall not take the value “true” when the input meets the requirements of 15.2.2. The variable “lock_lost” shall take the value true within 20 µs after the input frequency on the ORD circuit is less than or equal to 1.55 MHz or greater than or equal to 15.5 MHz.

On qualifying the synchronous signaling condition for signals received on the ORD circuit of the MAU, Data Transmit and Data Receive for that port shall be enabled. On loss of synchronous signaling qualification for the MAU, Data Transmit and Data Receive for that port shall be disabled, and the PMA sublayer shall send *OTD_remote_fault* on the MDI.

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17.3.9 Interface message time references

Delay and bit loss specification are measured from the occurrence of messages at the MDIs. The following describes the point where each message starts:

Message	Reference
OTD_output	leading bit cell boundary of first CD1 or CD0
OTD_sync_idle	last positive-going transition prior to start of SIDL
OTD_remote_fault	last positive-going transition prior to start of RF
ORD_input	leading bit cell boundary of first CD1 or CD0
ORD_sync_idle	last positive-going transition prior to start of SIDL
ORD_remote_fault	last positive-going transition prior to start of RF

17.3.10 MAU state diagrams

The state diagrams of Figure 17–2, Figure 17–3, and Figure 17–4[41] depict the full set of allowed MAU state functions relative to the circuits of the MDI and AUI Service Interface. The notation used in the state diagrams follows the conventions in 1.2.1. The variables, counters, and timers used in the state diagrams are defined in the following subclauses.

17.3.10.1 MAU state diagram variables

Variables are used in the state diagrams to indicate the status of the MAU's inputs and outputs, to control its operation, and to pass state information between functions.

In the variable definitions, the name of the variables is followed by a brief description of the variable and a list of values the variable may take. For those variables that are state diagram outputs, one value will be identified as the default. The variable has the default value when no active state contains a term assigning a different value.

The variables used in the state diagrams are as follows:

begin

The interprocess flag controlling state diagram initialization values.
Values: false (default).
true.

OTD

Controls the signal sent by the MAU's PMA to the OTD circuit.
Values: idle; the MAU sends *OTD_sync_idle*, SIDL (default).
output; the MAU sends *OTD_output*; CD0 or CD1, based on the *output* message from the repeater unit.
remote_fault; the MAU sends *OTD_remote_fault*, RF.

ORD

Status of the signal sent by the MAU's ORD circuit to the PMA.
Values: idle; the MAU receives *ORD_sync_idle*, SIDL.
input; the MAU receives *ORD_input*; CD0, CD1, or MV0,MV1 signal sequence meeting 17.2.4.
remote_fault; the MAU receives *ORD_remote_fault*, RF.

[41]The MAU state diagrams, Figures 17–2 through 17–4, follow 17.3.10.2.

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invalid_data; the MAU receives *ORD_invalid_data*, all signals not meeting 17.2.4. and 17.3.8.

OUT

Status of the messages sent by the repeater to the PMA.
Values: idle; receives *output_idle* message from the repeater unit.
output; receives *output* message from the repeater unit.

IN

Controls the signal sent by the MAUs PMA to the repeater.
Values: idle; the MAU sends the *input_idle* message to the repeater (default).
input; the MAU sends the *input* message to the repeater.
OUT; the MAU sends messages from the repeater back to the repeater.

COL

Controls the signal sent by the MAUs PMA to the repeater.
Values: mau_available; the MAU sends the *mau_available* message to the repeater (default).
signal_quality_error; The MAU sends the *signal_quality_error* message to the repeater.

low_light_detected

Controls the paths of the signals received from the ORD circuit.
Values: true; low light condition is being detected.
false; low light condition is not being detected (default).

rcv_jab_detected

Also controls the path of the signals received from the ORD circuit.
Values: false; receive jabber condition is not being detected (default).
true; receive jabber condition is being detected.

low_light_level

Status of the optical signal level received on the ORD circuit.
Values: true; insufficient light is being received for reliable reception (see 17.3.7).
false; sufficient light is being received for reliable reception.

lock_lost

Status of the Synchronous Qualification function of the ORD circuit.
Values: true; clock has not been recovered.
false; clock has been recovered.

link_valid

Interprocess flag indicating that the link is valid.
Values: false; link is determined to be invalid (default).
true; link is determined to be valid.

17.3.10.2 MAU state diagram timers

All timers operate in the same fashion. A timer is reset and starts counting upon entering a state where “start x_timer” is asserted. When the timer has expired, x_timer_done is asserted and remains asserted until the timer is reset. At all other times, x_timer_not_done is asserted. The timer is reset and restarted even if the entered state is the same as the exited state.

The timers used in the MAU state diagrams are defined as follows:

validation_timer. Timer for synchronous link detection (17.3.8).

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rcv_max_timer. Timer for excessively long reception (17.3.6).

rcv_unjab_timer. Timer for the length of time the ORD circuit must have no excessively long activity to exit the jabber state (17.3.6).

low_light_heal_timer. Timer for low light condition cessation (17.3.7).

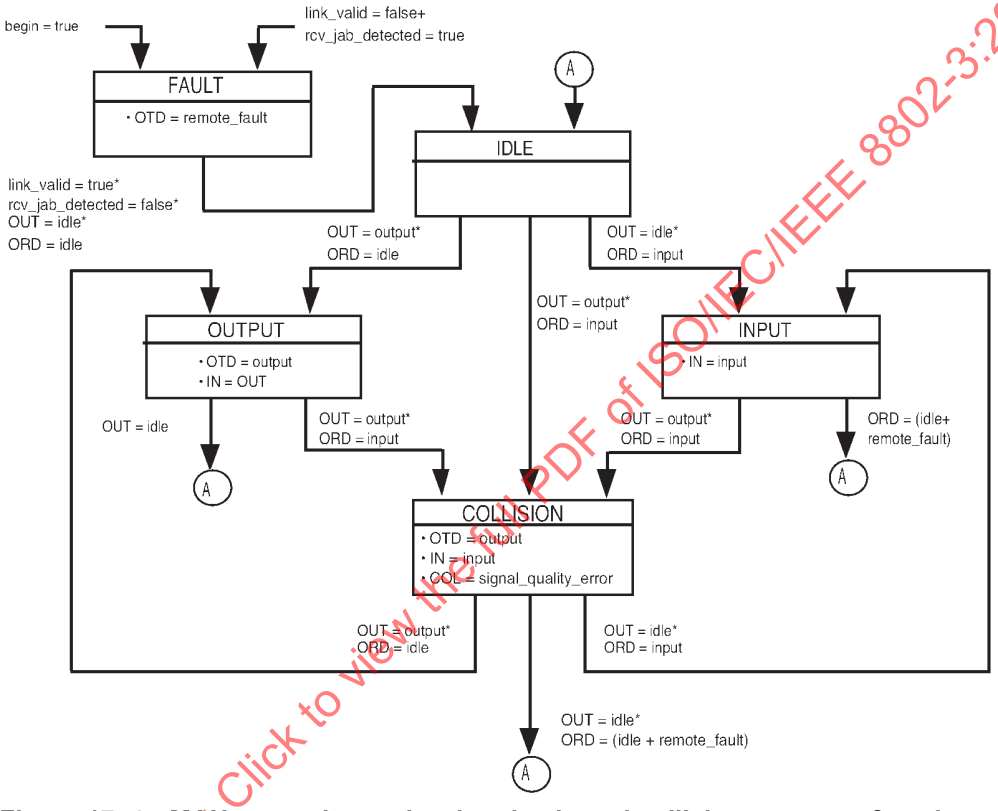

Figure 17–4—MAU transmit, receive, loopback, and collision presence functions state diagram

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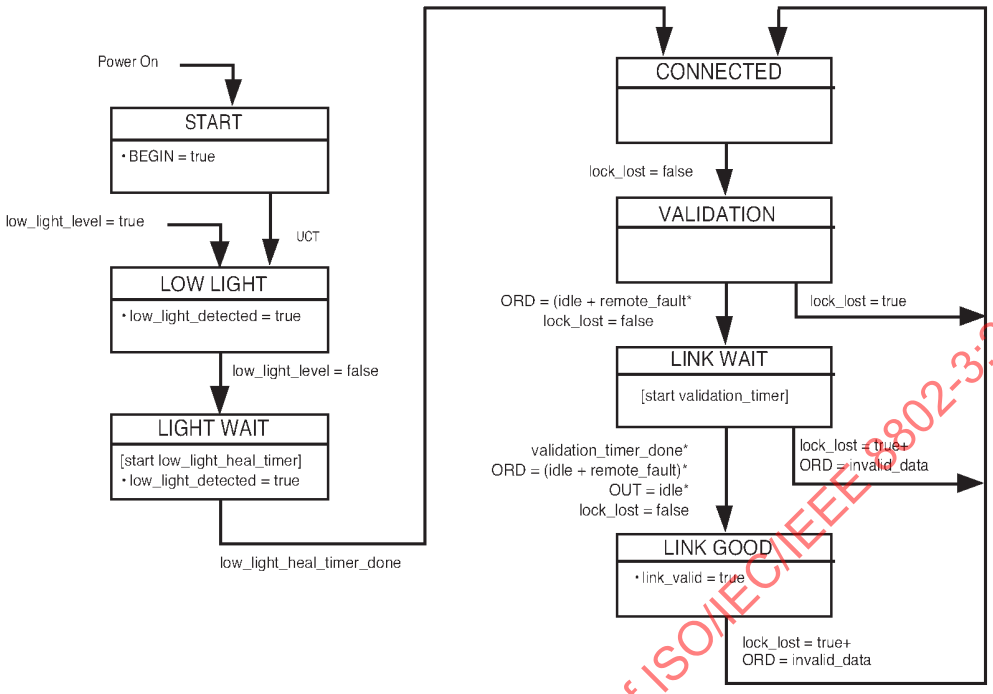

Figure 17–2—Synchronous qualification state diagram

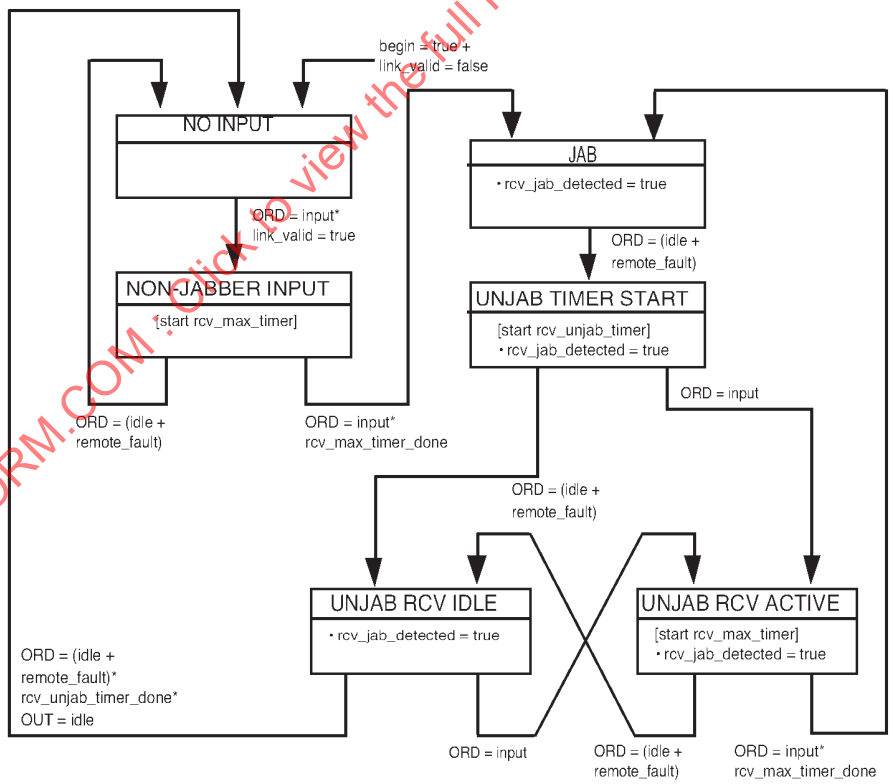

Figure 17–3—Receive jabber state diagram

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17.4 Timing summary

Table 17–2 summarizes the timing requirements for the 10BASE-FB fiber link. This table is a summary; for complete descriptions of the timing requirements, refer to the referenced subclauses. All times are in bit times.

Table 17–2—Maximum timing parameters

Symbol	Function	Bit loss	Invalid bits	Steady-state prop. delay	Start-up delay		Specified in
					Max	Var.	
M1	*ORD_input* to *input* to PMA	0.0	0.0	2.0	2.0	2.0	17.3.2.1
M2	*output* on PMA to *OTD_output*	0.0	0.0	2.0	2.0	2.0	17.3.1.1
M3	ORD_*input* * *output* to *signal_quality_error*				3.5		17.3.3.1
M4	*ORD_sync_idle* + *output_idle* (end of collision) to *mau_available*				5.0		17.3.3.2
M5	*ORD_input* * *output* to *input* to PMA from circuit ORD				5.0		17.3.3.2
M6	*ORD_sync_idle* **output* to *input* to PMA from PMA output circuit				5.0		17.3.3.2
M9	*output* on PMA to *input* to PMA	0.0	0.0	2.0			17.3.4
F1	Fiber Optic Cable Propagation (2000 m)	0	0	100	100		15.3.1.3

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17.5 Protocol implementation conformance statement (PICS) proforma for Clause 17, Fiber optic medium attachment unit, type 10BASE-FB[42]

17.5.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 17, Fiber optic medium attachment unit, type 10BASE-FB, shall complete the following protocol implementation conformance statement (PICS) proforma.

A completed PICS proforma is the PICS for the implementation in question. The PICS is a statement of which capabilities and options of the protocol have been implemented. The PICS can be used for a variety of purposes by various parties, including the following:

— As a checklist by the protocol implementer, to reduce the risk of failure to conform to the International Standard through oversight;
— As a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard PICS proforma, by the supplier and acquirer, or potential acquirer, of the implementation;
— As a basis for initially checking the possibility of interworking with another implementation by the user, or potential user, of the implementation (note that, while interworking can never be guaranteed, failure to interwork can often be predicted from incompatible PICs);
— As the basis for selecting appropriate tests against which to assess the claim for conformance of the implementation, by a protocol tester.

17.5.2 Abbreviations and special symbols

17.5.2.1 Status symbols

The following symbols are used in the PICS proforma:

M mandatory field/function
O optional field/function
O.<n>optional field/function, but at least one of the group of options labeled by the same numeral <n> is required
O/<n>optional field/function, but one and only one of the group of options labeled by the same numeral <n> is required
X prohibited field/function
<item>:simple-predicate condition, dependent on the support marked for <item>

17.5.2.1.1 Abbreviations

N/A not applicable

17.5.3 Instructions for completing the PICS proforma

17.5.3.1 General structure of the PICS proforma

The first part of the PICS proforma, Implementation Identification and Protocol Summary, is to be completed as indicated with the information necessary to identify fully both the supplier and the implementation.

[42] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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The main part of the PICS proforma is a fixed-format questionnaire divided into subclauses, each containing a group of items. Answers to the questionnaire items are to be provided in the right-most column, either by simply marking an answer to indicate a restricted choice (usually Yes, No, or Not Applicable), or by entering a value or a set or range of values. (Note that there are some items where two or more choices from a set of possible answers can apply; all relevant choices are to be marked.)

Each item is identified by an item reference in the first column; the second column contains the question to be answered; the third column contains the reference or references to the material that specifies the item in the main body of the International Standard; the fourth column contains values and/or comments pertaining to the question to be answered. The remaining columns record the status of the item—whether the support is mandatory, optional, or conditional—and provide the space for the answers; see also 17.5.3.4 below.

The supplier may also provide, or be required to provide, further information, categorized as either Additional Information or Exception Information. When present, each kind of further information is to be provided in a further subclause of items labeled A<i> or X<i>, respectively, for cross-referencing purposes, where <i> is any unambiguous identification for the item (e.g., simply a numeral); there are no other restrictions on its format or presentation.

A completed PICS proforma, including any Additional Information and Exception Information, is the protocol implementation conformance statement for the implementation in question.

Note that where an implementation is capable of being configured in more than one way, according to the items listed under 17.5.5, Major Capabilities/Options, a single PICS may be able to describe all such configurations. However, the supplier has the choice of providing more than one PICS, each covering some subset of the implementation's configuration capabilities, if that would make presentation of the information easier and clearer.

17.5.3.2 Additional information

Items of Additional Information allow a supplier to provide further information intended to assist the interpretation of the PICS. It is not intended or expected that a large quantity will be supplied, and the PICS can be considered complete without any such information. Examples might be an outline of the ways in which a (single) implementation can be set up to operate in a variety of environments and configurations; or a brief rationale, based perhaps upon specific application needs, for the exclusion of features which, although optional, are nonetheless commonly present in implementations of the 10BASE-FB protocol.

References to items of Additional Information may be entered next to any answer in the questionnaire, and may be included in items of Exception Information.

17.5.3.3 Exception information

It may occasionally happen that a supplier will wish to answer an item with mandatory or prohibited status (after any conditions have been applied) in a way that conflicts with the indicated requirement. No preprinted answer will be found in the Support column for this; instead, the supplier is required to write into the Support column an X<i> reference to an item of Exception Information, and to provide the appropriate rationale in the Exception item itself.

An implementation for which an Exception item is required in this way does not conform to this International Standard.

Note that a possible reason for the situation described above is that a defect in the International Standard has been reported, a correction for which is expected to change the requirement not met by the implementation.

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17.5.3.4 Conditional items

The PICS proforma contains a number of conditional items. These are items for which both the applicability of the item itself, and its status if it does apply—mandatory, optional, or prohibited—are dependent upon whether or not certain other items are supported.

Individual conditional items are indicated by a conditional symbol of the form "<item>:<s>" in the Status column, where "<item>" is an item reference that appears in the first column of the table for some other item, and "<s>" is a status symbol, M, O, or X.

If the item referred to by the conditional symbol is marked as supported, the conditional item is applicable, and its status is given by "<s>"; the support column is to be completed in the usual way. Otherwise, the conditional item is not relevant and the Not Applicable (N/A) answer is to be marked.

Each item whose reference is used in a conditional symbol is indicated by an asterisk in the Item column.

17.5.4 Identification

17.5.4.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

17.5.4.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 17, Fiber optic medium attachment unit, type 10BASE-FB
Identification of amendments and corrigenda to this PICS proforma which have been completed as part of this PICS	
Have any Exception items been required? No [ ]Yes [ ] (See 17.5.3.3; The answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	

Date of Statement	

17.5.5 PICS proforma for the type 10BASE-FB MAU

None.

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17.5.6 PICS proforma for the type 10BASE-FB MAU

17.5.6.1 Compatibility considerations

Item	Feature	Subclause	Value/Comment	Status	Support
CC1	Compatibility Considerations: 10BASE-FB Systems compatible at 10BASE-FB MDI	15.1.3.2		M	Yes [ ]
CC2	Mode of operation	15.1.3.5	normal mode only	M	Yes [ ]

17.5.6.2 Optical transmit parameters

Item	Feature	Subclause	Value/Comment	Status	Support
OT1	Center wavelength	15.2.1.1	min. 800 nm max. 910 nm	M	Yes [ ]
OT2	Spectral width (FWHM)	15.2.1.2	< 75 nm	M	Yes [ ]
OT3	Optical modulation extinction ratio	15.2.1.3	< –13 dB	M	Yes [ ]
OT4	Optical idle signal amplitude	15.2.1.4	See 15.2.1.10	M	Yes [ ]
OT5	Optical transmit pulse logic polarity	15.2.1.5	High Optical Power=LO on AUI DO and MDI. Low Optical Power =HI on AUI DO and MDI	M	Yes [ ]
	Optical transmit pulse rise and fall times	15.2.1.6	Measured from 10% to 90% level		
OT6	Max. (Data)		10.0 ns	M	Yes [ ]
OT7	Min. (Data)		0.0 ns	M	Yes [ ]
OT8	Max. difference (Data)		3.0 ns	M	Yes [ ]
OT9	Max. (Idle)		10.0 ns	M	Yes [ ]
OT10	Min. (Idle)		0.0 ns	M	Yes [ ]
OT11	Max. difference (Idle)		3.0 ns	M	Yes [ ]
OT12	Optical Transmit Pulse Overshoot	15.2.1.7	< 25%	M	Yes [ ]
OT13	Optical Transmit Pulse Undershoot	15.2.1.7	< 10%	M	Yes [ ]
	Optical Transmit Pulse Edge Jitter	15.2.1.8	Measured as in 15.2.1.8		
OT14	Added		± 2.0 ns	M	Yes [ ]
OT15	Total at MDI (Data)		± 4.0 ns	M	Yes [ ]
	Total at MDI (Idle)				
	Optical Transmit Pulse Duty Cycle Distortion	15.2.1.9	Measured at median power level		
OT16	Max. (Data)		± 2.5 ns	M	Yes [ ]
OT17	Max. (Idle)		± 2.5 ns	M	Yes [ ]
	Optical Transmit Average Power Range	15.2.1.10			
OT18	Min.		–20 dBm	M	Yes [ ]
OT19	Max.		–12 dBm	M	Yes [ ]
OT20	Transmit Signal Templates	Figure 15–4	Optical signals within template	M	Yes [ ]

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17.5.6.3 Optical receive parameters

Item	Feature	Subclause	Value/Comment	Status	Support
OR1	BER between two AUIs attached to a single segment	15.2.2	< one part in 10^9 (measurement made by inference)	M	Yes [ ]
	Optical Receive Average Power	15.2.2.1	When a single transmitter transmits on the medium		
OR2	Min.		–32.5 dBm	M	Yes [ ]
OR3	Max.		–12.0 dBm	M	Yes [ ]
	MAU optical receive Edge Jitter (Data)	15.2.2.2	Measured as in 15.2.2.2		
OR4	Received at MDI		± 2.0 ns at median	M	Yes [ ]
OR5	Total at DI circuit (MAU end of AUI)		± 6.5 ns at zero crossing points	M	Yes [ ]
OR6	Optical Receive Pulse Logic Polarity	15.2.2.3	High Optical Power = LO on AUI DI and MDI. Low Optical Power = HI on AUI DI and MDI.	M	Yes [ ]
	Optical Receive Pulse Rise and Fall Times	15.2.2.4	Measured from 10% to 90% level		
OR7	Max. (Data)		31.5 ns	M	Yes [ ]
OR8	Min. (Data)		0.0 ns	M	Yes [ ]
OR9	Max. difference (Data)		3.0 ns	M	Yes [ ]
OR10	Max. (Idle)		31.5 ns	M	Yes [ ]
OR11	Min. (Idle)		2.0 ns	M	Yes [ ]
OR12	Max. difference (Idle)		3.0 ns	M	Yes [ ]

17.5.6.4 Optical medium connector plug and socket

Item	Feature	Subclause	Value/Comment	Status	Support
CS1	Connector socket	15.3.2	BFOC/2.5—see IEC 60874-10:1992	M	Yes [ ]

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17.5.6.5 MAU functions

Item	Feature	Subclause	Value/Comment	Status	Support
MF1	Transmit data	17.3.1.1		M	Yes [ ]
MF2	Transmit SIDL	17.3.1.2		M	Yes [ ]
MF3	Transmit RF	17.3.1.3		M	Yes [ ]
MF4	Data Loopback	17.3.4		M	Yes [ ]
MF5	Receive data	17.3.2.1		M	Yes [ ]
MF6	Receive SIDL	17.3.2.2		M	Yes [ ]
MF7	Receive RF	17.3.2.2		M	Yes [ ]
MF8	Collision Presence	17.3.3		M	Yes [ ]
MF9	Fault Handling	17.3.5		M	Yes [ ]
MF10	Jabber	17.3.6		M	Yes [ ]
MF11	Low light level detect	17.3.7		M	Yes [ ]

17.5.6.6 PMA-to-MDI OTD messages and signaling

Item	Feature	Subclause	Value/Comment	Status	Support
OTD1	Repeater port to MAU PMA messages	17.2	As in 7.2.1 and 15.5.4	M	Yes [ ]
OTD2	Signal sent on OTD corresponding to *OTD_output* message	17.2.2	CD1,CD0	M	Yes [ ]
OTD3	Signal sent on OTD corresponding to *OTD_sync_idle* message	17.2.2	SIDL (i.e., MV1, MV1,MV0,MV0)	M	Yes [ ]
OTD4	Signal sent on OTD corresponding to *OTD_remote_fault* message	17.2.2	RF (i.e., MV1,MV1, MV1,MV0,MV0,MV0)	M	Yes [ ]
OTD5	Signal sent on OTD when repeater port is partitioned	17.2.2.3	SIDL (i.e., MV1 MV1,MV0,MV0)	M	Yes [ ]
OTD6	Synchronization of transmitted signals	17.2.2	To local bit clock	M	Yes [ ]
OTD7	AUI	17.1.1	Logical service interface only	M	Yes [ ]

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17.5.6.7 MDI ORD-to-PMA messages and signaling

Item	Feature	Subclause	Value/Comment	Status	Support
ORD1	Signal received on ORD corresponding to *ORD_input* message	17.2.3.2	CD1, CD0	M	Yes [ ]
ORD2	Signal received on ORD corresponding to *ORD_sync_idle* message	17.2.3.3	SIDL (i.e., MV1,MV1, MV0,MV0)	M	Yes [ ]
ORD3	Signal received on ORD corresponding to *ORD_remote_fault* message	17.2.3.4	RF (i.e., MV1,MV1, MV1, MV0,MV0,MV0)	M	Yes [ ]
ORD4	Signal received on ORD corresponding to *ORD_invalid_data* message	17.2.3.5	Not CD0, CD1, SIDL, or RF	M	Yes [ ]

17.5.6.8 Transitions between signals

Item	Feature	Subclause	Value/Comment	Status	Support
TBS1	SIDL to data transition	17.2.4	Only at any bit cell boundary	M	Yes [ ]
TBS2	Start of SIDL	17.2.4	End of last bit cell of packet. Start with first MV1 of signal.	M	Yes [ ]
TBS3	Start of RF	17.2.4	Next bit cell boundary following fault detection. Start with first MV1 of signal.	M	Yes [ ]
TBS4	Transition between status signals	17.2.4	Only after signal sequence has been completed	M	Yes [ ]
TBS5	Interpretation of signal containing alternating MV0 and MV1, starting with MV0	17.2.4	CD0, CD1	M	Yes [ ]

17.5.6.9 Signaling rate

Item	Feature	Subclause	Value/Comment	Status	Support
SR1	Signaling rate	17.2.5	As in 7.3.2	M	Yes [ ]

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17.5.6.10 Transmit functions

Item	Feature	Subclause	Value/Comment	Status	Support
XT1	Data Transmit Path for *output* message	17.3.1	Repeater unit to MDI OTD circuit	M	Yes [ ]
XT2	Levels and timing of optical signal	17.3.1	15.2.1	M	Yes [ ]
XT3	Transition from one signal to another	17.3.1	17.2.4	M	Yes [ ]
XT4	Data Transmit	17.3.1.1	Receives *output* message and sends it on the MDI OTD circuit	M	Yes [ ]
XT5	Information received from repeater and passed to MDI OTD	17.3.1.1	All	M	Yes [ ]
XT6	Information passed to MDI OTD that was not received from repeater	17.3.1.1	None	M	Yes [ ]
XT7	Conditions for SIDL transmission on OTD circuit of the MDI	17.3.1.2	Whenever repeater sends *idle* message and the PMA is not sending the *OTD_remote_fault* message	M	Yes [ ]
XT8	Conditions for RF transmission on OTD circuit of the MDI	17.3.1.3	Whenever *receive_jabber*, *low_light*, or unqualified input signal is detected at port's receive MDI	M	Yes [ ]
XT9	Maximum start-up and steady-state delay circuit of the MDI	17.3.1.1	2 BT between *output* message and transmission on MDI	M	Yes [ ]

17.5.6.11 Receive functions

Item	Feature	Subclause	Value/Comment	Status	Support
RCV1	Data Receive Path for *input* or *idle* message	17.3.2	MDI ORD circuit to repeater unit	M	Yes [ ]
RCV2	Optical to Electrical conversion	17.3.2	15.2.2.3	M	Yes [ ]

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17.5.6.12 Data receive function

Item	Feature	Subclause	Value/Comment	Status	Support
DR1	Bits of information received from ORD MDI and not passed to repeater	17.3.2.1	None	M	Yes [ ]
DR2	Bits of information passed to repeater other than those received from ORD MDI	17.3.2.1	None	M	Yes [ ]
DR3	Signals detected as *ORD_invalid_data*	17.3.2.1	Signals with transitions not meeting 17.2.4 requirements	M	Yes [ ]
DR4	Action when CD0 or CD1 is received on ORD MDI	17.3.2.1	Send *input* message to repeater	M	Yes [ ]
DR5	Maximum start-up and steady-state delay	17.3.2.1	2 BT from reception on MDI to *input* message	M	Yes [ ]
DR6	Action when *ORD_invalid_data* message is received	17.3.2.1	Prevent data transmission	M	Yes [ ]

17.5.6.13 Remote status message handling

Item	Feature	Subclause	Value/Comment	Status	Support
RSM1	Action when SIDL or RF is received on ORD MDI	17.3.2.2	Send *input_idle* message to repeater	M	Yes [ ]
RSM2	Action when RF is received on ORD MDI	17.3.2.2	Prevent data transmission	M	Yes [ ]
RSM3	Action when *ORD_remote_fault* or *ORD_invalid_data* is received	17.3.2.2	Prevent *output* message from the repeater	M	Yes [ ]

17.5.6.14 Collision function requirements

Item	Feature	Subclause	Value/Comment	Status	Support
CF1	Collision Detected	17.3.3.1	Simultaneous occurrence of *output* and *ORD_input*.	M	Yes [ ]
CF2	Action when collision detected	17.3.3.1	Send *signal_quality_error* to repeater within 3.5 BT	M	Yes [ ]

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17.5.6.15 End of collision

Item	Feature	Subclause	Value/Comment	Status	Support
EOC1	End of collision determination	17.3.3.2	*OTD_sync_idle* or messages other than *ORD_input* received from ORD circuit	M	Yes [ ]
EOC2	Action when end of collision is detected	17.3.3.2	Send *mau_available* message and idle message to repeater within 5 BT	M	Yes [ ]

17.5.6.16 Loopback function

Item	Feature	Subclause	Value/Comment	Status	Support
LP1	MAU transmitting on OTD and not receiving *ORD_input* message on the ORD circuit	17.3.4	Transmit *output* messages as *input* messages or transmit *output_idle* messages as *input_idle* messages	M	Yes [ ]
LP2	Steady-state propagation delay	17.3.4	≤ 2 BT	M	Yes [ ]

17.5.6.17 Fault-handling function

Item	Feature	Subclause	Value/Comment	Status	Support
FH1	Types of faults detected	17.3.5	Local and remote	M	Yes [ ]
FH2	Signal at OTD MDI for different fault conditions	17.3.5	See 17.3.5	M	Yes [ ]
FH3	Action during reception of remote fault signals	17.3.5	Transmit SIDL unless local fault detected	M	Yes [ ]

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17.5.6.18 Jabber-handling function

Item	Feature	Subclause	Value/Comment	Status	Support
JAB1	Sending of *input* message to repeater during jabber	17.3.6	Inhibit	M	Yes [ ]
JAB2	Transmission of *OTD_sync_idle* during jabber	17.3.6	Disabled	M	Yes [ ]
JAB3	rcv_max_timer	17.3.6	8 ms min., 12 ms max.	M	Yes [ ]
JAB4	Message sent to repeater during jabber	17.3.6	signal_quality error	M	Yes [ ]
JAB5	Receive unjabber timer duration	17.3.6	0.5 s ± 0.25 s	M	Yes [ ]
JAB6	Detection of jabber	17.3.6	Reception ≥ rcv_max_timer	M	Yes [ ]
JAB7	MAU self-interrupt	17.3.6	As in Figure 17–3	M	Yes [ ]
JAB8	Message sent to OTD MDI during jabber	17.3.6	OTD_remote_fault	M	Yes [ ]
JAB9	Message sent to OTD MDI on power reset or after rcv_unjab_timer	17.3.6	OTD_sync_idle	M	Yes [ ]

17.5.6.19 Low light detection

Item	Feature	Subclause	Value/Comment	Status	Support
LLD1	Low light detection	17.3.7	Interrupt reception of signals from ORD MDI when receive optical power does not support BER of 1 part in 10^{10} for between 30 BT and 2000 BT	M	Yes [ ]
LLD2	Low light not detected	17.3.7	Average receive optical power > –32.5 dBm for 0.5 MHz to 25 MHz frequency band	M	Yes [ ]
LLD3	End of low light	17.3.7	Resume reception of signals from ORD MDI when receive optical power is more than needed to support BER of 1 part in 10^{10}	M	Yes [ ]
LLD4	State of Data Receive	17.3.7	Disabled	M	Yes [ ]
LLD5	State of Data Transmit	17.3.7	Disabled	M	Yes [ ]
LLD6	Signal sent on OTD MDI during low light	17.3.7	RF	M	Yes [ ]
LLD7	Low light state exit timer	17.3.7	0.5 s ± 0.25 s	M	Yes [ ]

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17.5.6.20 Synchronous qualification

Item	Feature	Subclause	Value/Comment	Status	Support
SQ1	Condition for interrupt of reception at MDI	17.3.8	When reliable reception cannot be assured	M	Yes [ ]
SQ2	Synchronous signaling qualification	17.3.8	SIDL or RF detected for the duration of a period between 64 BT and 128 BT of clock recovery valid	M	Yes [ ]
SQ3	Action on successful synchronous signaling qualification	17.3.8	Data Transmit = enabled Data Receive = enabled	M	Yes [ ]
SQ4	Action on loss of synchronous signaling qualification	17.3.8	Data Transmit = disabled Data Receive = disabled *OTD_remote_fault* sent on MDI	M	Yes [ ]
SQ5	Clock recovery jitter tolerance	17.3.8	As in 15.2.2.1	M	Yes [ ]
SQ6	*lock_lost* not true	17.3.8	As in 15.2.2	M	Yes [ ]
SQ7	*lock_lost* true	17.3.8	Within 20 μs when input frequency on ORD ≥ 15.5 MHz or ≤ 1.55 MHz	M	Yes [ ]

17.5.6.21 MAU state diagram requirements

Item	Feature	Subclause	Value/Comment	Status	Support
SD1	Synchronous Qualification function state diagram	17.3.10	Meets requirements of Figure 17–2	M	Yes [ ]
SD2	Receive Jabber function state diagram	17.3.10	Meets requirements of Figure 17–3	M	Yes [ ]
SD3	MAU Transmit, Receive, Loopback and Collision Presence Functions state diagram	17.3.10	Meets requirements of Figure 17–4	M	Yes [ ]

17.5.6.22 MAU reliability

Item	Feature	Subclause	Value/Comment	Status	Support
MR1	Mean Time Before Failure	15.4	> 10^7 hours without causing communications failure among other stations	M	Yes [ ]

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17.5.6.23 PLS–PMA requirements

Item	Feature	Subclause	Value/Comment	Status	Support
PMA1	Messages between PLS in Repeater and PMA	15.5.4	As in 7.2.1	M	Yes [ ]

17.5.6.24 *signal_quality_error* message (SQE)

Item	Feature	Subclause	Value/Comment	Status	Support
SQE1	Local MAU transmitting and no collision or fault detected	15.5.4.2.1	*MAU_available* message sent to repeater	M	Yes [ ]
SQE2	Whenever a collision exists as described in 17.3.3	15.5.4.2.1	*signal_quality_error* message sent to repeater	M	Yes [ ]
SQE3	Message sent in the absence of SQE	15.5.4.2.1	*MAU_available* message	M	Yes [ ]

17.5.6.25 Environmental requirements

Item	Feature	Subclause	Value/Comment	Status	Support
E1	Ambient plane wave field in which MAU meets specification	15.6.2	2 V/m from 10 kHz to 30 MHz. 5 V/m from 30 MHz to 1 GHz.	M	Yes [ ]
E2	Electromagnetic emissions and susceptibility	15.6.2	Comply with local and/or national requirements. If none exist, comply with CISPR 22: 1993.	M	Yes [ ]

17.5.6.26 MAU labeling

Item	Feature	Subclause	Value/Comment	Status	Support
LBL1	MAU Type	15.7	10BASE-FB	O	Yes [ ] No [ ]
LBL2	Data Rate	15.7	10 Mb/s	O	Yes [ ] No [ ]
LBL3	Safety Warnings	15.7	Any applicable	O	Yes [ ] No [ ]
LBL4	Port Labeling	15.7	Input and output	O	Yes [ ] No [ ]

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18. Fiber optic medium attachment unit, type 10BASE-FL

18.1 Scope

18.1.1 Overview

This clause, along with Clause 15, defines the functional, electrical, optical, and mechanical characteristics of a fiber optic link for interconnecting DTEs and repeaters. The relationship of this specification to the OSI Reference Model is shown in Figure 15-1c). This link, which may be interconnected to other 10 Mb/s baseband segments using repeaters, consists of a 10BASE-FL MAU (including a fiber optic MDI specified in 15.2), and the fiber optic medium specified in 15.3. The purpose of the MAU is to provide a simple, inexpensive, and flexible means of attaching devices to the LAN medium.

18.1.1.1 10BASE-FL medium attachment unit (MAU)

The 10BASE-FL MAU has the following general characteristics:

a) It enables coupling the PLS by way of the AUI to the baseband fiber link defined in Clause 15.
b) It supports message traffic at a data rate of 10 Mb/s.
c) It provides for operating over 0 to at least 2000 m of the fiber optic cable specified in 15.3 without the use of a repeater.
d) It permits the DTE or repeater to confirm operation of the MAU and availability of the medium.
e) It supports network configurations using the CSMA/CD access method with baseband signaling.
f) It supports a point-to-point interconnection between MAUs and, when used with repeaters having multiple ports, supports a star wiring topology.
g) It allows incorporation of the MAU within the physical bounds of a DTE or repeater.

18.1.1.2 Repeater unit

The repeater unit is used to extend the physical system topology and provides for coupling two or more segments. Repeaters are an integral part of all 10BASE-FL networks with more than two DTEs (see Figure 13–1 and Figure 13–2). The repeater unit is defined in Clause 9. Multiple repeater units are permitted within a single collision domain to provide the maximum connection path length specified in Clause 13. The repeater unit is not a DTE and therefore has slightly different requirements for its attached MAUs as defined in 9.4.1. It is recommended that repeater sets with 10BASE-FL MAUs provide the Auto Partition/ Reconnection algorithm on those ports as specified in 9.6.6.2.

18.2 PMA interface messages

The messages between the PLS in the DTE and the PMA in the MAU shall comply with the PMA interface messages described in 7.2.1. These messages also are used in repeater unit to PMA communication. The messages between the PMA and the PLS in the DTE are specified in 15.5.4.1 and 15.5.4.2. These messages are also used in repeater unit to PMA communications. The messages between the PMAs and the fiber optic link segment are summarized in the following subclauses.

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18.2.1 PMA to fiber optic link segment messages

The following messages can be sent by the MAU PMA to the Fiber Optic Link Segment:

Message	Circuit	Signal	Meaning
OTD_output	OTD	CD1, CD0	Output information
OTD_idle	OTD	OPT_IDL	No information to output

18.2.1.1 *OTD_output*.

The PMA sublayer sends the *OTD_output* message to the OTD (Optical Transmit Data) circuit when the DTE or repeater outputs a bit of data, the MAU is available and is in the link test pass state. The physical realization of the *OTD_output* message shall be a CD0 or CD1 signal sent by the PMA. The encoding for CD1 and CD0 is the same as used on the AUI. Retiming of the CD1 and CD0 signals within the MAU is neither prohibited nor required.

18.2.1.2 OTD_idle

The PMA sublayer sends the *OTD_idle* message to the OTD circuit when the DTE or repeater sends idle; or upon detection of jabber or link integrity test failure. The physical realization of the *OTD_idle* message shall be the OPT_IDL defined in 18.3.1.1.

18.2.2 Fiber optic link segment to PMA messages

The following messages can be received by the MAU PMA from the Fiber Optic Link Segment:

Message	Circuit	Signal	Meaning
ORD_input	ORD	CD1, CD0	Input information
ORD_idle	ORD	OPT_ILD	No information to input

18.2.2.1 ORD_input

When the PMA sublayer receives the *ORD_input* message on its ORD (Optical Receive Data) circuit, it detects a bit of data. The physical realization of the *ORD_input* message shall be a CD0 or CD1 signal.

18.2.2.2 ORD_idle

When the PMA sublayer receives the *ORD_idle* message on its ORD circuit, it detects idle. The physical realization of the *ORD_idle* message shall be the OPT_IDL signal defined in 18.3.1.1.

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18.2.3 Interface message time references

Delay and bit loss specifications are measured from the occurrence of messages at the MDI and MAU AUI. A "positive-going" transition is from LO to HI. The following describes the point where each message starts:

Message	Reference
output	leading bit cell boundary (BCB) of first valid CD1 or CD0
output_idle	last positive-going transition prior to start of IDL
input	leading BCB of first valid CD1 or CD0
input_idle	last positive-going transition prior to start of IDL
signal_quality_error	first transition of valid amplitude
mau_available	last positive-going transition prior to start of IDL
OTD_output	leading BCB of first valid CD1 or CD0
OTD_idle	last positive going_transition prior to start of OPT_IDL
ORD_output	leading BCB of first valid CD1 or CD0
ORD_idle	last positive-going transition prior to start of OPT_IDL

18.3 MAU functional specifications

The MAU provides the means by which signals on the three AUI signal circuits to and from the DTE or repeater and their associated interlayer messages are coupled to the fiber optic link segment. The MAU provides the following functional capabilities to handle message flow between the DTE or repeater and the fiber optic link segment:

a) Transmit function. Provides the ability to transfer Manchester-encoded data from the DO circuit to the OTD circuit. While not sending Manchester-encoded data on the OTD circuit, an idle signal, OPT_IDL, is sent on the OTD circuit.
b) Receive function. Provides the ability to transfer Manchester-encoded data from the ORD circuit to the DI circuit. While not sending Manchester-encoded data on the DI circuit, an idle signal, IDL, is sent on the DI circuit.
c) Loopback function (half duplex mode only). Provides the ability to transfer Manchester-encoded data from the DO to the DI circuit when the MAU is sending Manchester-encoded data to the OTD circuit.
d) Collision Presence function. Provides the ability to detect simultaneous occurrence of Manchester-encoded data on the ORD and DO circuits and to report such an occurrence as a collision.
e) *signal_quality_error* Message (SQE) Test function. Provides the ability to indicate to the DTE that the Collision Presence function is operational and that the *signal_quality_error* message can be sent by the MAU.
f) Jabber function. Provides the ability to prevent abnormally long reception of Manchester-encoded data on the DO circuit from indefinitely disrupting transmission on the network. While such a condition is present, transfer of Manchester-encoded data by the Transmit and Loopback functions is disabled.
g) Link Integrity Test function. Provides the ability to protect the network from the consequences of failure of the simplex link attached to the ORD circuit. While such a failure is present, transfer of Manchester-encoded data by the Transmit, Receive, and Loopback functions is disabled.

18.3.1 MAU functions

The MAU shall provide the Transmit, Receive, Loopback, Collision Presence, Jabber, and Link Integrity Test functions for half duplex mode DTEs and repeater units. The MAU shall provide the Transmit, Receive, Jabber, and Link Integrity Test functions, and shall not provide the Loopback function, for full duplex mode

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DTEs. The SQE Test function shall be performed by MAUs that are connected to half duplex DTEs and shall not be performed by MAUs that are connected to repeaters.

MAUs connected to full duplex mode DTEs are permitted, but not required, to implement the Collision Presence function, the SQE Test function, and the generation of the CS0 signal on the CI circuit by the Jabber function. If these optional capabilities are implemented in a MAU connected to a full duplex mode DTE, either all of the optional functions shall be implemented, or none of them shall be.

The MAU function requirements are summarized in the table below:

MAU connected to:			
Function	**Repeater**	**Half duplex DTE**	**Full duplex DTE**
Transmit	Required	Required	Required
Receive	Required	Required	Required
Loopback	Required	Required	Prohibited
Jabber	Required	Required	Required
Link Integrity Test	Required	Required	Required
Collision Presence	Required	Required	Optional (note 2)
SQE Test	Prohibited	Required	Optional (note 2)
Generation of CS0 signal on the CI circuit by Jabber	Required	Required	Optional (note 2)

NOTE 1—The functional requirements of a MAU connected to a full duplex DTE are a proper subset of the requirements for half duplex operation.
NOTE 2—Optional capabilities, if implemented, must be implemented as a group (i.e., all or none).

A capability may be provided in the MAU to activate or inhibit the SQE Test function or to configure the MAU for full or half duplex operation. It is not required that a MAU determine that it is connected to either a DTE or a repeater and automatically activate or inhibit the SQE Test function. It is also not required that a MAU determine that it is connected to either a half duplex or full duplex DTE and automatically activate or inhibit the appropriate functions for those modes.

18.3.1.1 Transmit function requirements

The MAU shall receive messages on the DO circuit and send the appropriate signals to the OTD circuit of the MDI.

At the start of a packet transmission, no more than 2 bits shall be received from the DO circuit and not transmitted on the OTD circuit. In addition, it is permissible for the first bit sent to contain phase violations or invalid amplitude. All subsequent bits of the packet shall be reproduced with levels and timing meeting the specifications of 15.2.1. The second bit transmitted on the OTD circuit shall be transmitted with the correct timing and signal levels. The steady-state propagation delay between the DO circuit input and the OTD circuit shall not exceed 2.0 BT.

For any two packets that are separated by 9.6 ms or less, the start-up delay (bit loss plus steady-state propagation delay) of the first packet shall not exceed that of the second packet by more than 2.0 BT.

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Whenever data is not being transmitted on the OTD circuit, an idle signal, OPT_IDL, shall be transmitted on the OTD circuit. OPT_IDL consists of a start of idle (4 BT to 21 BT of the lower light level) followed by a periodic pulse waveform of frequency 1 MHz +25%, –15%. Following a packet and the start of idle, the periodic pulse wave form shall start with a transition to the higher optical light level.

Transmission of OPT_IDL may be terminated at any time with respect to the periodic pulse waveform. It shall be terminated such that no more than the first transmitted bit of a packet is corrupted, and with no more delay than is specified for bit loss and steady-state propagation.

18.3.1.2 Receive function requirements

The MAU shall receive the signals on the ORD circuit of the MDI and send the appropriate message to the DI circuit. The optical-to-electrical conversion shall be as specified in 15.2.2.3.

At the start of a packet reception from the ORD circuit, no more than 2 bits shall be received on the ORD circuit and not transmitted onto the DI circuit. In addition, it is permissible for the first bit sent on the DI circuit to contain phase violations or invalid data; however, all successive bits of the packet shall be sent with no more than the amount of jitter specified in 15.2. The steady-state propagation delay between the ORD circuit and the DI circuit shall not exceed 2.0 BT.

For any two packets that are separated by 9.6 µs or less, the start-up delay of the first packet shall not exceed that of the second packet by more than 2.0 BT.

18.3.1.3 Loopback function requirements (half duplex mode only)

When the MAU is transmitting on the OTD circuit and is not receiving *ORD_input* messages (18.2.2.1) on the ORD circuit, the MAU shall transmit on the DI circuit the signals received on the DO circuit in order to provide loopback of the transmitted signal. At the start-of-packet transmission on the OTD circuit, no more than 5 bits of information shall be received from the DO circuit and not transmitted to the DI circuit. In addition, it is permissible for the first bit sent on the DI circuit to contain phase violations or invalid data; however, all successive bits of the packet shall meet the jitter specified in 15.2. The steady-state propagation delay between the DO circuit and the DI circuit shall not exceed 1.0 BT.

18.3.1.4 Collision Presence function requirements (half duplex mode only)

The MAU shall detect as a collision the simultaneous occurrence of activity on the DO circuit and the ORD circuit while in the Link Test Pass state. While a collision is detected, a CS0 signal (see 7.3.1.2) shall be sent on the CI circuit. The signal shall be presented to the CI circuit no more than 3.5 BT after the occurrence of a collision. The signal shall be de-asserted within 7.0 BT after the DO circuit or the ORD circuit changes from active to idle.

When CS0 is asserted on the CI circuit due to a collision, the data on the ORD circuit shall be sent to the DI circuit within 9.0 BT.

When the ORD circuit changes from active to idle and data is present on the DO circuit, the data on the DO circuit shall be sent to the DI circuit within 7.0 BT.

The signal presented on the CI circuit in the absence of collision, SQE test, or Jabber shall be the IDL signal.

MAUs connected to full duplex mode DTEs are permitted, but not required, to implement the Collision Presence function (see 18.3.1).

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18.3.1.5 *signal_quality_error* Message (SQE) Test function requirements

The SQE Test function shall be performed by MAUs that are connected to DTEs and shall not be performed by MAUs that are connected to repeaters. When the SQE test is performed, the MAU shall send CS0 on the CI circuit for a time "SQE_test" beginning a time "SQE_test_wait" after the last positive transition of a packet on the DO circuit. The value of "SQE_test" shall be 10 BT ±5 BT and the value of "SQE_test_wait" shall be between 0.6 and 1.6 µs. This function should use as much of the normal collision detection and signaling circuitry as possible without introducing extraneous signals on the OTD circuit or the DI circuit.

The CS0 signal shall not be sent by the SQE Test function while in any of the Link Test Fail states.

MAUs connected to full duplex mode DTEs are permitted, but not required to implement the SQE Test function (see 18.3.1).

18.3.1.6 Jabber function requirements

The MAU shall contain a self-interrupt capability to prevent an illegally long transmission by a DTE from permanently disrupting transmission on the network and to disable loopback to the DI circuit (Figure 18–3). The MAU shall provide a window "xmit_max" during which time the Transmit function may continuously transmit *OTD_output* messages to the OTD circuit. The value of "xmit_max" shall be between 20 and 150 ms. If a transmission exceeds this duration, the Jabber function shall

a) Inhibit the Loopback function and the transmission of *OTD_output* messages by the Transmit function, and shall
b) Send the CS0 signal on the CI circuit, when the MAU is connected to a DTE operating in half duplex mode. MAUs connected to DTEs operating in full duplex mode are permitted, but not required, to send the CS0 signal on the CI circuit in this manner (see 18.3.1).

These actions shall continue until *output_idle* has been continuously present on the DO circuit for a time "unjab." The value of "unjab" shall be 0.5 s ± 0.25 s.

It is permissible to activate the Jabber function when the OTD circuit transmitter is sending *OTD_output* messages for longer than "xmit_max."

The MAU shall not activate its Jabber function when the repeater's MAU Jabber Lockup Protection function operates at its longest permitted time as specified in 9.6.5.

18.3.1.7 Link Integrity Test function requirements

In order to protect the network from the consequences of a simplex fiber optic link segment failure, the MAU shall monitor the light level on the ORD circuit. When a light level below that required for reliable reception (low light) is detected, the MAU shall enter the Link Test Fail Low Light state and cause the *input_idle* message to be sent on the DI circuit and the *OTD_idle* message to be sent on the OTD circuit (Figure 18–4).

Low light shall not be detected if the optical power level at the ORD circuit exceeds –32.5 dBm. Low light shall also not be detected if the low light condition remains for less than 30 BT. It shall be detected and the Link Test Fail Low Light state entered if the optical power level at ORD circuit has fallen to a level lower than the optical power level that corresponds to a BER = 10^{-10} for the MAU for a duration of 2000 BT. Additionally, when the optical receive average power has maintained a value less than –30 dBm for 2000 BT and then falls lower than the level that corresponds to a BER = 10^{-10} for the MAU for a duration of 500 BT, low light shall be detected and the Link Test Fail Low Light state entered.

The MAU shall exit the Link Test Fail Low Light state once the optical power level on the ORD circuit exceeds –32.5 dBm for 0.5 s ±0.25 s. Exiting the Link Test Fail Extend state and entering the Link Test Pass state (thus,

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re-enabling the OTD and DI circuits) shall be deferred until the signals on the ORD and DO circuits become idle. Optionally, a MAU may exit the Link Test Fail Extend state and enter the Link Test Pass state when the ORD circuit becomes idle and the Jabber function has disabled transmission on the OTD circuit.

While the MAU is not in the Link Test Pass state, the Link Integrity Test function shall disable the bit transfer of the Transmit, Receive, and Loopback functions, and the Collision Presence and SQE Test functions.

At power-on, in place of entering the Link Test Pass state as shown in Figure 18–4,[43] a MAU may optionally enter the Link Test Fail Low Light state.

If a visible indicator is provided on the MAU to indicate the link status, it is recommended that the color be green and that the indicator be labeled appropriately. It is further recommended that the indicator be on when the MAU is in the Link Test Pass state and off otherwise.

18.3.1.8 Auto-Negotiation

The Auto-Negotiation algorithm of Clause 28, while the preferred method for the determination of half or full duplex operation, is not currently defined for fiber MAUs.

Manual configuration, while not recommended for copper-based MAUs, is the only practical choice for fiber implementations. Connecting incompatible DTE/MAU combinations such as a full duplex mode DTE to a half duplex mode MAU, or a full duplex mode station (DTE and MAU) to a half duplex network, can lead to severe network performance degradation, increased collisions, late collisions, CRC errors, and undetected data corruption.

18.3.2 MAU state diagrams

The state diagrams of Figure 18–1a), Figure 18–1b), Figure 18–2, Figure 18–3, and Figure 18–4 depict the full set of allowed MAU state functions relative to the circuits of the AUI and MDI.

The notation used in the state diagrams follows the conventions in 1.2.1. The variables and timers used in the state diagrams are defined in the following subclauses.

18.3.2.1 MAU state diagram variables

Variables are used in the state diagrams to indicate the status of MAU inputs and outputs, to control MAU operation, and to pass state information between functions.

In the variable definitions, the name of the variable is followed by a brief description of the variable and a list of values the variable may take. For those variables which are state diagram outputs, one value will be identified as the default. The variable has the default value when no active state contains a term assigning a different value.

For example, the variable “xmit” has the value “disable” whenever the Jabber function or the Link Integrity Test function is in a state that asserts “xmit=disable”. The variable has the default value “enable” all other times.

[43]The MAU state diagrams, Figures 18–1 through 18–4, follow 18.3.2.2.

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The variables used in the state diagrams are defined as follows:

DI

Controls the signal sent by the MAU on the DI circuit.
Values: idle; MAU is sending *input_idle*, IDL (default).
DO; MAU sends the signal received on the DO circuit.
lpbk = disable overrides this and causes *input_idle* to be sent.
ORD; MAU sends the signal received on the ORD circuit.
rcv = disable overrides this and causes *input_idle* to be sent.

CI

Controls the signal sent by the MAU on the CI circuit.
Values: idle; MAU sends *mau_available*, IDL (default).
SQE; MAU sends *signal_quality_error*, CS0.

DO

Status of the signal received by the MAU on the DO circuit.
Values: idle; MAU is receiving *output_idle*, IDL.
active; MAU is receiving *output*, CD0 or CD1.

OTD

Controls the signal sent by the MAU on the OTD circuit.
Values: idle; MAU sends *OTD_idle*, OPT_IDL (default).
DO; MAU sends the signal received on the DO circuit.
xmit = disable overrides this and causes *OTD_idle* to be sent.

ORD

Status of the signal received by the MAU on the ORD circuit.
Values: idle; MAU is receiving *ORD_idle*; OPT_idle.
active; MAU is receiving *ORD_input*; CD0 or CD1.

low_light_level

Status of the light level received by the MAU on the ORD circuit.
Values: false; MAU is receiving sufficient light level for reliable reception.
true; MAU is not receiving sufficient light level for reliable reception (see 18.3.1.7).

rcv

Controls the path from the ORD circuit to the DI circuit.
Values: enable; receive is enabled (default).
disable; the output to the DI circuit will be input_idle when DI=ORD.

lpbk

Controls the path from the DO circuit to the DI circuit.
Values: enable; loopback is enabled (default).
disable; the output to the DI circuit will be input_idle when DI=DO.

xmit

Controls the path from the DO circuit to the OTD circuit.
Values: enable; transmit is enabled (default).
disable; transmit is disabled and the signal sent on the OTD circuit will be OPT_IDL.

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18.3.2.2 MAU state diagram timers

All timers operate in the same fashion. A timer is reset and starts counting upon entering a state where start x_timer is asserted. Time x after the timer has been started, x_timer_done is asserted and remains asserted until the timer is reset. At all other times, x_timer_not_done is asserted.

When entering a state where start x_timer is asserted, the timer is reset and restarted even if the entered state is the same as the exited state.

low_light_heal_timer. Timer for low light condition cessation.

SQE_test_timer. Timer for the duration of the CS0 signal used for the SQE Test function (18.3.1.5).

SQE_test_wait_timer. Timer for the delay from end of packet to the start of the CS0 signal used for the SQE Test function (18.3.1.5).

unjab_timer. Timer for the length of time the DO circuit must be continuously idle to allow transmission to be re-enabled (18.3.1.6).

xmit_max_timer. Timer for excessively long transmit time (18.3.1.6).

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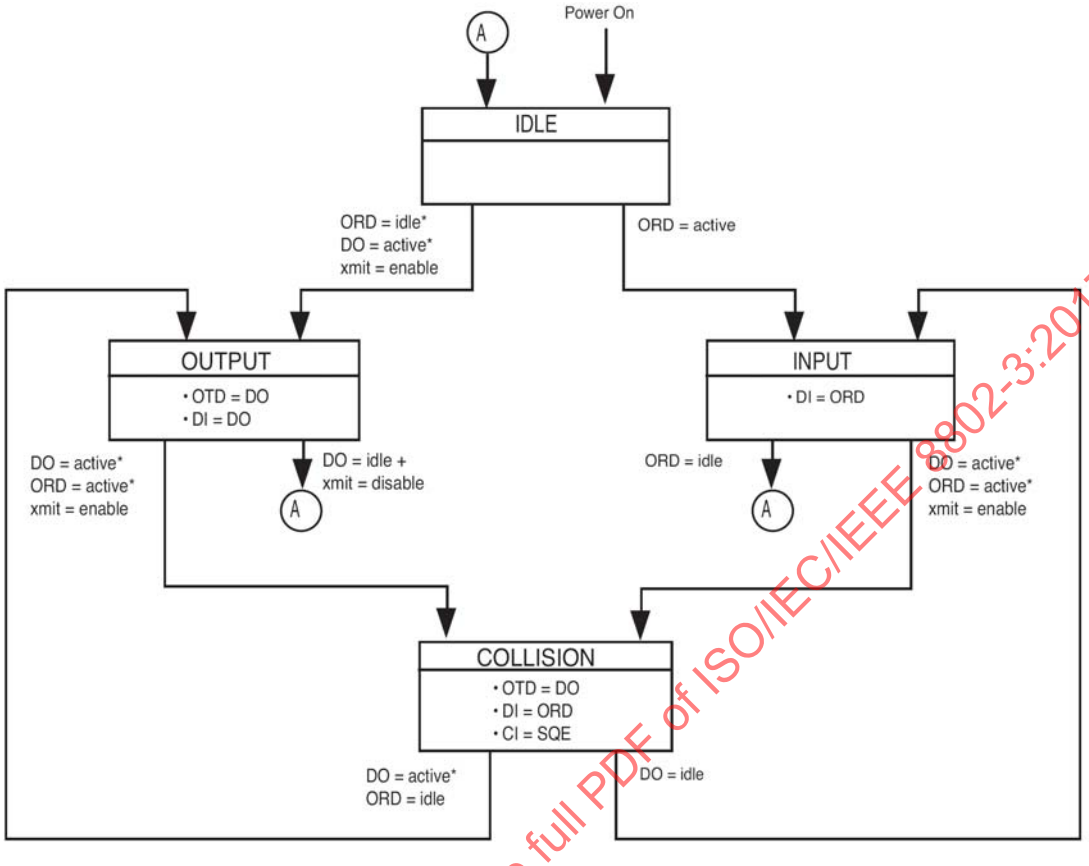
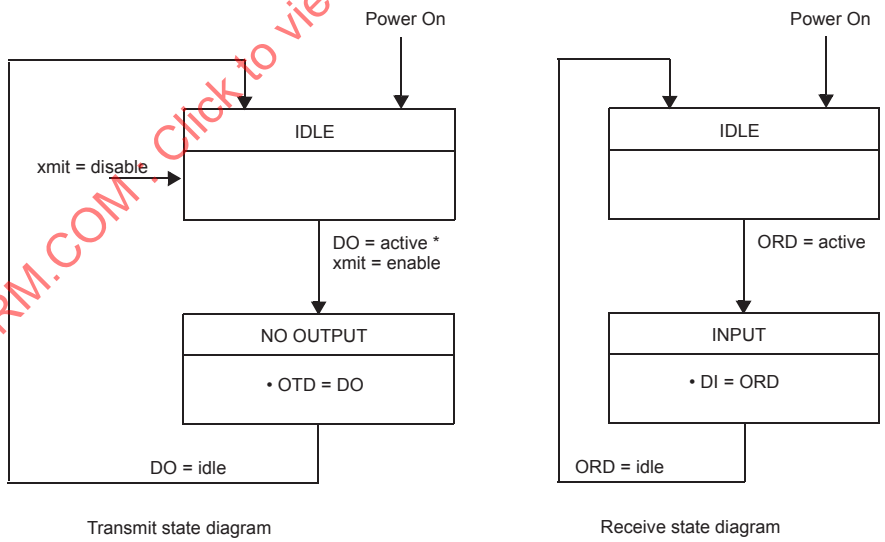


a) MAU Transmit, Receive, Loopback, and Collision Presence functions (half duplex mode)



b) MAU Transmit and Receive functions (full duplex mode)

Figure 18–1—MAU state diagrams

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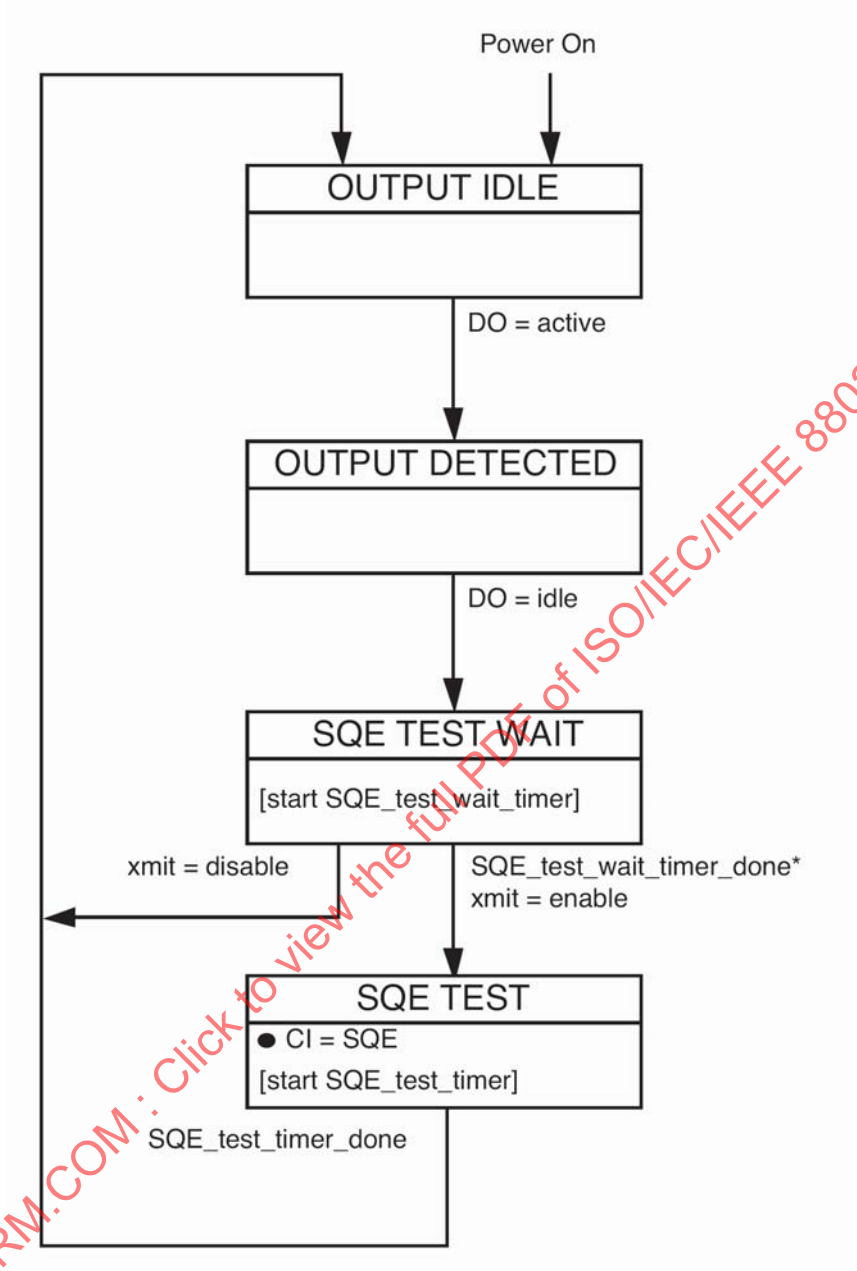

Figure 18–2—*signal_quality_error* Message Test function state diagram

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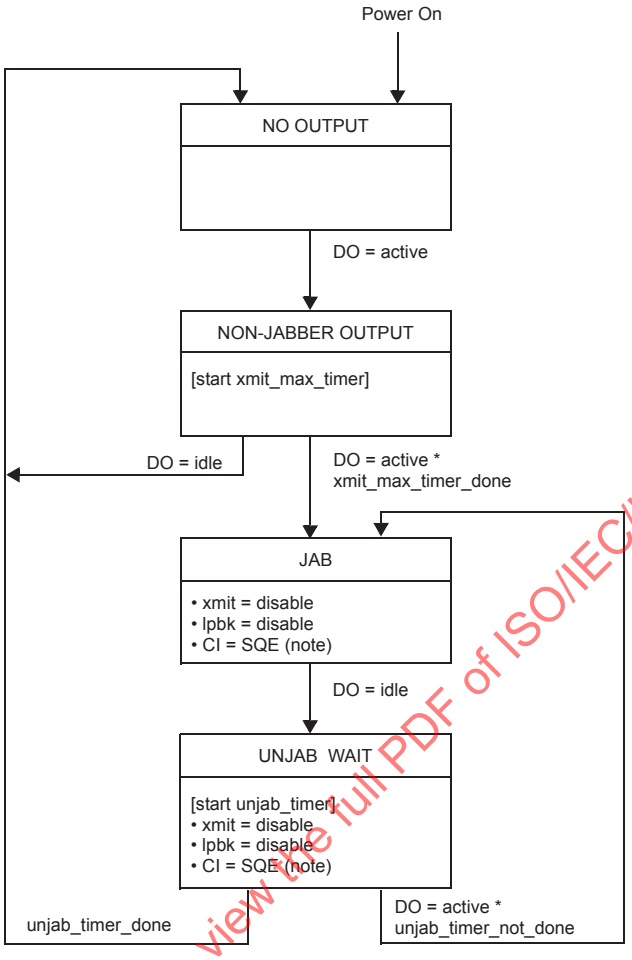

NOTE 1—Optional for MAUs connected to DTEs operating in full duplex mode.

NOTE 2—The implementation of the Collision Presence function is not required in a MAU connected to a full duplex mode DTE, and is not shown in Figure 18–1b).

NOTE 3—The implementation of the SQE Test function shown in Figure 18–2 is not required in a MAU connected to a full duplex mode DTE.

NOTE 4—The enabling of the variable *lpbk* in Figure 18–4 is applicable in half duplex mode only.

Figure 18–3—Jabber function state diagram

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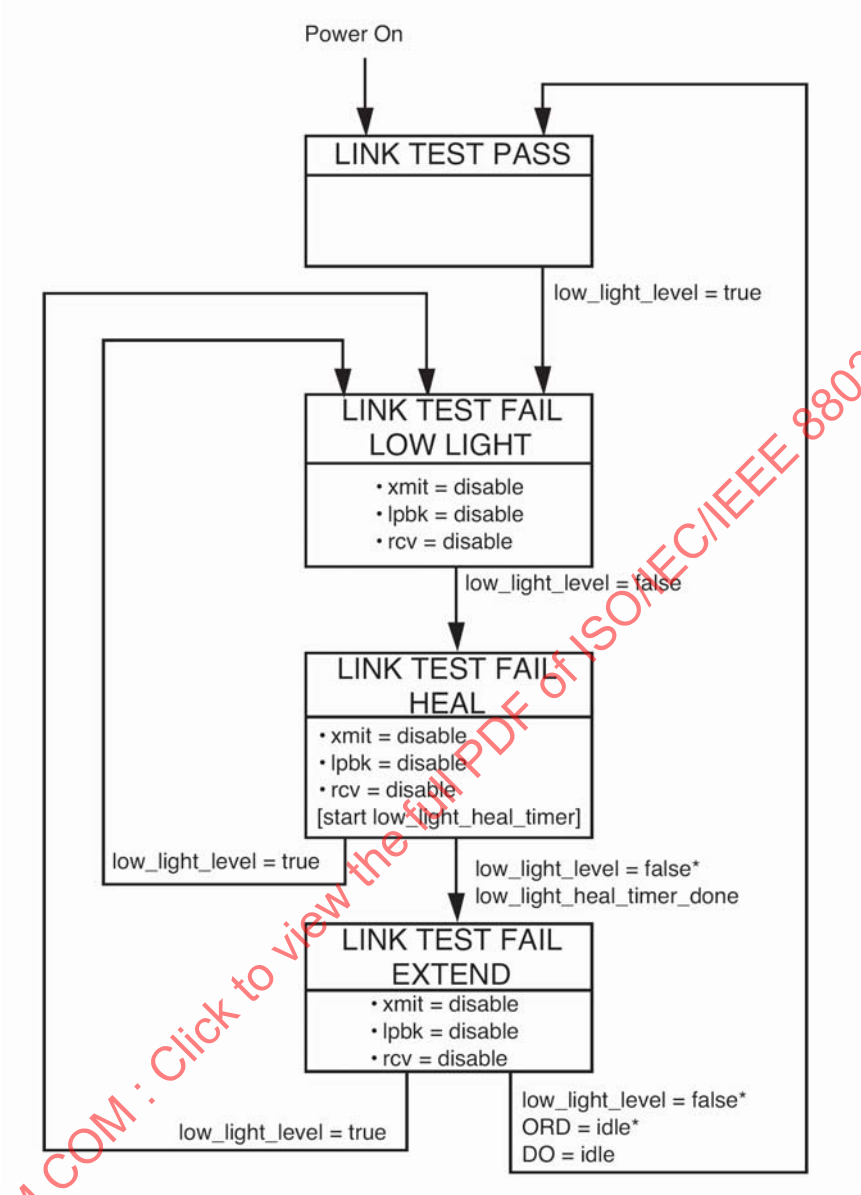

Figure 18–4—Link Integrity Test function state diagram

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18.4 Timing summary

Table 18–1 summarizes the timing requirements for the 10BASE-FL fiber link. This table is a summary; for complete descriptions of the timing requirements, refer to the referenced clauses. All times are in bit times.

Table 18–1—Maximum timing parameters

Symbol	Function	Bit loss	Invalid bits	Steady-state prop. delay	Start-up delay		
					Max.	Var	Specified in
M1	*ORD_input* to *input* on DI	2.0	1.0	2.0	5.0	2.0	18.3.1.2
M2	*output* on DO to *OTD_output*	2.0	1.0	2.0	5.0	2.0	18.3.1.1
M3	*ORD_input* **output* to *signal_quality_error*				3.5		18.3.1.4
M4	*ORD_idle* + *output_idle* (end of collision) to *mau_available*				7.0		18.3.1.4
M5	*ORD_input* **output* to *input* on DI from circuit ORD				9.0		18.3.1.4
M6	*ORD_idle* **output* to *input* on DI from circuit DO				7.0		18.3.1.4
M7	*output_idle* on DO to *signal_quality_error*				$6 < x < 16$		18.3.1.5
M8	*signal_quality_error* duration for SQE test				$5 \leq x \geq 15$		18.3.1.5
M9	*output* on DO to *input* on DI	5.0	1.0	1.0	7.0		18.3.1.3
F1	Fiber Optic Cable Propagation (2000 m)	0	0	100	100		15.3.1.3
A1	AUI Cable Propagation (50 m)	0	0	2.57	2.57		7.4.3.7

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18.5 Protocol implementation conformance statement (PICS) proforma for Clause 18, Fiber optic medium attachment unit, type 10BASE-FL[44]

18.5.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 18, Fiber optic medium attachment unit, type 10BASE-FL, shall complete the following protocol implementation conformance statement (PICS) proforma.

A completed PICS proforma is the PICS for the implementation in question. The PICS is a statement of which capabilities and options of the protocol have been implemented. The PICS can be used for a variety of purposes by various parties, including the following:

— As a checklist by the protocol implementer, to reduce the risk of failure to conform to the standard through oversight;
— As a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard PICS proforma, by the supplier and acquirer, or potential acquirer, of the implementation;
— As a basis for initially checking the possibility of interworking with another implementation by the user, or potential user, of the implementation (note that, while interworking can never be guaranteed, failure to interwork can often be predicted from incompatible PICs);
— As the basis for selecting appropriate tests against which to assess the claim for conformance of the implementation, by a protocol tester.

18.5.2 Abbreviations and special symbols

18.5.2.1 Status symbols

The following symbols are used in the PICS proforma:

M	mandatory field/function
O	optional field/function
O.<n>	optional field/function, but at least one of the group of options labeled by the same numeral <n> is required
O/<n>	optional field/function, but one and only one of the group of options labeled by the numeral <n> is required
X	prohibited field/function
<item>:	simple-predicate condition, dependent on the support marked for <item>

18.5.2.2 Abbreviations

N/A	Not applicable

In addition, the following predicate names are defined for use when different implementations from the set above have common parameters:

*HRP : HDX or RPT
*HDS : HDX or FDS
*HFC : HDX or FDS or RPT

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18.5.3 Instructions for completing the PICS proforma

18.5.3.1 General structure of the PICS proforma

The first part of the PICS proforma, Implementation Identification and Protocol Summary, is to be completed as indicated with the information necessary to identify fully both the supplier and the implementation.

The main part of the PICS proforma is a fixed-format questionnaire divided into subclauses, each containing a group of items. Answers to the questionnaire items are to be provided in the right-most column, either by simply marking an answer to indicate a restricted choice (usually Yes, No, or Not Applicable), or by entering a value or a set or range of values. (Note that there are some items where two or more choices from a set of possible answers can apply; all relevant choices are to be marked.)

Each item is identified by an item reference in the first column; the second column contains the question to be answered; the third column contains the reference or references to the material that specifies the item in the main body of the standard; the fourth column contains values and/or comments pertaining to the question to be answered. The remaining columns record the status of the item—whether the support is mandatory, optional, or conditional—and provide the space for the answers; see also 18.5.3.4 below.

The supplier may also provide, or be required to provide, further information, categorized as either Additional Information or Exception Information. When present, each kind of further information is to be provided in a further subclause of items labeled A<i> or X<i>, respectively, for cross-referencing purposes, where <i> is any unambiguous identification for the item (e.g., simply a numeral); there are no other restrictions on its format or presentation.

A completed PICS proforma, including any Additional Information and Exception Information, is the protocol implementation conformance statement for the implementation in question.

Note that where an implementation is capable of being configured in more than one way, according to the items listed under 18.5.5, Major Capabilities/Options, a single PICS may be able to describe all such configurations. However, the supplier has the choice of providing more than one PICS, each covering some subset of the implementation's configuration capabilities, if that would make presentation of the information easier and clearer.

18.5.3.2 Additional information

Items of Additional Information allow a supplier to provide further information intended to assist the interpretation of the PICS. It is not intended or expected that a large quantity will be supplied, and the PICS can be considered complete without any such information. Examples might be an outline of the ways in which a (single) implementation can be set up to operate in a variety of environments and configurations; or a brief rationale, based perhaps upon specific application needs, for the exclusion of features which, although optional, are nonetheless commonly present in implementations of the 10BASE-FL protocol.

References to items of Additional Information may be entered next to any answer in the questionnaire, and may be included in items of Exception Information.

18.5.3.3 Exception information

It may occasionally happen that a supplier will wish to answer an item with mandatory or prohibited status (after any conditions have been applied) in a way that conflicts with the indicated requirement. No preprinted answer will be found in the Support column for this; instead, the supplier is required to write into the Support column an X<i> reference to an item of Exception Information, and to provide the appropriate rationale in the Exception item itself.

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An implementation for which an Exception item is required in this way does not conform to this standard.

Note that a possible reason for the situation described above is that a defect in the standard has been reported, a correction for which is expected to change the requirement not met by the implementation.

18.5.3.4 Conditional items

The PICS proforma contains a number of conditional items. These are items for which both the applicability of the item itself, and its status if it does apply—mandatory, optional, or prohibited—are dependent upon whether or not certain other items are supported.

Individual conditional items are indicated by a conditional symbol of the form "<item>:<s>" in the Status column, where "<item>" is an item reference that appears in the first column of the table for some other item, and "<s>" is a status symbol, M, O, or X.

If the item referred to by the conditional symbol is marked as supported, the conditional item is applicable, and its status is given by "<s>"; the support column is to be completed in the usual way. Otherwise, the conditional item is not relevant and the Not Applicable (N/A) answer is to be marked.

Each item whose reference is used in a conditional symbol is indicated by an asterisk in the Item column.

18.5.4 Identification

18.5.4.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

18.5.4.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 18, Fiber optic medium attachment unit, Type 10BASE-FL
Identification of amendments and corrigenda to this PICS proforma which have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See 17.5.3.3; The answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	

Date of Statement	

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18.5.5 Major capabilities/options

Item	Feature	Subclause	Value/ Comment	Status	Support
*DTE	MAU supports DTE connections	15.1.1	N/A	O.1	Yes [ ] No [ ]
*RPT	MAU supports repeater connections	15.1.1	N/A	O.1	Yes [ ] No [ ]
*AUI	AUI connection physically exists and is accessible for test.	15.1.3.2	N/A	O	Yes [ ] No [ ]
*APW	AUI powers MAU	15.5.3	N/A	AUI: O.2	N/A [ ] Yes [ ] No [ ]
*SPW	AUI implemented but MAU powered separately	15.5.3	N/A	AUI: O.2	N/A [ ] Yes [ ] No [ ]
*FDX	MAU supports full duplex mode DTE connections	15.1.3.5	N/A	DTE: O.3	N/A [ ] Yes [ ] No [ ]
*HDX	MAU supports half duplex mode DTE connections	15.1.3.5	N/A	DTE: O.3	N/A [ ] Yes [ ] No [ ]
*FDS	MAU supports optional set of SQE related function for full duplex mode DTE connections	18.3.1	N/A	FDX: O	N/A [ ] Yes [ ] No [ ]

18.5.6 PICS proforma tables for the type 10BASE-FL MAU

18.5.6.1 Compatibility considerations

Item	Feature	Subclause	Value/Comment	Status	Support
CC1	Compatibility considerations: 10BASE-FL systems compatible at 10BASE-FL MDI	15.1.3.2		M	Yes [ ]
CC2	10BASE-FL MAUs interoperable with FOIRL MAUs except for media connector	15.1.3.2		M	Yes [ ]
CC3	Mode of operation	15.1.3.5	normal mode only	M	Yes [ ]

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18.5.6.2 Optical transmit parameter

Item	Feature	Subclause	Value/Comment	Status	Support
OT1	Center wavelength	15.2.1.1	min. 800 nm; max. 910 nm	M	Yes [ ]
OT2	Spectral width (FWHM)	15.2.1.2	< 75 nm	M	Yes [ ]
OT3	Optical modulation extinction ratio	15.2.1.3	< –13 dB	M	Yes [ ]
OT4	Optical Idle signal amplitude	15.2.1.4	See 15.2.1.10	M	Yes [ ]
OT5	Optical transmit pulse logic polarity	15.2.1.5	High Optical Power = LO on AUI DO and MDI. Low Optical Power = HI on AUI DO and MDI.	M	Yes [ ]
	Optical transmit pulse rise and fall times	15.2.1.6	Measured from 10% to 90% level		
OT6	Max. (Data)		10.0 ns	M	Yes [ ]
OT7	Min. (Data)		0.0 ns	M	Yes [ ]
OT8	Max. Difference (Data)		3.0 ns	M	Yes [ ]
OT9	Max. (Idle)		25.0 ns	M	Yes [ ]
OT10	Min. (Idle)		0.0 ns	M	Yes [ ]
OT11	Max. Difference (Idle)		25.0 ns	M	Yes [ ]
OT12	Optical transmit pulse overshoot	15.2.1.7	< 25%	M	Yes [ ]
OT13	Optical transmit pulse undershoot	15.2.1.7	< 10%	M	Yes [ ]
	Optical transmit pulse edge jitter added	15.2.1.8	Measured as in 15.2.1.8		
OT14	DO circuit to MDI		± 2.0 ns	M	Yes [ ]
OT15	Total at MDI		±4.0 ns	M	Yes [ ]
	Optical transmit pulse duty cycle distortion	15.2.1.9	Measured at median power level		
OT16	Max. (Data)		± 2.5 ns	M	Yes [ ]
OT17	Max. (Idle)		± 50.0 ns	M	Yes [ ]
	Optical transmit average power range	15.2.1.10			
	Min.				
OT18	Max.		–20 dBm	M	Yes [ ]
OT19			–12 dBm	M	Yes [ ]
OT20	Transmit signal templates	Figure 15–5	Optical signals within template	M	Yes [ ]

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18.5.6.3 Optical receive parameters

Item	Feature	Subclause	Value/Comment	Status	Support
OR1	BER between two AUIs attached to a single segment	15.2.2	< one part in 10^9	M	Yes [ ]
	Optical receive average power	15.2.2.1	When a single transmitter transmits on the medium		
OR2	Min.		–32.5 dBm	M	Yes [ ]
OR3	Max.		–12.0 dBm	M	Yes [ ]
	MAU optical receive Edge jitter (Data)	15.2.2.2	Measured as in 15.2.2.2		
OR4	Received at MDI		± 6.5 ns at median power	M	Yes [ ]
OR5	Added MDI to DI circuit		± 8.5 ns	M	Yes [ ]
OR6	Total at DI circuit (MAU end of AUI)		± 15.0 ns at zero crossing points	M	Yes [ ]
OR7	Optical receive pulse logic polarity	15.2.2.3	High Optical Power = LO on AUI DI and MDI. Low Optical Power = HI on AUI DI and MDI	M	Yes [ ]
	Optical receive pulse rise and fall times:	15.2.2.4	Measured from 10% to 90% level		
OR8	Max. (Data)		31.5 ns	M	Yes [ ]
OR9	Min. (Data)		0.0 ns	M	Yes [ ]
OR10	Max. Difference (Data)		3.0 ns	M	Yes [ ]
OR11	Max. (Idle)		41.0 ns	M	Yes [ ]
OR12	Min. (Idle)		0.0 ns	M	Yes [ ]
OR13	Max. Difference (Idle):		25.0 ns	M	Yes [ ]

18.5.6.4 Optical medium connector plug and socket

Item	Feature	Subclause	Value/Comment	Status	Support
CS1	Connector socket for MAU	15.3.2	BFOC/2.5—see IEC 60874-10:1992	M	Yes [ ]

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18.5.6.5 MAU functions

Item	Feature	Subclause	Value/Comment	Status	Support
MF1	Transmit	18.3.1.1		M	Yes [ ]
MF2	Receive	18.3.1.2		M	Yes [ ]
MF3	Loopback	18.3.1.3		HRP: M FDX: X	N/A [ ] M: Yes [ ] N/A [ ] X: Yes [ ]
MF4	Collision Presence	18.3.1.4		HFC: M	N/A [ ] M: Yes [ ]
MF5	Jabber	18.3.1.6		M	Yes [ ]
MF6	Link Integrity Test	18.3.1.7		M	Yes [ ]
MF7	SQE Test	18.3.1.5		HDS: M RPT: X	N/A [ ] M: Yes [ ] N/A [ ] X: Yes [ ]

18.5.6.6 PMA interface messages

Item	Feature	Subclause	Value/Comment	Status	Support
PIM1	Messages between the PLS in the DTE and the PMA in the MAU	18.2	As described in 7.2.1	M	Yes [ ]

18.5.6.7 PMA-to-MDI OTD messages

Item	Feature	Subclause	Value/Comment	Status	Support
OTD1	Signal sent on OTD corresponding to *OTD_output* message	18.2.1.1	CD1,CD0	M	Yes [ ]
OTD2	Signal sent on OTD corresponding to *OTD_idle* message	18.2.1.2	OPT_IDL	M	Yes [ ]

18.5.6.8 MDI ORD-to-PMA messages

Item	Feature	Subclause	Value/Comment	Status	Support
ORD1	Signal received on ORD corresponding to *ORD_input* message	18.2.2.1	CD1,CD0	M	Yes [ ]
ORD2	Signal received on ORD corresponding to *ORD_idle* message	18.2.2.2	OPT_IDL or signal other than valid Manchester Data	M	Yes [ ]

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18.5.6.9 Transmit function

Item	Feature	Subclause	Value/Comment	Status	Support
XT1	Data Transmit path for *output* message	18.3.1.1	DO circuit to OTD circuit	M	Yes [ ]
XT2	Levels and timing of optical signal	18.3.1.1	As in 15.2.1	M	Yes [ ]
XT3	Start-up bit loss (DO to OTD circuits)	18.3.1.1	2 bits max.	M	Yes [ ]
XT4	Transmit settling time	18.3.1.1	Second and following bits meet jitter, level, and waveform specifications of 15.2.1	M	Yes [ ]
XT5	Transmit steady-state delay	18.3.1.1	2 BT max.	M	Yes [ ]
XT6	Transmit delay variability	18.3.1.1	2 BT max.	M	Yes [ ]
XT7	Signal sent on OTD corresponding to OPT_IDL message	18.3.1.1	Start of idle followed by a periodic pulse waveform	M	Yes [ ]
XT8	Periodic pulse waveform	18.3.1.1	1 MHz +25%, –15%	M	Yes [ ]
XT9	OPT_IDL termination with respect to start of packet	18.3.1.1	Normal start-of-packet requirement apply	M	Yes [ ]

18.5.6.10 Receive function

Item	Feature	Subclause	Value/Comment	Status	Support
RCV1	Optical to electrical	18.3.1.2	As specified in 15.2.2.3	M	Yes [ ]
RCV2	Receive path	18.3.1.2	ORD circuit to DI circuit	M	Yes [ ]
RCV3	Start-up bit loss (ORD to DI circuits)	18.3.1.2	2 bits max.	M	Yes [ ]
RCV4	Receive settling time	18.3.1.2	Second and following bits meet jitter specifications of 15.2	M	Yes [ ]
RCV5	Receive steady-state delay	18.3.1.2	2 BT max.	M	Yes [ ]
RCV6	Receive delay variability	18.3.1.2	2 BT max.	M	Yes [ ]

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18.5.6.11 Loopback function

Item	Feature	Subclause	Value/Comment	Status	Support
LP1	Loopback function requirements when ORD = idle and DO = active	18.3.1.3	DO signals to DI circuit.	HRP: M	N/A [ ] M: Yes [ ]
LP2	Loopback bit loss (DO to DI circuits)	18.3.1.3	5 bits max	HRP: M	N/A [ ] M: Yes [ ]
LP3	Loopback settling time	18.3.1.3	Second and following bits meet jitter specifications.	HRP: M	N/A [ ] M: Yes [ ]
LP4	Loopback steady-state delay	18.3.1.3	1 BT max	HRP: M	N/A [ ] M: Yes [ ]

18.5.6.12 Collision Presence function

Item	Feature	Subclause	Value/Comment	Status	Support
CP1	Collision Presence function requirements	18.3.1.4	CS0 on CI circuit if DO=active, ORD=active and in Link Test Pass state.	HFC: M	N/A [ ] M: Yes [ ]
CP2	Collision indication delay	18.3.1.4	3.5 BT max.	HFC: M	N/A [ ] M: Yes [ ]
CP3	Collision indicate deassert delay	18.3.1.4	7 BT max.	HFC: M	N/A [ ] M: Yes [ ]
CP4	CI circuit with no collision, SQE Test, or jabber	18.3.1.4	IDL signal	HFC: M	N/A [ ] M: Yes [ ]
CP5	DI circuit source switch delay from CS0 assert	18.3.1.4	9 BT max.	HFC: M	N/A [ ] M: Yes [ ]
CP6	DI circuit source switch delay from CS0 deassert	18.3.1.4	7 BT max.	HFC: M	N/A [ ] M: Yes [ ]

18.5.6.13 *signal_quality_error* Message (SQE) Test function

Item	Feature	Subclause	Value/Comment	Status	Support
STF1	SQE Test induced OTD or DI circuit signals	18.3.1.5	No extraneous signals permitted	HDS: M	N/A [ ] M: Yes [ ]
STF2	SQE_test_wait timer range	18.3.1.5	0.6 to 1.6 µs	HDS: M	N/A [ ] M: Yes [ ]
STF3	SQE_test timer range	18.3.1.5	5 to 15 BT	HDS: M	N/A [ ] M: Yes [ ]
STF4	CI circuit during SQE Test	18.3.1.5	CS0 signal	HDS: M	N/A [ ] M: Yes [ ]
STF5	SQE Test in Link Fail states	18.3.1.5	CS0 must not be sent	HDS: M	N/A [ ] M: Yes [ ]

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18.5.6.14 Jabber function

Item	Feature	Subclause	Value/Comment	Status	Support
JAB1	Jabber function implementation	18.3.1.6	Self-interrupt of transmit and loopback.	M	Yes [ ]
JAB2	Xmit_max. timer range	18.3.1.6	20 ms min., 150 ms max.	M	Yes [ ]
JAB3	CI circuit during jabber	18.3.1.6	CS0 signal	HFC: M	N/A [ ] M: Yes [ ]
JAB4	Unjab timer range	18.3.1.6	0.5 s ± 0.25 s	M	Yes [ ]
JAB5	MAU Jabber Lockup Protection	18.3.1.6	Jabber not activated by the longest permitted output specified in 9.6.5	M	Yes [ ]

18.5.6.15 Link Integrity Test function

Item	Feature	Subclause	Value/Comment	Status	Support
LI1	Low light detected	18.3.1.7	ORD optical power does not support a BER of 10^{-10} for a duration of 2000 BT, or ORD optical power is < –30 dBm for 2000 BT and does not support a BER of 10^{-10} for a duration of 500 BT	M	Yes [ ]
LI2	Low light not detected	18.3.1.7	ORD optical power exceeds –32.5 dBm or low light condition remains < 30 BT	M	Yes [ ]
	Signals during detected failure	18.3.1.7			
LI3	OTD circuit		OPT_IDL	M	Yes [ ]
LI4	DI circuit		IDL	M	Yes [ ]
LI5	CI circuit		IDL (except when jabber condition is also present)	M	Yes [ ]

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LI6	Link Test Fail state exit conditions	18.3.1.7	ORD optical power exceeds –32.5 dBm for 0.5 s ± 0.25 s	M	Yes [ ]
	Link fail effect on MAU functions	18.3.1.7			
LI7	Transmit		Disable	M	Yes [ ]
LI8	Receive		Disable	M	Yes [ ]
LI9	Loopback		Disable	M	Yes [ ]
LI10	Collision Presence		Disable	M	Yes [ ]
LI11	SQE Test		Disable	M	Yes [ ]
LI12	Link Test Fail Extend state exit condition	18.3.1.7	Deferred until ORD = idle and DO = idle	M	Yes [ ]
LI13	Power-on state	18.3.1.7	Link Test Fail Low Light	O	Yes [ ] No [ ]
LI14	Link status indicator	18.3.1.7	Color=green on=Link Test Pass	O	Yes [ ] No [ ]

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18.5.6.16 MAU state diagram requirements

Item	Feature	Subclause	Value/Comment	Status	Support
SD1	Full duplex mode MAU Transmit and Receive functions state diagram	18.3.2	Meets requirements of Figure 18–1b)	FDX: M	N/A [ ] M: Yes [ ]
SD2	Half duplex Transmit, Receive, Loopback, and Collision Presence functions state diagrams	18.3.2	Meets requirements of Figure 18–1a)	HFC:M	N/A [ ] M: Yes [ ]
SD3	*signal_quality_error* Message Test function state diagram	18.3.2	Meets requirements of Figure 18–2	HDS: M	N/A [ ] M: Yes [ ]
SD4	Jabber function state diagram	18.3.2	Meets requirements of Figure 18–3	M	Yes [ ]
SD5	Link Integrity Test function state diagram	18.3.2	Meets requirements of Figure 18–4	M	Yes [ ]

18.5.6.17 MAU-to-AUI signal characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
ASC1	Signaling rate (stated on label)	7.3.2	10 Mb/s	AUI: M	N/A [ ] M: Yes [ ]
ASC2	CS0 signal frequency (on CI)	7.3.1.2	10 MHz ± 15%	AUI: M	N/A [ ] M: Yes [ ]
ASC3	CS0 signal duty cycle	7.3.1.2	60:40 worst case	AUI: M	N/A [ ] M: Yes [ ]

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18.5.6.18 MAU-to-AUI DI and CI driver characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
ADC1 ADC2	Differential output voltage Idle state Start of idle	7.4.1.1	≤ 40 mV after 80 BT Figure 7–12	AUI: M	N/A [ ] M: Yes [ ]
ADC3	Current into test load while idle	7.4.1.1	4 mA max. after 80 BT	AUI: M	N/A [ ] M: Yes [ ]
ADC4	Requirements after idle	7.4.1.2	1st bit to Figure 7–11	AUI: M	N/A [ ] M: Yes [ ]
ADC5	Common-mode output voltage, ac	7.4.1.3	≤ 2.5 V peak for 30 Hz to 40 kHz, ≤ 160 mV peak for 40 kHz to 10 MHz, Figure 7–13	AUI: M	N/A [ ] M: Yes [ ]
ADC6	Differential output voltage, open circuit	7.4.1.4	13 V peak max.	AUI: M	N/A [ ] M: Yes [ ]
ADC7	Common-mode output voltage, dc	7.4.1.5	≤ 5.5 V, Figure 7–13	AUI: M	N/A [ ] M: Yes [ ]
ADC8	Fault tolerance	7.4.1.6	Figure 7–14	AUI: M	N/A [ ] M: Yes [ ]
ADC9	Fault current	7.4.1.6	≤ 150 mA, any state, Figure 7–14	AUI: M	N/A [ ] M: Yes [ ]

18.5.6.19 AUI-to-MAU DO receiver characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
DO1	Unsquelched threshold	7.4.2.1	160 mV max. differential	AUI: M	N/A [ ] M: Yes [ ]
DO2	Squelch	15.5.1	Reject signals < ±160 mV differential	AUI: M	N/A [ ] M: Yes [ ]
DO3	High to idle transition	7.4.1.1	Must not cause output	AUI: M	N/A [ ] M: Yes [ ]
DO4	Differential input impedance	7.4.2.2	Real part: 77.83 Ω ± 6%, 0 ≤ phase angle ≤ real part ∗ 0.0338	AUI: M	N/A [ ] M: Yes [ ]
DO5	Common-mode range, ac	7.4.2.3	3 V min. for 30 Hz to 40 kHz, 200 mV min. for 40 kHz to 10 MHz	AUI: M	N/A [ ] M: Yes [ ]
DO6	Total common-mode range	7.4.2.4	Magnitude of 0 to 5.5 V ac+dc	AUI: M	N/A [ ] M: Yes [ ]
DO7	Common-mode current limit	7.4.2.4	≤ 1 mA	AUI: M	N/A [ ] M: Yes [ ]
DO8	IDL detection	7.3.1.1	≤ 1.6 BT	AUI: M	N/A [ ] M: Yes [ ]
DO9	Requirements after idle	7.4.2.5	Receiver in specification after start-up delay	AUI: M	N/A [ ] M: Yes [ ]
DO10	Receiver fault tolerance	7.4.2.6	Figure 7–16	AUI: M	N/A [ ] M: Yes [ ]
DO11	Input fault current	7.4.2.6	3 mA max. for Figure 7–16	AUI: M	N/A [ ] M: Yes [ ]

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18.5.6.20 AUI circuit termination

Item	Feature	Subclause	Value/Comment	Status	Support
ACT1	Common-mode termination	7.5.2.6	If used, must be to VC	AUI: M	N/A [ ] M: Yes [ ]
ACT2	Pins 1, 4, 8, 11, 14 impedance to VC circuit	7.5.2.8	≤ 5 Ω at 5 MHz	AUI: M	N/A [ ] M: Yes [ ]
ACT3	Pins 1, 4, 8, 11, 14 coupling to VC circuit	7.5.2.8	Capacitive	AUI: M	N/A [ ] M: Yes [ ]

18.5.6.21 MAU-to-AUI mechanical connections

Item	Feature	Subclause	Value/Comment	Status	Support
AM1	D-type connector dimensions	7.6.2	IEC 60807-2:1992 15-pole male	AUI: M	N/A [ ] M: Yes [ ]
AM2	Shell plating material	7.6.2	Conductive	AUI: M	N/A [ ] M: Yes [ ]
AM3	Shell multiple contact points	7.6.2	Number not defined (recommended)	AUI: M	N/A [ ] M: Yes [ ]
AM4	Shell life expectancy	7.6.2	≤ 5 mΩ after 500 matings	AUI: M	N/A [ ] M: Yes [ ]
AM5	Locking posts and mounting	7.6.1	Figures 7–18 and 7–20	AUI: M	N/A [ ] M: Yes [ ]
	Pin connections	7.6.3	Circuit		
AM6	3		Data Out A	AUI: M	N/A [ ] M: Yes [ ]
AM7	10		Data Out B	AUI: M	N/A [ ] M: Yes [ ]
AM8	11		Capacitor to VC	AUI: M	N/A [ ] M: Yes [ ]
AM9	5		Data In A	AUI: M	N/A [ ] M: Yes [ ]
AM10	12		Data In B	AUI: M	N/A [ ] M: Yes [ ]
AM11	4		Capacitor to VC	AUI: M	N/A [ ] M: Yes [ ]
AM12	7		No connection	AUI: M	N/A [ ] M: Yes [ ]
AM13	15		No connection	AUI: M	N/A [ ] M: Yes [ ]
AM14	8		Capacitor to VC	AUI: M	N/A [ ] M: Yes [ ]
AM15	2		Control In A	AUI: M	N/A [ ] M: Yes [ ]
AM16	9		Control In B	AUI: M	N/A [ ] M: Yes [ ]
AM17	1		Capacitor to VC	AUI: M	N/A [ ] M: Yes [ ]
AM18	6		Voltage common	AUI: M	N/A [ ] M: Yes [ ]
AM19	13		Voltage plus	AUI: M	N/A [ ] M: Yes [ ]
AM20	14		Capacitor to VC	AUI: M	N/A [ ] M: Yes [ ]
AM21	Shell		Isolated from all pins	AUI: M	N/A [ ] M: Yes [ ]

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18.5.6.22 MAU reliability

Item	Feature	Subclause	Value/Comment	Status	Support
MR1	Mean Time Before Failure	15.4	$> 10^7$ hours without causing communications failure among other stations	M	Yes [ ]

18.5.6.23 Power consumption

Item	Feature	Subclause	Value/Comment	Status	Support
PC1	Power surge limitation	15.5.3	$< 2 \times 10^{-3}$ A–s	APW: M	N/A [ ] M: Yes [ ]
PC2	Power surge duration	15.5.3	100 ms max.	APW: M	N/A [ ] M: Yes [ ]
PC3	Steady-state current drawn power-up capability:	15.5.3	≤ 0.5 A	APW: M	N/A [ ] M: Yes [ ]
PC4	Current-limited sources	15.5.3	0.5 A limited	APW: M	N/A [ ] M: Yes [ ]
PC5	Voltage-limited sources	7.5.2.5	11.28 to 15.75 V via any AUI cable	APW: M	N/A [ ] M: Yes [ ]
PC6	Labeling	15.5.3	As in 15.5.3	APW: M	N/A [ ] M: Yes [ ]
PC7	Power cycle behavior	15.5.3	No extraneous signals on MDI, DI, or CI	AUI: M	N/A [ ] M: Yes [ ]
PC8	Low VP behavior	7.5.2.5	No disruption of media	APW: M	N/A [ ] M: Yes [ ]
PC9	Power sourced on pin 13 of AUI	15.5.3	None if separate power source is implemented	SPW: X	N/A [ ] X: Yes [ ]
PC10	Optional power source isolation	15.5.3	If implemented, shall withstand one of 15.3.4 tests	SPW: M	N/A [ ] M: Yes [ ]

18.5.6.24 PLS–PMA requirements

Item	Feature	Subclause	Value/Comment	Status	Support
PMA1	Messages between PLS in DTE or Repeater and PMA	15.5.4	As in 7.2.1	M	Yes [ ]

18.5.6.25 *signal_quality_error* message (SQE)

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Item	Feature	Subclause	Value/Comment	Status	Support
SQE1	Local MAU transmitting and no collision or fault detected	15.5.4.2.1	*MAU_available* sent on CI	M	Yes [ ]
SQE2	Whenever a collision exists as described in 18.3.1.4	15.5.4.2.1	SQE sent	HFC: M	N/A [ ] M: Yes [ ]
SQE3	SQE Test as described in 18.3.1.5	15.5.4.2.1	SQE sent	HDS:M RPT: X	N/A [ ] M: Yes [ ] N/A [ ] X: Yes [ ]
SQE4	Jabber Condition exists as described in 18.3.1.6	15.5.4.2.1	SQE sent	HFC:M	N/A [ ] M: Yes [ ]
SQE5	Message sent in the absence of SQE	15.5.4.2.1	*MAU_available* message	M	Yes [ ]

18.5.6.26 Environmental requirements

Item	Feature	Subclause	Value/Comment	Status	Support
E1	Ambient Plane Wave field in which MAU meets specification	15.6.2	2 V/m from 10 kHz to 30 MHz. 5 V/m from 30 MHz to 1 GHz.	M	Yes [ ]
E2	Electromagnetic Emissions and Susceptibility	15.6.2	Comply with local and/or national requirements. If none exist, comply with CISPR 22: 1993.	M	Yes [ ]

18.5.6.27 MAU labeling

Item	Feature	Subclause	Value/Comment	Status	Support
LBL1	MAU type	15.7	10BASE-FL	O	Yes [ ] No [ ]
LBL2	Data rate	15.7	10 Mb/s	O	Yes [ ] No [ ]
LBL3	Power level	15.7	Maximum current drain	O	Yes [ ] No [ ]
LBL4	Safety warnings	15.7	Any applicable	O	Yes [ ] No [ ]
LBL5	Port labeling	15.7	Input and output	O	Yes [ ] No [ ]
LBL6	Full duplex mode	15.7	Full duplex capable	FDX: O	N/A [ ] Yes [ ] No [ ]

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19. Layer Management for 10 Mb/s baseband repeaters

Clause 19 is deprecated by Clause 30.

19.1 Introduction

The Repeater Management specification has been developed in accordance with the OSI management architecture as specified in ISO/IEC 7498-4: 1989 and the specific requirements of IEEE Std 802.1F-1993. Implementation of this clause is not a requirement for conformance to Clause 9.

19.1.1 Scope

This clause defines a set of mechanisms that enable management of Ethernet 10 Mb/s baseband repeater units. The managed objects within this International Standard are defined in terms of their behaviour, attributes, actions, notifications, and packages in accordance with IEEE 802.1 and ISO/IEC International Standards for network management. Managed objects are grouped into mandatory and optional packages.

This International Standard is defined to be independent of any particular management application or management protocol. The means by which the managed objects defined in this International Standard are accessed is beyond the scope of this International Standard.

19.1.2 Relationship to objects in IEEE Std 802.1F-1993

The following managed object classes, if supported by an implementation, shall be as specified in IEEE Std 802.1F-1993: oResourceTypeID, oEWMAMetricMonitor:

a) **oResourceTypeID.** This object class is mandatory and shall be implemented as defined in IEEE Std 802.1F-1993. This object is bound to repeater as defined by the NAMEBINDING in 19.2.4 and H.2.2.1.
b) **oEWMAMetricMonitor.** This object class is optional. When implemented, it shall be implemented as defined in IEEE Std 802.1F-1993, subject to the specific requirements described below. This object is bound to system as defined by the NAMEBINDING in H.2.2.1.

Implementations of Repeater Management that support the oEWMAMetricMonitor managed object class are required to support values of aGranularityPeriod as small as one second. Implementations are required to support at least one sequence of low and high thresholds. The granularity period may be set to equal to the moving time period as a minimal conformant implementation.

19.1.3 Definitions

See 1.4.

19.1.4 Symbols and abbreviations

See 1.5.

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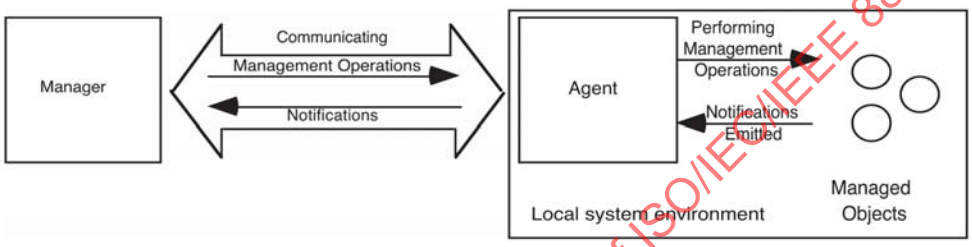
19.1.5 Management model

This International Standard describes management of repeaters in terms of a general model of management of resources within the open systems environment. The model is described in ISO/IEC 10040: 1992, a brief summary of the model is included here.

Management is viewed as a distributed application modeled as a set of interacting management processes. These processes are executed by systems within the open environment. A managing system executes a managing process that invokes management operations. A managed system executes a process that is receptive to these management operations and provides an interface to the resources to be managed. A managed object is the abstraction of a resource that represents its properties as seen by (and for the purpose of) management. Managed objects respond to a defined set of management operations. Managed objects are also capable of emitting a defined set of notifications. This interaction of processes is shown in Figure 19–1.



NOTE—Figure 1 of ISO/IEC 10040 has been reproduced with the permission of ISO. Copies of the complete standard may be obtained from the International Organization for Standardization, Case Postale 56, 1 rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse.

Figure 19–1—Interaction between manager, agent, and objects

A managed object is a management view of a resource. The resource may be a logical construct, function, physical device, or anything subject to management. Managed objects are defined in terms of four types of elements:

a) *Attributes*. Data-like properties (as seen by management) of a managed object.
b) *Actions*. Operations that a managing process may perform on an object or its attributes.
c) *Notifications*. Unsolicited reports of events that may be generated by an object.
d) *Behaviour*. The way in which managed objects, attributes, and actions interact with the actual resources they model and with each other.

The above items are defined in 19.2.3 through 19.2.6 of this International Standard in terms of the template requirements of ISO/IEC 10165-4: 1992.

Some of the functions and resources within a repeater are appropriate targets for management. They have been identified by specifying managed objects that provide a management view of the functions or resources. Within this general model, a repeater is viewed as a managed device. It performs functions as defined by the applicable standard for such a device. Managed objects providing a view of those functions and resources appropriate to the management of a repeater are specified. The purpose of this International Standard is to define the object classes associated with repeaters in terms of their attributes, operations, notifications, and behaviour.

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19.2 Managed objects

19.2.1 Introduction

This document defines the management of IEEE 802.3 repeaters by defining associated managed objects. This management encompasses two distinct aspects of repeater management.

The first aspect provides the means to monitor and control the functions of a repeater. These functions include, but are not limited to, identifying a repeater, testing and initializing a repeater, and enabling/disabling a port.

The second aspect provides the means to monitor traffic from attached segments, and to measure traffic sourced by DTEs connected to these segments. This is done by gathering statistics on packets that enter a repeater and maintaining those statistics on a per-port basis.

19.2.2 Overview of managed objects

Managed objects provide a means to

a) Identify a resource
b) Control a resource
c) Monitor a resource

19.2.2.1 Text description of managed objects

In case of conflict, the formal behaviour definitions in 19.2.3 through 19.2.6 take precedence over the text descriptions in this subclause.

a) **repeater.** The topmost managed object class of that portion of the containment tree shown in Figure 19–3. All other managed objects and their attributes defined in this clause are contained within the repeater managed object.
b) **repeaterMonitor.** A managed object class called out by IEEE Std 802.1F-1993.
c) **resourceTypeID.** A managed object class called out by IEEE Std 802.1F-1993.
d) **group.** The group managed object class is a view of a collection of ports.
e) **port.** The port managed object class provides a view of the functional link between the data transfer service and a single PMA. The attributes associated with port deal with the monitoring of traffic being handled by the repeater from the port and control of the operation of the port. The port enable/disable function as reported by portAdminState is preserved across events involving loss of power.

NOTE—Attachment to nonstandard PMAs is outside the scope of this International Standard.

19.2.2.2 Port functions to support management

The port object class contains seven functions that are used to collect statistics on the activity received by the port. The relationship of the functions to the port and to the port attributes is shown in Figure 19–2.

a) **Activity Timing function.** Measures the duration of the assertion of the CarrierEvent signal. This duration value must be adjusted by removing the value of Carrier Recovery Time (see 9.5.6.5) to obtain the true duration of activity on the network. The output of the Activity Timing function is the ActivityDuration value, which represents the duration of the CarrierEvent signal as expressed in units of bit times.
b) **Carrier Event function.** Asserts the CarrierEvent signal when the repeater exits the IDLE state (see Figure 9–2) and the port has been determined to be port N. It de-asserts the CarrierEvent signal when, for a duration of at least Carrier Recovery Time (see 9.5.6.5), both the DataIn(N) variable has

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the value II and the CollIn(N) variable has the value -SQE. The value N is the port assigned at the time of transition from the IDLE state.

c) **Collision Event function.** Asserts the CollisionEvent signal when the CollIn(X) variable has the value SQE. The CollisionEvent signal remains asserted until the assertion of any CarrierEvent signal due to the reception of the following event.

d) **Cyclic Redundancy Check function.** Verifies that the sequence of octets output by the framing function contains a valid frame check sequence field. The frame check sequence field is the last four octets received from the output of the framing function. The algorithm for generating an FCS from the octet stream is specified in 3.2.9. If the FCS generated according to this algorithm is not the same as the last four octets received from the framing function, then the FCSError signal is asserted. The FCSError signal is cleared upon the assertion of the CarrierEvent signal due to the reception of the following event.

e) **Framing function.** Recognizes the boundaries of an incoming frame by monitoring the CarrierEvent signal and the decoded data stream. Data bits are accepted while the CarrierEvent signal is asserted. The framing function strips preamble and start of frame delimiter from the received data stream. The remaining bits are aligned along octet boundaries. If there is not an integral number of octets, then FramingError shall be asserted. The FramingError signal is cleared upon the assertion of the CarrierEvent signal due to the reception of the following event.

f) **Octet Counting function.** Counts the number of complete octets received from the output of the framing function. The output of the octet counting function is the OctetCount value. The OctetCount value is reset to zero upon the assertion of the CarrierEvent signal due to the reception of the following event.

g) **Source Address function.** Extracts octets from the stream output by the framing function. The seventh through twelfth octets shall be extracted from the octet stream and output as the SourceAddress variable. The SourceAddress variable is set to an invalid state upon the assertion of the CarrierEvent signal due to the reception of the following event.

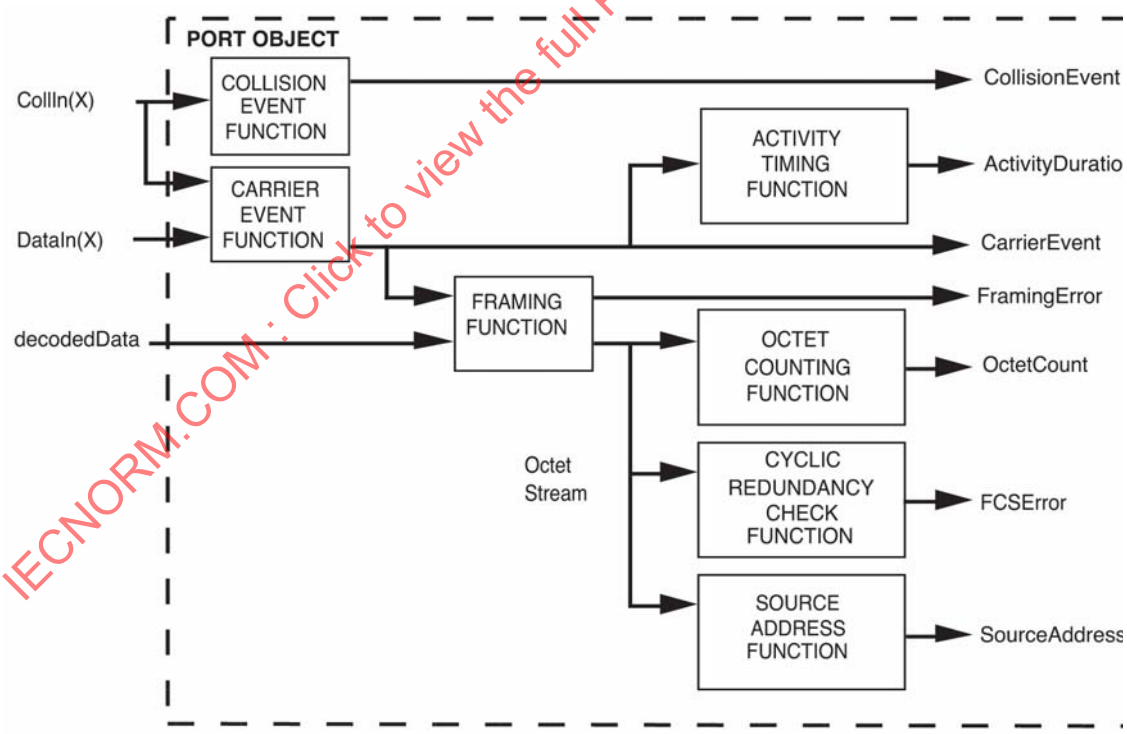

Figure 19–2—Functions relationship

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19.2.2.3 Containment

A containment relationship is a structuring relationship for managed objects in which the existence of a managed object is dependent on the existence of a containing managed object. The contained managed object is said to be the subordinate managed object and the containing managed object the superior managed object. The containment relationship is used for naming managed objects. The local containment relationships among object classes are depicted in Figure 19–3. This figure also shows the names, naming attributes, and data attributes of the object classes as well as whether a particular containment relationship is one-to-one or one-to-many. For further requirements on this topic, see IEEE Std 802.1F-1993.

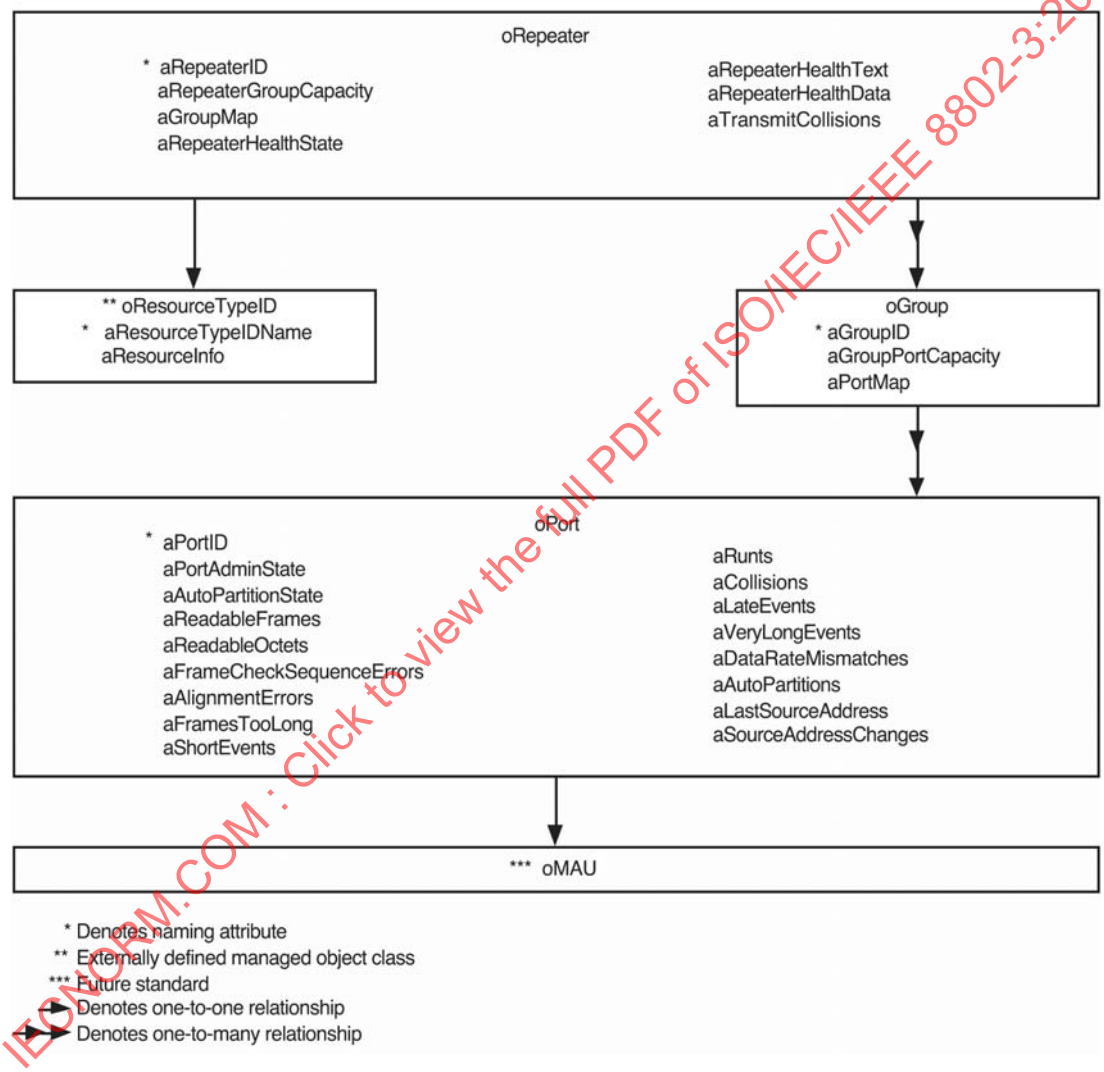

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Figure 19–3—Entity relationship diagram

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19.2.2.4 Naming

The name of an individual managed object is hierarchically defined within a managed system. For example, a port might be identified as “repeater 3, group 01, port 13,” that is, port 13 of group 01 of a repeater with repeaterID 3 within the managed system. This is represented in the relationship of the naming attributes in Figure 19–3.

19.2.2.5 Packages and capabilities

This International Standard makes use of the concept of “packages” as defined in ISO/IEC 10165-4: 1992 as a means of grouping behaviour, attributes, actions, and notifications within a managed object class definition. Packages may either be mandatory or conditional, that is to say, present if a given condition is true. Within this International Standard, “capabilities” are defined, each of which corresponds to a set of packages, which are components of a number of managed object class definitions and which share the same condition for presence. The “Basic Control Capability” consists of the set of mandatory packages. All other capabilities are optional and comprise sets of conditional packages. For a managed repeater to be conformant to this International Standard, it shall fully implement the Basic Control Capability. For the repeater to be conformant to an optional capability, it shall implement that entire capability. The capabilities and their associated packages are summarized in Table 19–1 (see facing page).

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Table 19–1—Packages and capabilities

		Basic Control Capability (Mandatory)	Performance Monitor Capability (Optional)	Address Tracking Capability (Optional)
oRepeater managed object class				
aRepeaterID	ATTRIBUTE GET	X		
aRepeaterGroupCapacity	ATTRIBUTE GET	X		
aGroupMap	ATTRIBUTE GET	X		
aRepeaterHealthState	ATTRIBUTE GET	X		
aRepeaterHealthText	ATTRIBUTE GET	X		
aRepeaterHealthData	ATTRIBUTE GET	X		
aTransmitCollisions	ATTRIBUTE GET		X	
acResetRepeater	ACTION	X		
acExecuteNonDisruptiveSelfTest	ACTION	X		
nRepeaterHealth	NOTIFICATION	X		
nRepeaterReset	NOTIFICATION	X		
nGroupMapChange	NOTIFICATION	X		
oResourceTypeID managed object class				
aResourceTypeIDName	ATTRIBUTE GET	X		
aResourceInfo	ATTRIBUTE GET	X		
oGroup managed object class				
aGroupID	ATTRIBUTE GET	X		
aGroupPortCapacity	ATTRIBUTE GET	X		
aPortMap	ATTRIBUTE GET	X		
nPortMapChange	NOTIFICATION	X		
oPort managed object class				
aPortID	ATTRIBUTE GET	X		
aPortAdminState	ATTRIBUTE GET	X		
aAutoPartitionState	ATTRIBUTE GET	X		
aReadableFrames	ATTRIBUTE GET		X	
aReadableOctets	ATTRIBUTE GET		X	
aFrameCheckSequenceErrors	ATTRIBUTE GET		X	
aAlignmentErrors	ATTRIBUTE GET		X	
aFramesTooLong	ATTRIBUTE GET		X	
aShortEvents	ATTRIBUTE GET		X	
aRunts	ATTRIBUTE GET		X	
aCollisions	ATTRIBUTE GET		X	
aLateEvents	ATTRIBUTE GET		X	
aVeryLongEvents	ATTRIBUTE GET		X	
aDataRateMismatches	ATTRIBUTE GET		X	
aAutoPartitions	ATTRIBUTE GET		X	
aLastSourceAddress	ATTRIBUTE GET			X
aSourceAddressChanges	ATTRIBUTE GET			X
acPortAdminControl	ACTION	X		
Common Attributes Template				
aRMCounter	ATTRIBUTE GET		X	X

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19.2.3 Repeater managed object class

This subclause formally defines the behaviours for Repeater managed object classes, attributes, actions, and notifications.

19.2.3.1 Repeater attributes

19.2.3.1.1 aRepeaterID

ATTRIBUTE
APPROPRIATE SYNTAX
INTEGER
BEHAVIOUR DEFINED AS:
The value of aRepeaterID is assigned so as to uniquely identify a repeater among the subordinate managed objects of system (systemID and system are defined in ISO/IEC 10165-2: 1992).

19.2.3.1.2 aRepeaterGroupCapacity

ATTRIBUTE
APPROPRIATE SYNTAX
INTEGER
BEHAVIOUR DEFINED AS:
The aRepeaterGroupCapacity is the number of groups that can be contained within the repeater. Within each managed repeater, the groups are uniquely numbered in the range from 1 to aRepeaterGroupCapacity. Some groups may not be present in a given repeater instance, in which case the actual number of groups present is less than aRepeaterGroupCapacity. The number of groups present is never greater than aRepeaterGroupCapacity.

19.2.3.1.3 aGroupMap

ATTRIBUTE
APPROPRIATE SYNTAX
BITSTRING
BEHAVIOUR DEFINED AS:
A string of bits which reflects the current configuration of units which are viewed by group managed objects. The length of the bitstring is "aRepeaterGroupCapacity" bits. The first bit relates to group 1. A "1" in the bitstring indicates presence of the group, "0" represents absence of the group.

19.2.3.1.4 aRepeaterHealthState

ATTRIBUTE
APPROPRIATE SYNTAX:
An ENUMERATED VALUE LIST that has the following entries:

other	--undefined or unknown
ok	--no known failures
repeaterFailure	--known to have a repeater related failure
groupFailure	--known to have a group related failure
portFailure	--known to have a port related failure
generalFailure	--has a failure condition, unspecified type

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BEHAVIOUR DEFINED AS:

The aRepeaterHealthState attribute indicates the operational state of the repeater. The aRepeaterHealthData and aRepeaterHealthText attributes may be consulted for more specific information about the state of the Repeater's health. In case of multiple kinds of failures (e.g., repeater failure and port failure), the value of this attribute shall reflect the highest priority in the following order:

repeater failure
group failure
port failure
general failure.

19.2.3.1.5 aRepeaterHealthText

ATTRIBUTE
APPROPRIATE SYNTAX:

A PrintableString, 255 characters max.

BEHAVIOUR DEFINED AS:

The aRepeaterHealthText attribute is a text string that provides information relevant to the operational state of the repeater. Repeater vendors may use this mechanism to provide detailed failure information or instructions for problem resolution.
The contents are vendor specific.

19.2.3.1.6 aRepeaterHealthData

ATTRIBUTE
APPROPRIATE SYNTAX:

OCTET STRING, 0–255.

BEHAVIOUR DEFINED AS:

The aRepeaterHealthData attribute is a block of data octets that provides information relevant to the operational state of the repeater. The encoding of this data block is vendor dependent. Repeater vendors may use this mechanism to provide detailed failure information or instructions for problem resolution.

19.2.3.1.7 aTransmitCollisions

ATTRIBUTE
APPROPRIATE SYNTAX:

Generalized non-resettable counter. This counter has a maximum increment rate of 75 000 counts per second.

BEHAVIOUR DEFINED AS:

This counter is incremented every time the repeater state machine enters the TRANSMIT COLLISION state from any state other than ONE PORT LEFT (see Figure 9–2).

19.2.3.2 Repeater actions

19.2.3.2.1 acResetRepeater

ACTION
APPROPRIATE SYNTAX

None required

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BEHAVIOUR DEFINED AS:

This is the transition to the START state of Figure 9–2 in Clause 9. The repeater performs a disruptive self-test that has the following characteristics:

a) The components are not specified.
b) The test resets the repeater but without affecting management information about the repeater.
c) The test does not inject packets onto any segment.
d) Packets received during the test may or may not be transferred.
e) The test does not interfere with management functions.

This causes an nRepeaterReset notification to be sent.

19.2.3.2.2 acExecuteNonDisruptiveSelfTest

ACTION

APPROPRIATE SYNTAX

None required

BEHAVIOUR DEFINED AS:

The repeater performs a vendor-specific, non-disruptive self-test that has the following characteristics:

a) The components are not specified.
b) The test does not change the state of the repeater or management information about the repeater.
c) The test does not inject packets onto any segment.
d) The test does not prevent the transfer of any packets.
e) Completion of the test causes an nRepeaterHealth to be sent.

19.2.3.3 Repeater notifications

19.2.3.3.1 nRepeaterHealth

NOTIFICATION

APPROPRIATE SYNTAX

A SEQUENCE of 3 data types. The first is mandatory, the following two are optional. The first is value of the attribute aRepeaterHealthState. The second is the value of the attribute aRepeaterHealthText. The third is the value of the attribute aRepeaterHealthData.

BEHAVIOUR DEFINED AS:

This notification conveys information related to the operational state of the repeater. See the aRepeaterHealthState, aRepeaterHealthText, and aRepeaterHealthData attributes for descriptions of the information that is sent. The nRepeaterHealth notification is sent only when the health state of the repeater changes. The nRepeaterHealth notification shall contain repeaterHealthState. repeaterHealthData and repeaterHealthText may or may not be included. The nRepeaterHealth notification is not sent as a result of powering up a repeater.

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19.2.3.3.2 nRepeaterReset

NOTIFICATION
APPROPRIATE SYNTAX
A SEQUENCE of 3 data types. The first is mandatory, the following two are optional. The first is value of the attribute aRepeaterHealthState. The second is the value of the attribute aRepeaterHealthText. The third is the value of the attribute aRepeaterHealthData.
BEHAVIOUR DEFINED AS:
This notification conveys information related to the operational state of the repeater. The nRepeaterReset notification is sent when the repeater is reset as the result of a power-on condition or upon completion of the acResetRepeater action. The nRepeaterReset notification shall contain repeaterHealthState. repeaterHealthData and RepeaterHealthText may, or may not be included.

19.2.3.3.3 nGroupMapChange

NOTIFICATION
APPROPRIATE SYNTAX
BITSTRING
BEHAVIOUR DEFINED AS:
This notification is sent when a change occurs in the group structure of a repeater. This occurs only when a group is logically removed from or added to a repeater. The nGroupMapChange notification is not sent when powering up a repeater. The value of the notification is the updated value of the aGroupMap attribute.

19.2.4 ResourceTypeID Managed Object Class

Implementation of this managed object in accordance with the definition contained in IEEE Std 802.1F-1993 is a conformance requirement of this International Standard. A single instance of the Resource Type ID managed object exists within the Repeater managed object class. The managed object itself is contained in IEEE Std 802.1F-1993; therefore, only the name binding appears in this International Standard.

19.2.5 Group managed object class

This subclause formally defines the behaviours for Group managed object classes attributes and notification.

19.2.5.1 Group attributes

19.2.5.1.1 aGroupID

ATTRIBUTE
APPROPRIATE SYNTAX
INTEGER
BEHAVIOUR DEFINED AS:
A value unique within the repeater. This value is never greater than aRepeaterGroupCapacity.

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19.2.5.1.2 aGroupPortCapacity

ATTRIBUTE
APPROPRIATE SYNTAX
INTEGER
BEHAVIOUR DEFINED AS:
The aGroupPortCapacity is the number of ports contained within the group. Valid range is 1–1024. Within each group, the ports are uniquely numbered in the range from 1 to aGroupPortCapacity. Some ports may not be present in a given group instance, in which case the actual number of ports present is less than aGroupPortCapacity. The number of ports present is never greater than aGroupPortCapacity.

19.2.5.1.3 aPortMap

ATTRIBUTE
APPROPRIATE SYNTAX
BitString
BEHAVIOUR DEFINED AS:
A string of bits which reflects the current configuration of port managed objects within this group. The length of the bitstring is "aGroupPortCapacity" bits. The first bit relates to group 1. A "1" in the bitstring indicates presence of the port, "0" represents absence of the port.

19.2.5.2 Group Notifications

19.2.5.2.1 nPortMapChange

NOTIFICATION
APPROPRIATE SYNTAX
BitString
BEHAVIOUR DEFINED AS:
This notification is sent when a change occurs in the port structure of a group. This occurs only when a port is logically removed from or added to a group. The nPortMapChange notification is not sent when powering up a repeater. The value of the notification is the updated value of the aPortMap attribute.

19.2.6 Port managed object class

This subclause formally defines the behaviours for Port managed object classes attributes and action.

19.2.6.1 Port Attributes

19.2.6.1.1 aPortID

ATTRIBUTE
APPROPRIATE SYNTAX
INTEGER
BEHAVIOUR DEFINED AS:
A value unique in the group. It is assumed that ports are partitioned into groups that also have IDs. This value can never be greater than aGroupPortCapacity.

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19.2.6.1.2 aPortAdminState

ATTRIBUTE
APPROPRIATE SYNTAX:
An ENUMERATED VALUE LIST that has the following entries.
disabled
enabled
BEHAVIOUR DEFINED AS:
A disabled port neither transmits nor receives. The port shall be explicitly enabled to restore operation. The acPortAdminControl action provides this ability. The port enable/disable function as reported by this attribute is preserved across repeater reset including loss of power.
aPortAdminState takes precedence over auto-partition and functionally operates between the auto-partition mechanism and the AUI/PMA. Auto-partition is reinitialized whenever acPortAdminControl is enabled.

19.2.6.1.3 aAutoPartitionState

ATTRIBUTE
APPROPRIATE SYNTAX:
An ENUMERATED VALUE LIST that has the following entries.
autoPartitioned
notAutoPartitioned
BEHAVIOUR DEFINED AS:
The aAutoPartitionState flag indicates whether the port is currently partitioned by the repeater's auto-partition protection. The conditions that cause port partitioning are specified in partition state machine in Clause 9. They are not differentiated here.

19.2.6.1.4 aReadableFrames

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized non-resettable counter. This counter has a maximum increment rate of 15 000 counts per second.
BEHAVIOUR DEFINED AS:
A representation of the total frames of valid frame length. Increment counter by one for each frame whose OctetCount is greater than or equal to minFrameSize and less than or equal to maxFrameSize (see 4.4.2) and for which the FCSError and CollisionEvent signals are not asserted.

NOTE—This statistic provides one of the parameters necessary for obtaining the packet error ratio.

19.2.6.1.5 aReadableOctets

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized non-resettable counter. This counter has a maximum increment rate of 1 240 000 counts per second.
BEHAVIOUR DEFINED AS:
Increment counter by OctetCount for each frame which has been determined to be a readable frame.

NOTE—This statistic provides an indicator of the total data transferred.

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19.2.6.1.6 aFrameCheckSequenceErrors

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized non-resettable counter. This counter has a maximum increment rate of 15 000 counts per second.
BEHAVIOUR DEFINED AS:
Increment counter by one for each frame with the FCSError signal asserted and the FramingError and CollisionEvent signals deasserted and whose OctetCount is greater than or equal to minFrameSize and less than or equal to maxFrameSize (see 4.4.2).

19.2.6.1.7 aAlignmentErrors

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized non-resettable counter. This counter has a maximum increment rate of 15 000 counts per second.
BEHAVIOUR DEFINED AS:
Increment counter by one for each frame with the FCSError and FramingError signals asserted and CollisionEvent signal deasserted and whose OctetCount is greater than or equal to minFrameSize and less than or equal to maxFrameSize (see 4.4.2). If aAlignmentErrors is incremented then the aFrameCheckSequenceErrors attribute shall not be incremented for the same frame.

19.2.6.1.8 aFramesTooLong

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized non-resettable counter. This counter has a maximum increment rate of 815 counts per second.
BEHAVIOUR DEFINED AS:
Increment counter by one for each frame whose OctetCount is greater than maxFrameSize (see 4.4.2). If aFrameTooLong is counted then neither the aAlignmentErrors nor the aFrameCheckSequenceErrors attribute shall be incremented for the frame.

19.2.6.1.9 aShortEvents

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized non-resettable counter. This counter has a maximum increment rate of 75 000 counts per second.
BEHAVIOUR DEFINED AS:
Increment counter by one for each CarrierEvent with ActivityDuration less than ShortEventMaxTime. ShortEventMaxTime is greater than 74 bit times and less than 82 bit times. ShortEventMaxTime has tolerances included to provide for circuit losses between a conformance test point at the AUI and the measurement point within the state machine.

NOTE—shortEvents may indicate externally generated noise hits which will cause the repeater to transmit Runts to its other ports, or propagate a collision (which may be late) back to the transmitting DTE and damaged frames to the rest of the network.

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Implementers may wish to consider selecting the ShortEventMaxTime towards the lower end of the allowed tolerance range to accommodate bit losses suffered through physical channel devices not budgeted for within this International Standard.

19.2.6.1.10 aRunts

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized non-resettable counter. This counter has a maximum increment rate of 75 000 counts per second.
BEHAVIOUR DEFINED AS:
Increment counter by one for each CarrierEvent that meets one of the following two conditions. Only one test need be made. (1) The ActivityDuration is greater than ShortEventMaxTime and less than ValidPacketMinTime and the CollisionEvent signal is deasserted. (2) The OctetCount is less than 64, the ActivityDuration is greater than ShortEventMaxTime and the CollisionEvent signal is deasserted. ValidPacketMinTime is greater than or equal to 552 bit times and less than 565 bit times. An event whose length is greater than 74 bit times but less than 82 bit times shall increment either the aShortEvents attribute or the aRunts attribute but not both. A CarrierEvent greater than or equal to 552 bit times but less than 565 bit times may or may not be counted as a runt. ValidPacketMinTime has tolerances included to provide for circuit losses between a conformance test point at the AUI and the measurement point within the state machine.

NOTE—Runts usually indicate collision fragments, a normal network event. In certain situations associated with large diameter networks a percentage of runts may exceed ValidPacketMinTime.

19.2.6.1.11 aCollisions

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized non-resettable counter. This counter has a maximum increment rate of 75 000 counts per second.
BEHAVIOUR DEFINED AS:
Increment counter by one for each CarrierEvent in which the CollisionEvent signal is asserted.
Increment counter by one for any CarrierEvent signal on any port in which the CollisionEvent signal on this port is asserted.

19.2.6.1.12 aLateEvents

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized non-resettable counter. This counter has a maximum increment rate of 75 000 counts per second.
BEHAVIOUR DEFINED AS:
Increment counter by one for each CarrierEvent in which the CollIn(X) variable transitions to the value SQE (see 9.9.6.2) while the ActivityDuration is greater than the LateEventThreshold. Such a CarrierEvent is counted twice, as both a aCollision and as a aLateEvent. The LateEventThreshold is greater than 480 bit times and less than 565 bit times. LateEventThreshold has tolerances included to permit an

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implementation to build a single threshold to serve as both the LateEventThreshold and ValidPacketMinTime threshold.

19.2.6.1.13 aVeryLongEvents

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized non-resettable counter. This counter has a maximum increment rate of 250 counts per second.
BEHAVIOUR DEFINED AS:
Increment counter by one for each CarrierEvent whose ActivityDuration is greater than the MAU Jabber Lockup Protection timer TW3 (see 9.6.1, 9.6.5). Other counters may be incremented as appropriate.

19.2.6.1.14 aDataRateMismatches

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized non-resettable counter.
BEHAVIOUR DEFINED AS:
Increment counter by one for each frame received by this port that meets all of the conditions required by only one of the following two measurement methods: Measurement method A: 1) The CollisionEvent signal is not asserted. 2) The ActivityDuration is greater than ValidPacketMinTime. 3) The frequency (data rate) is detectably mismatched from the local transmit frequency. Measurement method B: 1) The CollisionEvent signal is not asserted. 2) The OctetCount is greater than 63. 3) The frequency (data rate) is detectably mismatched from the local transmit frequency. The exact degree of mismatch is vendor specific and is to be defined by the vendor for conformance testing.
When this event occurs, other counters whose increment conditions were satisfied may or may not also be incremented, at the implementer's discretion.

NOTE—Whether or not the repeater was able to maintain data integrity is beyond the scope of this International Standard.

19.2.6.1.15 aAutoPartitions

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized non-resettable counter.
BEHAVIOUR DEFINED AS:
Increment counter by one for each time that the repeater has automatically partitioned this port. The conditions that cause port partitioning are specified in the partition state machine in Clause 9. They are not differentiated here.

19.2.6.1.16 aLastSourceAddress

ATTRIBUTE
APPROPRIATE SYNTAX:
MACAddress
BEHAVIOUR DEFINED AS:

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The aLastSourceAddress attribute is the Source Address of the last readableFrame received by this port.

19.2.6.1.17 aSourceAddressChanges

ATTRIBUTE
APPROPRIATE SYNTAX:
Generalized non-resettable counter. This counter has a maximum increment rate of 15 000 counts per second.
BEHAVIOUR DEFINED AS:
Increment counter by one each time that the aLastSourceAddress attribute has changed.

NOTE—This may indicate whether a link is connected to a single DTE or another multiuser segment.

19.2.6.2 Port Actions

19.2.6.2.1 acPortAdminControl

ACTION
APPROPRIATE SYNTAX:
Same as aPortAdminState.
BEHAVIOUR DEFINED AS:
This action provides a means to alter aPortAdminState and exert a BEGIN on the Auto-Partition state machine (Figure 9–6) upon taking the value “enabled”.

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20. Layer Management for 10 Mb/s baseband medium attachment units

Clause 20 is deprecated by Clause 30.

20.1 Introduction

The MAU Management specification has been developed in accordance with the Open Systems Interconnection (OSI) management architecture as specified in ISO/IEC 7498-4: 1989.

20.1.1 Scope

This clause defines a set of mechanisms that enable management of IEEE 802.3 10 Mb/s integrated Medium Attachment Units (MAUs). In addition, for ports without integral MAUs, attributes are provided for characteristics observable from the AUI of the connected DTE or repeater. Direct management of MAUs that are external to their respective DTEs or repeaters is beyond the scope of this standard. The managed objects within this standard are defined as sets of attributes, actions, notifications, and behaviours in accordance with IEEE Std 802.1-1990 and ISO/IEC International Standards for network management. This clause builds upon the concepts and terminology that are defined more fully in Clause 19.

This standard is defined to be independent of any particular management application or management protocol. The means by which the managed objects defined in this standard are accessed is beyond the scope of this standard.

20.1.2 Management model

See 19.1.5.

20.2 Managed objects

20.2.1 Text description of managed objects

In case of conflict, the formal behaviour definitions in Annex H.3 take precedence over the text descriptions in this clause.

a) **oRepeaterPort.** The managed object that contains the MAU managed object in a repeater set.
b) **oDTEPort.** The managed object that contains the MAU managed object in a DTE.
c) **oMAU.** The managed object of that portion of the containment tree shown in Figure 20–1. The attributes, notifications and actions defined in this clause are contained within the MAU managed object.

Neither counter values nor the value of aMAUadminState is required to be preserved across events involving the loss of power.

20.2.1.1 Naming

The name of an individual managed object is hierarchically defined within a managed system. In the case of MAU management, this will present itself in one of the two forms that are appropriate for a MAU's use, that is, as associated with a CSMA/CD interface of a DTE or with a particular port of a managed repeater. For example, a MAU could be identified as "repeater 3, group 01, port 13, mau 1," that is, the MAU associated with port 13 of group 01 of a repeater with repeaterID 3 within the managed system. An example of this is represented in the relationship of the naming attributes in the Entity Relationship Diagram, Figure 19–3.

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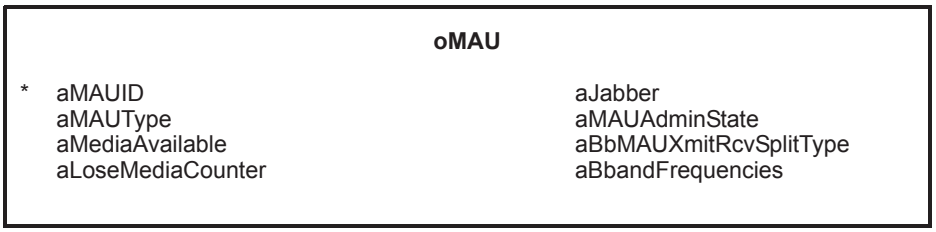

NOTE—The * denotes naming attribute.

Figure 20–1—Entity relationship diagram

20.2.1.2 Containment

A containment relationship is a structuring relationship for managed objects in which the existence of a managed object is dependent on the existence of a containing managed object. The contained managed object is said to be the subordinate managed object, and the containing managed object the superior managed object. MAU management is only valid in a system that provides management at the next higher containment level, that is, either a DTE or Repeater with Layer Management. The containment relationships among object classes are depicted in the Entity Relationship Diagram, Figure 20–1, and specified in the name bindings in Annex H, H.3.1.

20.2.1.3 Packages

This standard and ISO/IEC guidelines make provision for grouping attributes, actions, and notifications in implementation groups, or "packages," within each managed object class. The "Basic Control Package" is mandatory; all other packages are optional. For a managed MAU to be conformant to this standard, it shall fully implement the Basic Control Package. For a MAU to be conformant to an optional package, it shall implement that entire package. While nonconformant (reference aMAUType = "other") MAUs may utilize some or all of this clause to specify their management, conformance to this clause requires both a conformant MAU and conformant management. MAU Management is optional with respect to all other CSMA/CD Management. The packages are summarized in Table 20–1.

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Table 20–1—Packages

			Basic Package (Mandatory)	MAU Control Package (Optional)	Media Loss Tracking Package (Conditional)	Broadband DTE MAU Package (Conditional
MAU managed object class						
aMAUID	ATTRIBUTE	GET	X			
aMAUType	ATTRIBUTE	GET	X			
aMediaAvailable	ATTRIBUTE	GET	X			
aLoseMediaCounter	ATTRIBUTE	GET			X	
aJabber	ATTRIBUTE	GET	X			
aMAUAdminState	ATTRIBUTE	GET	X			
aBbMAUXmitRcvSplitType	ATTRIBUTE	GET				X
aBroadbandFrequencies	ATTRIBUTE	GET				X
acResetMAUAction	ACTION			X		
acMAUAdminControl	ACTION			X		
nJabber	NOTIFICATION		X			

20.2.2 MAU Managed object class

This subclause formally defines the behaviours for MAU Management objects, attributes, actions, and notifications.

20.2.2.1 MAU attributes

20.2.2.1.1 aMAUID

ATTRIBUTE
APPROPRIATE SYNTAX:
INTEGER
BEHAVIOUR DEFINED AS:
The value of aMAUID is assigned so as to uniquely identify a MAU among the subordinate managed objects of the containing object.

20.2.2.1.2 aMAUType

ATTRIBUTE
APPROPRIATE SYNTAX:
An INTEGER that meets the requirements of the description below. Additional values are needed for following types:

global	--reserved for future use
other	--see 20.2.1.3
unknown	--initializing, true state or type not yet known

BEHAVIOUR DEFINED AS:
Returns a value that identifies the 10 Mb/s internal MAU type. The enumeration of the type is such that the value matches the clause number of the standard that specifies the particular MAU. If an AUI is to be identified to access an external MAU, then type “AUI” is returned.

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20.2.2.1.3 aMediaAvailable

ATTRIBUTE
APPROPRIATE SYNTAX:

An ENUMERATED value list that has the following entries:

other	--undefined
unknown	--initializing, true state not yet known
available	--link or light normal, loopback normal
not available	--link loss or low light, no loop back
remote fault	--remote fault, applies only to 10BASE-FB
invalid signal	--invalid signal, applies only to 10BASE-FB

BEHAVIOUR DEFINED AS:

If the MAU is a link or fiber type (FOIRL, 10BASE-T, 10BASE-F), then this is equivalent to the link test fail state/low light function. For an AUI or a coaxial cable (including broadband) MAU, this indicates whether or not loopback is detected on the DI circuit. The value of this attribute persists between packets for MAU types AUI, 10BASE5, 10BASE2, 10BROAD36, and 10BASE-FP.

At power-up or following a reset, the value of this attribute will be "unknown" for AUI, 10BASE5, 10BASE2, 10BROAD36, and 10BASE-FP MAUs. For these MAUs, loopback will be tested on each transmission during which no collision is detected. If DI is receiving *input* when DO returns to IDL after a transmission and there has been no collision during the transmission, then loopback will be detected. The value of this attribute will only change during noncollided transmissions for AUI, coaxial cable, and 10BASE-FP MAUs.

20.2.2.1.4 aLoseMediaCounter

ATTRIBUTE
APPROPRIATE SYNTAX:

Generalized nonresetable counter. This counter has a maximum increment rate of 10 counts per second.

BEHAVIOUR DEFINED AS:

Counts the number of times that the MAU leaves MediaAvailState "available." Mandatory for MAU type "AUI," optional for all others.

20.2.2.1.5 aJabber

ATTRIBUTE
APPROPRIATE SYNTAX:

A SEQUENCE of two indications.

The first, JabberFlag, consists of an ENUMERATED value list that has the following entries:

other	--undefined
unknown	--initializing, true state not yet known
normal	--state is true or normal
fault	--state is false, fault, or abnormal

The second, jabberCounter, is a generalized nonresetable counter. This counter has a maximum increment rate of 40 counts per second.

BEHAVIOUR DEFINED AS:

If the MAU is in the jabber state, the jabberFlag portion of the attribute is set to the "fault" value. The jabberCounter portion of the attribute is incremented each time the flag is set to the "fault" value. This attribute returns the value "other" for type AUI.

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20.2.2.1.6 aMAUAdminState

ATTRIBUTE
APPROPRIATE SYNTAX:

An ENUMERATED value list that has the following entries:

other	--undefined
unknown	--initializing, true state not yet known
operational	--powered and connected
standby	--inactive but on
shutdown	--similar to power down

BEHAVIOUR DEFINED AS:

A MAU in management state "standby" forces DI and CI to idle and the media transmitter to idle or fault, if supported. The management state "standby" only applies to link type MAUs. The state of MediaAvailable is unaffected. A MAU or AUI in the management state "shutdown" assumes the same condition on DI, CI, and the media transmitter as if it were powered down or not connected. For an AUI, this management state will remove power from the AUI. The MAU may return the value "undefined" for Jabber and MediaAvailable attributes when it is in this management state. A MAU in the management state "operational" is fully functional, and operates and passes signals to its attached DTE or repeater port in accordance to its specification.

20.2.2.1.7 aBbMAUXmitRcvSplitType

ATTRIBUTE
APPROPRIATE SYNTAX:

An ENUMERATED value list that has the following entries:

other	--undefined
single	--single-cable system
dual	--dual-cable system, offset normally zero

BEHAVIOUR DEFINED AS:

Returns a value that indicates the type of frequency multiplexing/cabling system used to separate the transmit and receive paths for the 10BROAD36 MAU. All other types return "undefined."

20.2.2.1.8 aBroadbandFrequencies

ATTRIBUTE
APPROPRIATE SYNTAX:

A SEQUENCE of two instances of the type INTEGER.
The first INTEGER represents the Transmitter Carrier Frequency. The value of its integer represents the frequency of the carrier divided by 250 kHz.
The second INTEGER represents the Translation Offset Frequency. The value of its integer represents the frequency of the offset divided by 250 kHz.

BEHAVIOUR DEFINED AS:

Returns a value that indicates the transmit carrier frequency and translation offset frequency in MHz/4 for the 10BROAD36 MAU. This allows the frequencies to be defined to a resolution of 250 kHz.

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20.2.2.2 MAU actions

20.2.2.2.1 acResetMAU

ACTION
APPROPRIATE SYNTAX:
None required.
BEHAVIOUR DEFINED AS:
Resets the MAU in the same manner as would a power-off, power-on cycle of at least 0.5 s duration. During the 0.5 s DO, DI, and CI should be idle.

20.2.2.2.2 acMAUAdminControl

ACTION
APPROPRIATE SYNTAX:
The same as used for **aMAUAdminState**
BEHAVIOUR DEFINED AS:
Executing an acMAUAdminControl action causes the MAU to assume the aMAUAdminState attribute value of one of the defined valid management states for control input. The valid inputs are "standby," "operational," and "shutdown" state (see the behaviour definition bMAUAdminState for the description of each of these states) except that a "standby" action to a mixing type MAU or an AUI will cause the MAU to enter the "shutdown" management state.

20.2.2.3 MAU notifications

20.2.2.3.1 nJabber

NOTIFICATION
APPROPRIATE SYNTAX:
The same as used for **aJabber**
BEHAVIOUR DEFINED AS:
The notification is sent whenever a managed MAU enters the jabber state.

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Annex A

(informative)

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Annex B

(informative)

System guidelines

B.1 Baseband system guidelines and concepts, 10 Mb/s

B.1.1 Overall system objectives

The CSMA/CD Access Method, supported by baseband technology, depends on a variety of analog system components at and below the physical level of the OSI Reference Model. These components provide basic interconnection facilities for the CSMA/CD access mechanism itself and are defined throughout Clause 6, Clause 7, and Clause 8.

Overall performance of the analog baseband medium and related Physical Layer capabilities depends on an optimal and known set of analog capabilities within each of these critical system elements: the coaxial trunk cable, MAUs, branch cables, DTEs, and repeater units. These system elements affect the integrity with which the serial data bit stream analog signals are carried between open systems. There are at least three critical parameters of interest: bits lost in the transmission system, signal delays, and phase jitter. It is important that these be apportioned properly among the affected system elements.

The successful interconnection of multivendor system components mandates that the values for bits lost, signal delays, and phase jitter be allocated fairly and realistically among the various system elements. The balance of Annex B identifies the upper limits of values to be placed on the subject parameters. These values are based on the maximal system configuration (for example, four repeater units, 2.5 km trunk coaxial cable medium).

B.1.2 Analog system components and parameter values

The values given in the following table are in terms of bits and are stated as maximum values except for values given within ranges.

The initial mnemonic under each component entry refers to the system component as identified in Figure B–1. System parameters are stated in terms of the intralayer or interlayer messages sent within a station. Specific delays are called out as = delay.

The repeater concepts described throughout this annex are considered to be an acceptable set of specifications for a multirepeatered system. It is noted that the exact parametric values specified for the repeater environment are subject to minor refinement.

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Component and parameter	Start-up delay	Last in to last out delay	Start-up loss
MEDIUM			
Trunk Coaxial Cable			
C1 Propagation	0.0	21.65	0.0
POINT-TO-POINT LINK			
P1 Propagation	0.0	25.64	0.0
AUI			
A1 Propagation	0.0	2.57	0.0
MEDIUM ACCESS UNIT			
M1 DATA IN ASSERT → INPUT	6.0	0.5	3.0
M2 OUTPUT → DATA OUT ASSERT	3.0	0.5	2.0
M3 DATA IN COLLISION → SQE ASSERT	17.0	—	—
M4 COLLISION DEASSERT → SQE DEASSERT	20.0	—	—
M5 OUTPUT IDLE → SQE ASSERT	$6 < x < 16$	—	—
M6 SQE TEST ASSERT → SQE DEASSERT	$5 \leq x \leq 15$	—	—
DTE			
D1 INPUT → INPUT UNIT	18.0	—	18.0
D2 OUTPUT UNIT → OUTPUT	—	3.0	—
D3 INPUT → CARRIER STATUS = CARRIER ON	3.0	—	—
D4 INPUT IDLE → CARRIER STATUS = OFF	$3.0 < x \leq 6.0$	—	—
D5 SQE ASSERT → CARRIER STATUS = ON	3.0	—	—
D6 SQE DEASSERT → CARRIER STATUS = OFF	$3.0 < x \leq 6.0$	—	—
D7 SQE ASSERT → SIGNAL STATUS = ERROR	3.0	—	—
D8 SQE DEASSERT → SIGNAL STATUS = NO ERROR	$3.0 < x \leq 6.0$	—	—
D9 CARRIER STATUS = OFF → OUTPUT UNIT	$96 \leq x \leq 100$	—	—
D10 INPUT → OUTPUT	8.0	—	—
D11 SIGNAL STATUS = ERROR → JAM OUTPUT	16.0	—	—
D12 JAM OUTPUT DURATION	=32.0	—	—
REPEATER UNIT			$22 < x < 34$
R1 INPUT 1,2 → OUTPUT 2,1	7.5	—	—
R2 INPUT IDLE 1,2 → OUTPUT IDLE 2,1	—	12.5	—
R3 INPUT 1,2 → CARRIER STATUS = ON	3.0	—	—
R4 SQE → SOURCED OUTPUT	6.5	—	—
R5 JAM OUTPUT → OUTPUT IDLE	=96.0	—	—

Figure B–1 indicates the maximal system configuration and identifies the various system component parameters considered critical in determining analog system performance.

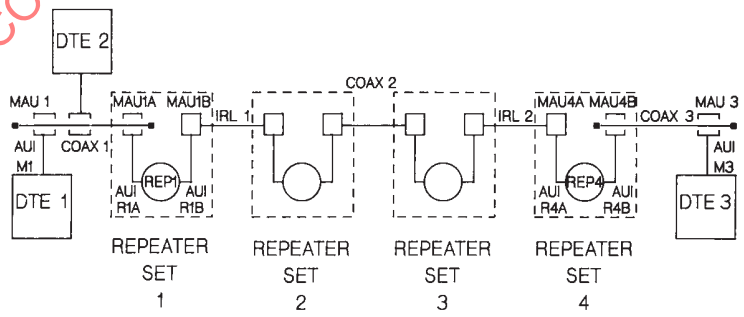

Figure B–1—Maximal system configuration bit budget apportionments

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B.1.3 Minimum frame length determination

The following table indicates the system elements that make up the minimum frame length calculation based on the worst-case numbers as outlined in the bit budget of B.1.2. The compilation in the following table is based on the following scenario:

a) DTE 1 transmits to an adjacent DTE 2 on coaxial segment 1.
b) DTE 3 transmission collides with DTE 1 transmission.
c) DTE 3 is assumed to be the worst-case distance from DTE 1 and its transmission just misses deferring to the DTE 1 message.
d) The collision fragment travels back down the network to inform DTE 1 that a collision has occurred on its message.

Component and function	Direction	Table entry	Delay	Total delay
DTE 1 STARTS TO PUT OUT FIRST BIT				0.0
DTE 1	FWD	D2	3.0	3.0
AUI M1	FWD	A1	2.57	5.57
MAU1	FWD	M2	3.0	8.6
COAX1	FWD	C1	21.65	30.2
REPEATER SET 1				
MAU 1A	FWD	M1	6.0	36.2
AUI R1A	FWD	A1	2.57	38.8
REP 1	FWD	R1	7.5	46.3
AUI R1B	FWD	A1	2.57	48.9
MAU 1B	FWD	M2	3.0	51.9
REPEATER SET TOTAL			21.64	
IRL 1	FWD	P1	25.64	77.5
REPEATER SET 2	FWD		21.6	99.1
COAX 2	FWD	C1	21.65	120.8
REPEATER SET 3	FWD		21.6	142.4
IRL 2	FWD	P1	25.64	168.1
REPEATER SET 4	FWD		21.6	189.7
COAX 3	FWD	C1	21.65	211.4
MAU 3	FWD	M1	6.0	217.4
AUI 3	FWD	A1	2.57	219.9
DTE 3 PUTS OUT A BIT	REV	D10	8.0	227.9
AUI 3	REV	A1	2.57	230.5
MAU 3	REV	M2	3.0	233.5
COAX 3	REV	C1	21.65	255.1
REPEATER SET 4				
MAU 4B	REV	M3	17.0	272.1
AUI 4B	REV	A1	2.57	274.7
REP 4	REV	R4	6.5	281.2
AI 4A	REV	A1	2.57	283.8
MAU 4A	REV	M2	3.0	286.8
REPEATER SET TOTAL			31.64	
IRL 2	REV	P1	25.64	312.4
REPEATER SET 3	REV		31.64	344.1
COAX 2	REV	C1	21.65	365.7
REPEATER 2	REV		31.64	397.4
IRL 1	REV	P1	25.64	423.0
REPEATER SET 1	REV		31.64	454.6
COAX 1	REV	C1	21.65	476.3
MAU 1	REV	M3	17.0	493.3
AUI M1	REV	A1	2.57	495.9
DTE 1	REV	D7	3.0	498.9

The frame length is constrained by two parameters:

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— The message from DTE 1 shall be long enough so that it is still sending when the collision is detected.
— The message from DTE 1 shall be short enough such that DTE 2 can throw out the message on the basis of being too short.

The above table provides the scenario that enables DTE 1 to determine a collision is taking place. DTE 1 shall transmit for at least 499 bit times. To determine how much longer DTE 2 will continue to receive bits, assume that DTE 1 is the last transmitter to provide bits to the DTE 2 MAU. DTE 2 then sees the following:

Component and function	Direction	Table entry	Delay	Total delay
DTE 1	FWD	D11	16.0	514.9
DTE 1	FWD	D12	32.0	547.9
AUI M1	FWD	A1	2.57	549.4

If Repeater Set 1 is the last system component to provide bits to DTE 2, then DTE 2 will see the following:

Component and function	Direction	Table entry	Delay	Total delay
REPEATER SET 1 (1st JAM BIT)				454.6
REP 1	REV	R5	96.0	550.6
COAX 1	REV	C1	21.65	572.3

The Repeater Set is the last transmitter to provide a bit to DTE 2. The DTE 2 MAU starts seeing bits at time 8.6, which means that DTE 2 sees 563.7 bits (572.3 – 8.6). DTE 2 sees a minimum of 61 preamble bits and 8 SFD bits. The preamble and SFD bits can be deleted from the 563.7 total because they are not counted in minimum frame length.

The minimum frame length determination from the above scenario is then 564.7 – 69.0 = 494.7 bits. The 10 Mb/s system value for minimum frame length has been set at 512 bits.

B.1.4 System jitter budgets

The typical jitter budget expected for the baseband system is apportioned in the following manner:

Encoder	0.5 ns
AUI Cable	1.0 ns (transmit end)
MAU Transmit	2.0 ns
Trunk Coax	7.0 ns
MAU Receive	–1.0 ns (with compensation)
AUI Cable	1.0 ns (receive end)
SNR on COAX	5.0 ns (SNR = 5:1)
SNR on AUI	0.5 ns (SNR = 5:1, transmit end)
SNR on AUI	0.5 ns (SNR = 5:1, receive end)
	16.5 ns

The 18 ns jitter budget leaves adequate design margin for implementation-dependent considerations.

B.1.4.1 Nominal jitter values

The jitter budget values given above are not expected to accommodate all step changes in phase jitter due to system parameter variations within one or a few bit times.

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B.1.4.2 Decoder evaluation

The phase decoder in the PLS sublayer should correctly decode a Manchester-encoded signal whose data transition point (center of a bit cell) has a peak-to-peak jitter of no more than 36 ns (± 18 ns deviation from the bit cell center). Figure B–2 and Figure B–3 show the test method.

Evaluation of decoder performance may be simulated and tested by application of three distinct waveforms representing worst-case and normal conditions. The waveforms contain Manchester-encoded bits whose center transitions represent the extremes of maximum skew. A 5 MHz (repetition rate) pulse train whose pulse width is either 64 ns or 136 ns simulates the two worst-case jitter conditions. The data output from the decoder should remain stable for each of the three test patterns and shifts between these extremes where there is a low rate of change in center transition skew. Note that the actual transmission system is not expected to permit sudden drastic changes in the steady-state edge deviation during the reception of any given frame. The above evaluation process is not intended to guarantee proper decoder performance under all operating conditions.

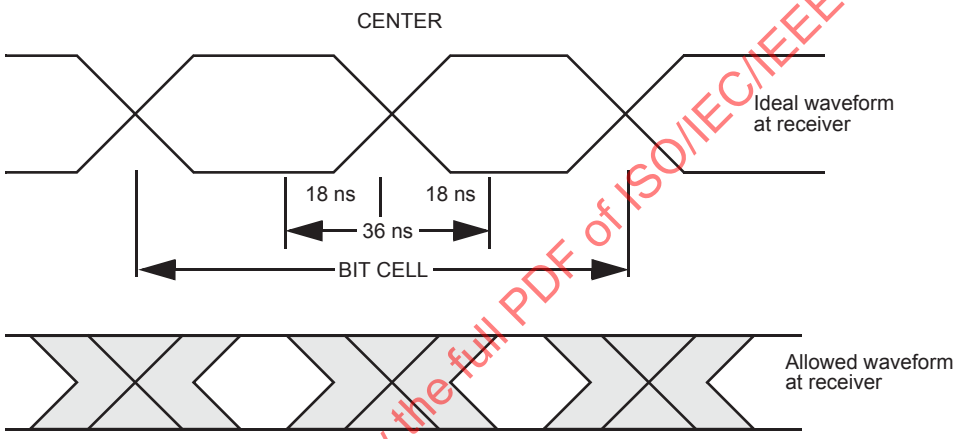

Figure B–2—Typical signal waveforms

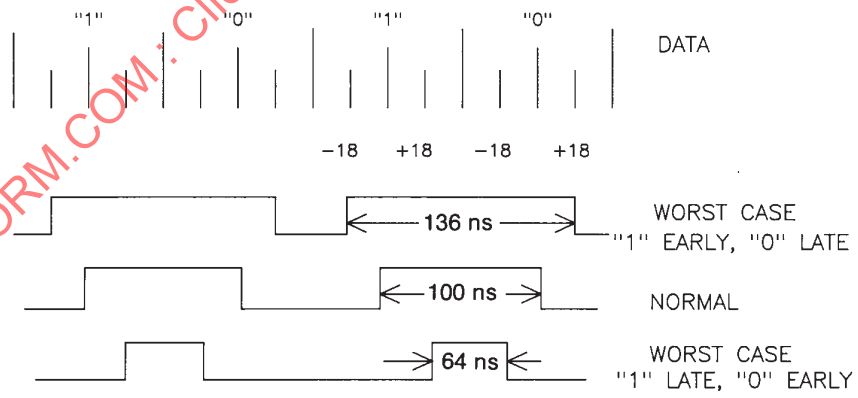

Figure B–3—Worst-case signal waveform variations

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B.1.5 Systems consideration calculations

B.1.5.1 Overview

Subclause B.1.3 contains a calculation of maximum fragment size for a network of 10BASE5 and IRL segments. That calculation was based on the maximum delay for a transmission to reach the far end of the network and for a collision to propagate back. Since that calculation was written, many new media and MAU types have been added to this standard. Also, the calculation of B.1.3 did not address the interpacket gap shrinkage, which can limit the network size. It is not practical to perform a separate calculation for each possible combination of segment types.

Some new segment types also support much longer media (up to 2 km). Introduction of longer media also required a more flexible calculation method that allowed trading segment length for repeaters. The method in this section was developed to meet these needs.

Actual numbers used to calculate delay and variability are tabulated (Table B–1) at the end of this subclause.

B.1.5.2 Maximum collision fragment size

The round-trip delay must be calculated to determine that collision will be received within the collision window of transmitting DTEs and that collision fragments will be less than the minimum frame size. The following scenario is used for the calculations (see Figure B–4):

a) DTE1 transmits.
b) DTE1's transmission propagates to DTE2.
c) DTE2 begins transmitting at the last possible time, colliding and transmitting 96 bits.
d) DTE2's transmission propagates to DTE1.
e) DTE1 detects collision, jams, and stops transmitting.

The following conditions must be met for proper network operation:

— DTE1 must detect collision before having transmitted the 512th bit (including preamble and SFD bits).
— DTE1 must stop transmitting before having transmitted a minimum length frame, 576 bits (512 bits after SFD).
— The overlap between DTE1's transmission and DTE2's transmission must be less than 575 bits (511 bits after the SFD transmitted by DTE1).

For all existing segment types, the last condition is the limiting factor; if it is met then the other two conditions are also met.

The maximum time between the first bit and the last bit of the overlapping transmissions of the two DTEs colliding across a path will be called the Path Delay Value (PDV). Many factors contribute to this delay. Simplification of the delay calculation, as compared to the method used in B.1.3, can be achieved by using a set of base numbers, Segment Delay Values (SDV), for each segment type that combines the factors that contribute to the round-trip delay associated with that segment. The PDV is the sum of SDVs of the segments that comprise the path.

For each segment type, one of three base SDVs is used depending on the position of the segment: left-end, mid-, or right-end. The left-end segment is connected to the DTE that transmits first (DTE1). The right-end segment is connected to the colliding DTE (DTE2). All segments between these are mid-segments.

For this calculation, the left-end base SDV contains all delays from DTE1 through the MAU and its AUI connected to the repeater unit. Each mid-base SDV includes the delays from the repeater unit on the left

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through the MAU and its AUI connected to the right repeater unit. The right-end base SDV includes the delays from the repeater unit immediately to its left through DTE2. (See Figure B–4.)

Only the bit loss of DTE1's MAU on the left-end segment contributes to fragment size. The steady-state delay of that MAU and the AUI cable delay do not contribute. For the remainder of the network, start-up delay (the sum of steady-state delay and bit loss) contribute. Therefore, the left-end base SDV uses MAU transmit bit loss and 1 AUI delay. In all other cases, start-up delay and 2 AUI delays are used.

Propagation delays for media are not included in the base SDVs. These are added in separately to allow for various segment lengths (see 13.4.1). The base SDVs for the mid- and right-end segments (except 10BASE-FB) include two 2 m AUI cables and the delay of each one is experienced twice, once in the forward path and once in the reverse path. Therefore, a delay of 0.5 BT per segment is added and corresponds to the round-trip delay through two 2 m AUI cables. The base numbers for the left segment include one 2 m AUI cable, 0.25 BT.

For each segment type, both the delay to transmission of the 96th bit after collision rise and delay to transmission of the last bit due to collision fall are calculated. The base SDV is the larger of these two.

The maximum allowed sum of SDVs plus media propagation delays is 575 BT.

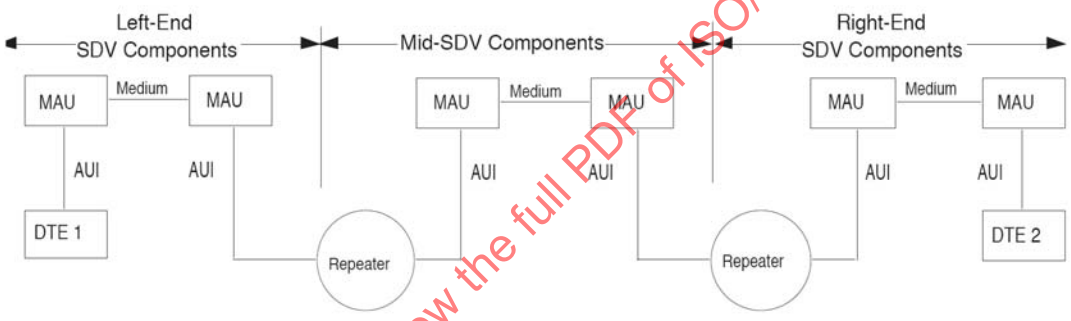

Figure B–4—Round-trip delay calculation model

B.1.5.2.1 Left-end base SDV

The Left-End Segment collision delay is the sum of the following:

Forward delay:

- AUI
- MAU transmit bit-loss delay
- Media rise time
- MAU receive start-up delay

Reverse delay:

- MAU transmit fall delay after collision
- MAU receive fall delay after collision

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B.1.5.2.2 Mid-base SDV

The Mid-Segment collision rise delay is the sum of the following:

Forward delay:
- AUI × 2
- Repeater start-of-packet propagation delay
- MAU transmit start-up delay
- Media rise time
- MAU receive start-up delay

Reverse delay:
- MAU transmit start-up delay
- MAU collision detect delay
- Repeater start-of-collision propagation delay

The Mid-Segment collision fall delay is the sum of the following:

Forward delay:
- AUI × 2
- Repeater start-of-packet propagation delay
- MAU transmit start-up delay
- Media rise time
- MAU receive start-up delay

Reverse delay:
- MAU transmit fall delay
- MAU collision fall delay
- Repeater cessation-of-jam propagation delay

B.1.5.2.3 Right-end base SDV

The Right-End Segment collision rise delay is the sum of the following:

Forward delay:
- AUI × 2
- Repeater start-of-packet propagation delay
- MAU transmit start-up delay
- Media rise time
- MAU receive start-up delay
- DTE receive-to-transmit-not-deferred delay

Reverse delay:
- MAU transmit start-up delay
- MAU collision detect delay
- Repeater start-of-collision propagation delay
- Repeater minimum transmit length

The Right-End Segment collision fall delay is the sum of the following:

Forward delay:
- AUI × 2
- Repeater start-of-packet propagation delay
- MAU transmit start-up delay

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Media rise time
MAU receive start-up delay
DTE receive-to-transmit-not-deferred delay
DTE minimum transmit length

Reverse delay:
MAU transmit fall delay
MAU collision fall delay
Repeater cessation-of-jam propagation delay

B.1.5.3 Interpacket Gap (IPG) shrinkage

IPG shrinkage occurs because two successive packets may experience differing bit loss on the same path. When the packet passes through a repeater, the lost preamble bits are regenerated. If the first packet experiences greater bit loss than the second, the IPG between them will shrink.

IPG shrinkage is also calculated using a lumped number for each segment, the Segment Variability Value (SVV). For each segment type, one of two SVVs is used depending on the position of the segment: transmitting end or mid. The transmitting end segment is connected to the transmitting DTE or DTEs. The mid-segments are all the remaining segments except the one connected to the receiving DTE.

The transmitting end segment and the mid-segment SVVs each include the variability from the transmitting MAU through the repeater unit. Since, IPG shrinkage only occurs when a repeater restores the lost bits, the final segment does not contribute any variability (see Figure B–5).

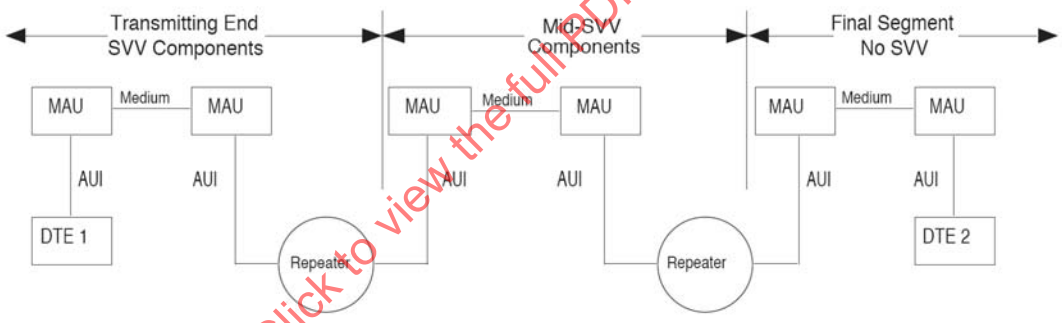

Figure B–5—Variability calculation model

B.1.5.3.1 Transmitting end segment variability value

The transmitting end segment variability value is the sum of the following:
MAU transmit start-up-delay variability
MAU transmit start-up-delay variability correction
MAU receive start-up-delay variability
MAU receive start-up-delay variability correction
Repeater start-of-packet propagation delay variability
Clock skew (2.5 BT)

NOTE—The variability correction values account for the possibility that on mixing segments the two successive packets can be originated by two different MAUs.

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B.1.5.3.2 Mid-segment variability value

The mid-segment variability value is the sum of the following:

MAU transmit start-up-delay variability
MAU receive start-up-delay variability
Repeater start-of-packet propagation delay variability

B.1.5.4 Timing parameters for round-trip delay and variability calculations

Table B–1 contains the timing parameters used in the calculation of SDVs and SVVs. The values in the table for MAU Collision Rise and MAU Collision Fall are those specific to the worst-case scenario. The parameters are defined in the following subclauses.

B.1.5.4.1 MAU parameters

Transmit Bit Loss: Number of bits received on the DO circuit and not transmitted to the MDI.

Transmit Start-up Delay: Delay from the first bit received on the DO circuit to the first bit transmitted to the MDI. This is the sum of transmit bit loss and steady-state delay.

Receive Start-up Delay: Delay from the first bit received on the MDI to the first bit transmitted to the DI circuit. This is the sum of receive bit loss and steady-state delay.

Collision Detect Delay: Delay from the arrival of collision at the MDI to transmission of signal_quality_error to the CI circuit. For 10BASE2 and 10BASE5, this includes the DC rise time on the media, given that the MAU has been transmitting for at least 20 BT when the collision arrives. For 10BASE-FP, this includes the delay until the second CRV occurs on the media (16.3.4.3).

Transmit Fall Delay: Delay from the last bit received on the DO circuit to the last bit transmitted to the MDI. This is the same as the steady-state delay.

Collision Fall Delay: Delay from arrival of end of collision at the MDI to end of transmission of signal_quality_error to the CI circuit. For 10BASE2 and 10BASE5, it includes the DC fall time of the media. For 10BASE-FP it includes the delay of 33 BT to pass with no more than one ORD_crv.

Transmit Start-up Delay Variability: Packet-to-packet variations in transmit start-up delay.

Transmit Start-up Delay Variability Correction: Additional variability, when the transmitting end segment is a mixing segment, due to two MAUs transmitting with different start-up delays. For 10BASE5 and 10BASE2, start-up delay variability plus transmit start-up delay variability correction equal transmit start-up delay since these MAUs may transmit with as little as 0 BT delay. For 10BASE-FP MAUs, implementation considerations imposed by the requirements of 16.3.1.1 require the MAU to have at least 2 BT start-up delay. Therefore, the transmit start-up delay variability correction equals the transmit start-up delay minus 2 BT.

Receive Start-up Delay Variability: Packet-to-packet variability in receive start-up delay.

Transmit Fall Delay After Collision: Delay from the last bit received on the DO circuit to the last bit transmitted to the MDI after the MAU has detected a collision. For all MAUs except 10BASE-FB, this is the same as transmit fall delay.

Receive Fall Delay After Collision: Delay from the last bit received on the MDI to the last bit transmitted to DI. For all MAUs except 10BASE-FB and 10BASE-FP, this is the same as receive steady-state delay.

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B.1.5.4.2 Repeater parameters

Start-of-Packet Propagation Delay: Delay from first bit received on DI to first bit transmitted on DO.

Start-of-Collision Propagation Delay: Delay from start of signal_quality_error on CI to first bit transmitted on DO.

Cessation-of-Jam Propagation Delay: Delay from end of signal_quality_error on CI to last bit transmitted on DO.

Minimum Transmit Length: Minimum delay from first bit transmitted on DO to last bit transmitted on DO.

Start-of-Packet Propagation Delay Variability: Packet-to-packet variation in start-of-packet propagation delay.

B.1.5.4.3 Media parameters

Media Rise Time: Start-of-packet DC rise time on 10BASE2 and 10BASE5 segments.

B.1.5.4.4 DTE parameters

Receive-to-Transmit-Not-Deferred Delay: Delay from first bit on DI to first bit on DO when the DTE does not detect carrier in time to defer.

Minimum Transmit Length: Minimum delay from first bit transmitted on DO to last bit transmitted on DO.

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Table B–1—Timing parameters for round-trip delay and variability calculations in bit times (BT)

Parameter	10BASE 5	10BASE 2	FOIRL	10BASE -T	10BASE-FP	10BASE-FB	10BASE-FL
AUI (2 m)	0.25	0.25	0.25	0.25	0.25	0.00	0.25
MAU							
Transmit bit loss	3.00	3.00	3.00	3.00	2.00	0.00	3.00
Transmit start-up delay	3.50	3.50	3.50	5.00	5.50	2.00	5.00
Receive start-up delay	6.50	6.50	3.50	8.00	2.50	2.00	5.00
Collision detect delay	17.00	17.00	3.50	9.00	9.50	3.50	3.50
Transmit fall delay	0.50	0.50	0.50	2.00	3.50	2.00	2.00
Collision fall delay	20.00	20.00	7.00	9.00	36.00	5.00	7.00
Transmit start-up delay variability	2.00	2.00	2.00	2.00	3.00	0.00	2.00
Transmit start-up delay variability correction	1.50	1.50	0.00	0.00	0.50	0.00	0.00
Receive start-up delay variability	5.00	5.00	2.00	2.00	1.00	0.00	2.00
Receive start-up delay variability correction	1.00	1.00	0.00	0.00	0.00	0.00	0.00
Transmit fall delay after collision	0.50	0.50	0.50	2.00	3.50	5.00	2.00
Receive fall delay after collision	0.50	0.50	0.50	2.00	3.00	5.00	2.00
REPEATER							
Start-of-packet propagation delay	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Start-of-collision propagation delay	6.50	6.50	6.50	6.50	6.50	6.50	6.50
Cessation-of-jam propagation delay	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Minimum transmit length	96.00	96.00	96.00	96.00	96.00	96.00	96.00
Start-of-packet propagation delay variability	4.00	4.00	4.00	4.00	4.00	2.00	4.00
MEDIA RISE TIME	1.00	1.00	0.00	0.00	0.00	0.00	0.00
DTE							
Receive-to-transmit-not-deferred delay	27.00	27.00	27.00	27.00	27.00	N/A[a]	27.00
Minimum transmit length	96.00	96.00	96.00	96.00	96.00	N/A[a]	96.00

[a]Not applicable; 10 BASE-FB does not support end (DTE) connections.

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B.2 System parameters and budgets for 1BASE5

B.2.1 Delay budget

The successful interconnection of multivendor system components mandates that the values for bits lost and signal delays be allocated fairly and realistically among the various system elements. The following table summarizes and indicates the derivation of some of the delays specified in 12.9. The breakdowns shown for the parameters are illustrative only; implementers are free to make other allocations of delay *within* a device so long as the specifications of 12.9 are not violated.

Component	Delay (BT)
DTE Initial Transmit Delay (see 12.9.2)	**3**
DTE Deference Delay (see 12.9.2)	**21**
unsquelch	3
Carrier detect	5
MAC detects carrier and defers	10
DTE Initial Transmit Delay	3
DTE Collision Shutdown Delay (see 12.9.2)	**58**
detect CP and report SIGNAL_ERROR	10
detect SIGNAL_ERROR and start jamming	16
jamSize	32
Medium Transit Delay (see 12.9.3)	**4**
Special Link Transit Delay (see 12.9.4)	**15**
Hub Startup Delay (see 12.9.5)	**12**
unsquelch	4
half fill FIFO	6
analogue of DTE Initial Transmit Delay	3
Hub Idle Collision Startup Delay (see 12.9.5) (same as Hub Startup Delay)	**12**
Hub Transit Delay (see 12.9.5)	**9**
half fill FIFO	6
analogue of DTE Initial Transmit Delay	3
Hub Delay Stretch/Shrink (see 12.9.5) ((preamble + <sfd> + maxFrameSize) · 0.01% · 2)	**3**
Hub Collision Detect Delay (see 12.9.5)	**21**
unsquelch	3
detect collision	6
Hub Transit Delay	9
First CVL or CVH may be preceded by CD0s and CD1s	3
Hub Active Collision Startup Delay (see 12.9.5)	**12**
Hub Transit Delay	9
First CVL or CVH may be preceded by CD0s and CD1s	3
Hub Collision Shutdown Delay (downward) (see 12.9.5) (same as Hub Transit Delay)	**9**
Hub Collision Shutdown Delay (upward) (see 12.9.5)	**25**
detect loss of carrier	20
clear FIFO, if necessary	2
analogue of DTE Initial Transmit Delay	3

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B.2.2 Minimum frame length determination

The minimum frame length for 1BASE5 is determined using the values specified in 4.4.2 and 12.9, applied to the following (worst) case:

a) DTE 1, connected to Hub 1 at a network extremity, transmits a message upward toward Hub 5.
b) There is a special link in the path between Hub 1 and Hub 5.
c) DTE 2, also connected to Hub 1, transmits, just missing deferring to the downward signal from DTE 1 that was wrapped around at Hub 5.
d) DTE 3, also connected to Hub 1, receives the transmission from DTE 1.
e) Hub 1 generates CP, which travels up and then back down the network to inform DTE 1 and DTE 2 that a collision has occurred on their messages.
f) DTE 1 and DTE 2 continue to transmit until they have received CP, reacted to it, and completed their jams.
g) DTE 3 continues to receive until the end of CP.

The minimum frame length must allow both of the following conditions to be met:

— DTE 1 is still sending when CP is received and recognized.
— DTE 3 can discard the message fragment it receives because it is too short.

Event	Bits	Total
DTE 1 → DTE 2		
DTE Initial Transmit Delay	3	3
8 · Medium Transit Delay	32	35
2 · Special Link Transit Delay	30	65
10 · Hub Startup Delay	120	185
DTE Deference Delay	21	206
DTE 2 → HUB 1 CP		
Medium Transit Delay	4	210
Hub Collision Detect Delay	21	231
HUB 1 CP → HUB 5 CP		
3 · Medium Transit Delay	12	243
Special Link Transit Delay	15	358
4 · max(Hub Startup Delay, Hub Active Collision Startup Delay, Hub Idle Collision Startup Delay)	48	306
HUB 5 CP → DTE 1 receives CP		
5 · Hub Active Collision Startup Delay	60	366
4 · Medium Transit Delay	16	382
Special Link Transit Delay	15	397
DTE 1 receives CP → DTE 1 stops transmitting DTE Collision Shutdown Delay	58	455
COMPUTATION OF MINIMUM FRAME SIZE	–64	391 = data bits transmitted
Original preamble + <sfd>		
5 · (Hub Collision Shutdown Delay (upward) – Hub Transit Delay)	80	471
5 · (Hub Collision Shutdown Delay (downward) – Hub Transit Delay)	0	471
Tiny fraction of Hub Delay Stretch/Shrink	0	471 = data bits received

The minimum frame length must exceed both the maximum number of bits sent before recognizing CP (391 – jamsize = 359) and the maximum collision fragment size (471), as computed above. The 1BASE5 system

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value for minimum frame length has been set at 512 bits, which exceeds both of these values with a margin for error.

B.2.3 Jitter budget

The total edge jitter of the signals on each link must be limited to allow proper decoding at the receiver. The following budget has been used to allocate jitter to the indicated components that contribute to the total jitter on each link:

Component	Jitter (ns)
Transmitter skew	±10
Cable intersymbol interference	9
Cable reflections	8
Reflections due to receiver termination mismatch	5
Total	±32

The cable intersymbol interference and reflection allowances form the basis for the limit specified in 12.7.2.3; the reflection component is sufficient to allow a single 20 Ω impedance mismatch anywhere along a cable segment. The receiver-mismatch allowance is derived from the reflection attenuation specified in 12.5.3.2.4. The total forms the basis for the specification in 12.5.3.2.2.

The remainder of the jitter that can be tolerated by the Manchester decoder in a receiver is reserved to allow for distortion of the signal due to noise, receiver threshold offset, receiver skew, and receiver sampling timing error.

A simple clocked receiver/decoder with an 8 MHz sampling rate (the worst case allowed for in the design of this standard), can achieve proper decoding with up to ± 125 ns of jitter between two edges, which is equivalent to ±62.5 ns on each edge. Other receiver designs may tolerate more edge jitter. For example, a 6 MHz sampling rate would allow up to ±83.33 ns of jitter on each edge and a 16 MHz sampling rate allows up to ±93.75 ns of jitter.

It may be necessary to use a low-pass filter as part of the receiver to reduce the noise level seen by that receiver (see 12.7.4 for a description of the noise environment). A filter that reduces the noise may also have an effect on the amplitude and edge rate of the received signal. The filtered signal's edge rate near the zero-crossing is used in the critical translation from mV of noise and receiver offset into ns of jitter.

An example receiver design using an 8 MHz sampling rate and a 2 MHz Butterworth input filter might be based on the following jitter budget:

Component	Jitter (ns)
Input jitter (from above)	±32
Noise and receiver threshold offset	19.5
Receiver skew (analog)	4
Receiver skew (digital)	7
Total	±62.5

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The two primary contributors to noise in a 1BASE5 cable are self-crosstalk and impulse noise (see 12.7.4). Because it is unlikely that both will be present at their 1% worst-case levels on any particular cable, the required bit error ratio attributable to each source can be set at half of the one in 10^8 error ratio required by 12.5.3.2.6.

Crosstalk noise is specified to be no more than 105 mV (peak) through a 2 MHz filter (see 12.7.4.2). Because crosstalk is present for the entire transmission of a packet, some crosstalk will coincide with the most sensitive part of the received signal. Therefore, the receiver must operate without error in the presence of this 105 mV of noise.

Impulse noise has a peak amplitude of 170 mV for ≤ 0.005 counts/s through the 2 MHz filter (see 12.7.4.1). This threshold does not directly correlate to jitter, however, because the derivation of the 62.5 ns jitter tolerance for an 8 MHz clock assumed worst-case sampling error. Assuming a random phasing of the sampling clock to the received signals, it can be shown that the 170 mV of noise is equivalent to a level of 85 mV with a worst-phase clock.

Jitter due to noise should be computed using the larger of the above two levels. The 105 mV for crosstalk noise, therefore, should be added to 50 mV for receiver threshold offset and the result should be divided by the edge rate of the filtered signal near the zero-crossing (7.9 mV/ns for the 2 MHz filter), yielding the 19.5 ns indicated above.

B.3 Example crosstalk computation for multiple disturbers, balanced-pair cable

A method for computing multiple-disturber, near end, crosstalk attenuation (MDNEXT) into each 1BASE5 pair is specified in 12.7.3.2. This annex provides example computations of MDNEXT using that method when only the distribution of X_{ij} is known.

The single-disturber probability distribution curve (labelled "1") shown in Figure B–6 is based on actual measurement of 25-pair, 24-gauge, unshielded, twisted pair cable. The remaining probability distribution curves (labelled with the number of disturbing pairs) were computed using Monte Carlo simulation. To compute each sample $MDNEXT_j$ for N disturbers, N values of crosstalk attenuation (X_i) were chosen from the single-disturber distribution and N values of crosstalk phase (θ_i) were chosen from a uniform distribution between 0 and 2π rad. These values were then used with the following equations to compute $MDNEXT_j$:

$$H_j = \sum_{1 \le i \le N} 10^{(-X_i/20)} \cos\theta_i$$

$$V_j = \sum_{1 \le i \le N} 10^{(-X_i/20)} \sin\theta_i$$

$$MDNEXT_j = 10\log_{10}(H_j^2 + V_j^2)$$

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Iterating this process several hundred times, each time producing a single $MDNEXT_j$ sample, resulted in distributions for MDNEXT that are summarized in the following table and Figure B–6:

Disturbers	Iterations	MDNEXT: Mean (dB)	Std. Dev. (dB)	99% (dB)
1		61.2	7.0	48.6
2	500	57.2	6.2	46.4
3	500	55.1	5.8	45.2
6	500	52.0	5.7	42.5
13	1000	48.5	5.4	39.1
18	500	47.1	5.3	37.8
24	500	45.9	5.9	36.2

Because two pairs are used for each 1BASE5 connection, the entries in this table for 18 and 24 disturbers are not applicable for normal installation of 25-pair cables. Furthermore, telephone cables with larger numbers of pairs are often constructed using sub-bundles of 25 pairs each and so might yield similar results (for example, the curves for 13 or fewer disturbers would be the most applicable ones).

The calculation method of this annex, though not the numeric values, applies to 10BASE-T.

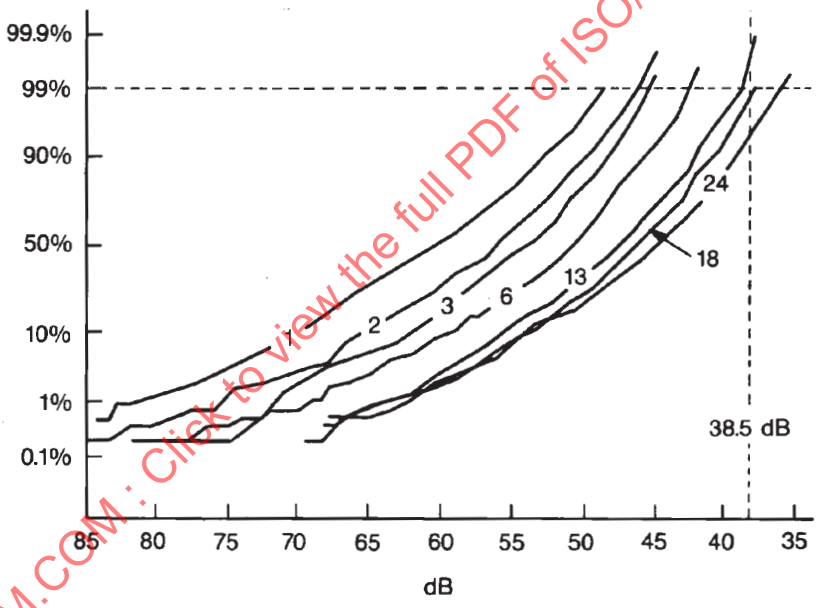

Figure B–6—MDNEXT cumulative probability distribution

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B.4 10BASE-T guidelines

B.4.1 System jitter budget

The jitter budget for 10BASE-T is apportioned as follows:

Jitter budget	Maximum-length twisted-pair link	Short-length twisted-pair link
	(jitter expressed in ±ns)	
Encoder	0.5	0.5
AUI cable including SNR (DO pair)	1.5	1.5
MAU transmitter	2.0	2.0
Twisted-pair medium with equalization	1.5	6.0
Noise jitter on twisted-pair medium	8.0	2.5
MAU receiver	1.5	1.5
AUI cable including SNR (DI pair)	1.5	1.5
Total	16.5	15.5

NOTE—Total transmit jitter for the combination of the MAU transmitter and link segment (14.3.1.2.3) is ±3.5 ns and ±8.0 ns for maximum- and short-length twisted-pair link segments, respectively. It is the sum of the entries for MAU transmitter and twisted-pair medium with equalization. The individual components cannot be easily observed on MAUs. Short-length segment is defined as a short, non-zero-length twisted-pair link. A short- rather than a zero-length segment is used in the calculation since a zero-length segment will have no significant noise and is a less severe case.

B.4.2 Filter characteristics

The implementation of the 3-pole, low-pass Butterworth filter should have the following characteristics:

3 dB cutoff frequency	15 MHz
Insertion loss (5 MHz to 10 MHz)	≤ 1.0 dB
30 MHz attenuation	≥17.5 dB
Input impedance (5 MHz to 10 MHz)	100 Ω
Return loss with 100 Ω load (5 MHz to 10 MHz)	≥20 dB

This filter is only used for the tests described in 14.3.1.3.2, 14.4.4.1, and 14.4.4.2. A buffer may be needed to achieve the above return loss when using an LC implementation of this filter.

B.4.3 Notes for conformance testing

The following notes are provided to assist in developing the conformance test.

B.4.3.1 Notes for 14.3.1.2.1 on differential output voltage

For testing harmonics measured on the TD circuit when the DO circuit is driven by an all-ones Manchester-encoded signal, it is acceptable to use a pattern of maximum length packets whose data field is all ones.

For testing of the maximum and minimum output signal to the template in Figure 14–10, the recommended measurement procedure is described as follows. An oscilloscope set for a zero voltage trigger with a positive slope is allowed to accumulate an eye pattern that must be within the template. Acquisition must be long

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enough to ensure that all data variations have been observed. When using packetized data, the TP_IDL and the first transmitted bit should be excluded from this measurement. Also, the interpacket interval may be adjusted so that transition-to-idle transient effects are excluded. When testing with the inverted template, the slope of the scope trigger should be negative.

B.4.3.2 Note for 14.3.1.2.2 on transmitter differential output impedance

The return loss (*RL*) is defined as follows:

$$RL = 20\log_{10}\frac{|Z_{\text{transmitter}} + Z_{\text{cable}}|}{|Z_{\text{transmitter}} - Z_{\text{cable}}|}$$

and also

$$RL = 20\log_{10}\frac{|V_{\text{i}}|}{|V_{\text{r}}|}$$

where

$Z_{\text{transmitter}}$ is the impedance of the transmitter
Z_{cable} is the impedance of the cable
V_{i} is the differential voltage incident upon the transmitter
V_{r} is the differential voltage reflected from the transmitter

a) A transmitter with a purely resistive source impedance of 96 Ω ± 20% will satisfy this requirement.
b) The requirement of 14.3.1.2.2 is equivalent to the following two constraints:
   1) The return loss when measured with an 85 Ω resistive source is at least 15 dB in the frequency range of 5 MHz to 10 MHz.
   2) The return loss when measured with a 111 Ω resistive source is at least 15 dB in the frequency range of 5 MHz to 10 MHz.

B.4.3.3 Note for 14.3.1.2.3 on output timing jitter

Adherence to the template of 14.3.1.2.1 with a jitterless source driving DO and the zero crossings constrained to 46.5 ns to 53.5 ns and 96.5 ns to 103.5 ns is sufficient to demonstrate compliance with the 3.5 ns jitter requirement. When measuring an integrated MAU, the zero crossing time interval should be constrained to 44.5 ns to 55.5 ns and 94.5 ns to 105.5 ns due to the additional allocation for encoder and AUI jitter. This test is simpler to perform than the test which follows, but failure of this test does not demonstrate noncompliance.

When triggering on one edge of the transmitted signal and observing another edge, the observed jitter measures the difference between the jitter of the triggering edge and the observed edge. When the two edges are separated such that the jitter of the edges is independent and clock drift is insignificant, the observed jitter is twice that of a single edge.

Therefore, a test that demonstrates compliance or noncompliance is as follows: Observe the zero crossings 8 BT and 8.5 BT from the triggering zero crossing while transmitting a pseudo-random data sequence of at least 511 bits. An external MAU with a jitterless source driving DO is compliant when all zero crossings fall within the time intervals 8.0 BT ± 7 ns and 8.5 BT ± 7 ns. An integrated MAU is compliant when all zero crossings fall within the time intervals 8.0 BT ± 11 ns and 8.5 BT ± 11 ns.

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When using packetized data, the TP_IDL and the first transmitted bit should be excluded from these measurements.

B.4.3.4 General note on common-mode tests

When performing tests specified as balanced or common-mode, the balance of the test equipment (such as matching resistors) must exceed that required by the test.

B.4.3.5 Note for 14.3.1.3.4 on receiver differential input impedance

The return loss (*RL*) is defined as follows:

$$RL = 20\log_{10}\frac{|Z_{receiver} + Z_{cable}|}{|Z_{receiver} - Z_{cable}|}$$

and also

$$RL = 20\log_{10}\frac{|V_i|}{|V_r|}$$

where

$Z_{receiver}$ is the impedance of the receiver
Z_{cable} is the impedance of the cable
V_i is the differential voltage incident upon the receiver
V_r is the differential voltage reflected from the receiver

a) A receiver with a resistive input impedance of 96 Ω ± 20% will satisfy this requirement.
b) The requirement of 14.3.1.3.4 is equivalent to the following two constraints:
   1) The return loss when measured with an 85 Ω resistive source is at least 15 dB in the frequency range of 5 MHz to 10 MHz.
   2) The return loss when measured with a 111 Ω resistive source is at least 15 dB in the frequency range of 5 MHz to 10 MHz.

B.4.3.6 Note for 14.3.1.3.3 on receiver idle input behavior

For conformance testing of receivers, the start of idle shall conform to the template shown in Figure 14–11. Additionally, the magnitude of the voltage-time integral of the undershoot (measured from the negative zero crossing that ends the positive idle pulse to the time when the differential signal settles to 0.0 mV ± 50 mV) shall be no greater than 1.2 times the voltage-time integral of the positive idle pulse (measured from the last positive zero crossing to the negative zero crossing).

B.4.3.7 Note for 14.3.1.3.5 on receiver common-mode rejection

For a stand-alone MAU, the receiver common-mode test may be performed with a jitterless E_s, so that the DI circuit should have no more than 4.0 ns of edge jitter.

For an integrated MAU, the common-mode test is performed with an E_s that has zero crossing jitter up to 11 ns from the ideal.

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B.5 10BASE-F

B.5.1 System jitter budget

The jitter budgets for 10BASE-FP, 10BASE-FB, and 10BASE-FL are apportioned as shown in Table B–2.

Table B–2—System jitter budgets

Encoder	10BASE-FP	10BASE-FB	10BASE-FL
Encoder	0.5	0.5	0.5
AUI Cable including SNR (DO Pair)	1.5	N/A	1.5
MAU DO Receiver (10BASE-FP only)	2.0	N/A	N/A
10BASE-FP total at retiming	4.0	N/A	N/A
Subtotal (10BASE-FP Retimes)	0.0	0.5	2.0
Transmitter*	2.0	4.0	4.5
Subtotal (at the MDI)	2.0	4.5	6.5
Fiber optic medium	0.0	0.0	0.0
10BASE-FP Passive Star	0.0	N/A	N/A
Fiber optic medium (10BASE-FP return)	0.0	N/A	N/A
Receiver**	1.0	2.0	8.5
10BASE-FP total at retiming	3.0	N/A	N/A
Subtotal (10BASE-FP Retimes)	0.0	6.5	15.0
Unallocated	8.5	10.0	0.0
MAU DI Transmitter (10BASE-FP only)	6.5	N/A	N/A
AUI cable incl-SNR (DI Pair)	1.5	N/A	1.5
Total	16.5 ns	16.5 ns	16.5 ns
*Includes jitter plus duty cycle distortion.			
** 10BASE-FL figure includes MAU DI Transmitter jitter allocation.			

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B.5.2 10BASE-FP fiber optic segment loss budget

The 10BASE-FP MDI optical parameters specified in 15.2.1 and 15.2.2 have been selected to guarantee operation using a properly specified system of up to 500 m radius segment. This annex illustrates how the

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loss budget may be allocated to star, optical fiber, and patch panel connectors, including examples at 100 m and 500 m radius.

The allowed system attenuation values are determined by the average transmit and receive power ranges specified in Table 15–1. The average optical power launched into a 62.5 µm fiber must be greater than –15 dBm and less than –11 dBm. (This includes any launch power variation and source degradation.) Receiver operation is specified for average received power greater than –41 dBm and less than –27 dBm. Thus the maximum attenuation allowed for optical plant, including star, is 26 dB, and the minimum allowed attenuation is 16 dB.

This attenuation can be allocated between the star, cabled optical fiber, and patch panel connectors in any manner as long as the maximum and minimum losses are within the limits stated in Table B–3. Note that the 10BASE-FP Star insertion loss includes the loss of one optical connector pair as specified in 16.5.2.1.

Table B–3—10BASE-FP fiber optic segment loss budget

Item	Min (dB)	Max (dB)
Star	16	20
Cabled optical fiber and connectors	0	6
Totals	16	26

Example 1: For a 500 m radius segment (1 km MDI to MDI) of 3.75 dB/km (measured at 850 nm) cabled optical fiber and a connector system with a maximum loss of 2 dB, the worst-case optical fiber and connector loss would be 5.75 dB. This would fall within the 6 dB limit, and result in a worst-case margin of 0.25 dB

Example 2: A horizontal structured building wiring system (e.g., as detailed in ANSI/TIA-568-C.0) of 100 m from the wiring closet to the desk top (100 m radius segment, 200 m MDI to MDI) of 3.75 dB/km optical fiber would have a loss of 0.75 dB. With four connector pairs in the path from MDI to MDI (wall plate, patch panel, patch panel, wall plate [see Figure 15–2]) and one connector pair at the 10BASE-FP Star (the other star connector pair is already included in the star loss [see 16.5.2.1)], and using a worst-case loss of 1 dB for each connector pair, the worst-case optical fiber and connector loss would be 5.75 dB. This would fall within the 6 dB limit, and would result in a worst-case margin of 0.25 dB.

In addition to these loss budgets, the overall system return loss must be greater than 27 dB. The return loss is the ratio of the desired signal to all undesired, multiple reflected signals, observed at a 10BASE-FP MAU MDI. Use of connectors with less return loss than specified in 15.3.2.2 as well as use of more than two patch panels on each side of the star is permitted, as long as the overall system return loss requirement is met.

The 8.0 dB differential flux budget (16.3.4.2) can be allocated as shown in Table B–4.

Table B–4—Eight decibel differential flux budget

Contribution	(dB)
Variation at Star Input due to combined effects	4.8
1/2 star connector	0.5
Star including 1/2 connector	2.5
Wavelength in ORD leg	0.2
Total	8.0

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Each of these contributions to the differential budget is a measurable quantity. For example, the variation in the optical power at the star input due to combined effects of launch power, LED lifetime degradation, connectors, distance from 10BASE-FP MAU to Star, and wavelength of transmitter can be measured at the star input port. Also, star differential loss measurement is described in 16.5.2.2.

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Annex C

(informative)

State diagram, MAC sublayer

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Annex D

(informative)

Application context, selected medium specifications

D.1 Introduction

This annex provides general guidance, to both the design engineer and the eventual user of specific product implementations, on the particular clauses of this standard considered useful for different 10 Mb/s application environments. It is to be emphasized that the material in this annex is very general, as the standard specifications are intended to be relatively application-independent. Nevertheless, certain specifications may apply more to one application environment than another. What follows are brief descriptions of application environments and lists of those generic parameters of the Physical Layer specifications thought to be useful in relating a general set of user requirements to a specific standard specification and its related medium. *Once a basic relationship is identified, the reader is directed to a specific clause of the standard for detailed design specifications.*

D.2 Type 10BASE5 applications

One of the major arenas for local area networks is the interconnection of work stations throughout a large department or single building. The ability to handle all kinds of message traffic at relatively high data rates among a large set of work stations are typical characteristics of these environments. Usually the basic interconnection trunk cable is installed and left in place permanently or for extended periods while work station placement may shift from time to time. The Type 10BASE5 specification provides the primary baseband backbone for intraplant CSMA/CD interconnections. Clause 7 and Clause 8 of the standard provide detailed specifications for the Physical Layers associated with Type 10BASE5 environments. The generic Physical Layer parameters are as follows:

Maximum unrepeatered cable segment500 m
Maximum number of MAUs per segment100
Connector typeType N or coaxial “tap”
Breakdown voltage, MAU function250 V ac rms
MTBF1 million hours
Total Segment Resistance5 Ω
MAU separation2.5 m
Connection shunt capacitance4 pF
AUI functionalityDO, DI, CI, (CO optional)

D.3 Type 10BASE2 applications

Another major arena for local area networks is the interconnection of work stations throughout a small department or work area. The ability to handle all kinds of message traffic at relatively high data rates among a selected set of locally clustered work stations are the typical characteristics of these environments. In addition, the basic interconnection trunk cable is likely to be moved frequently by the local users of the equipment to suit evolving needs. The Type 10BASE2 specification provides an interconnection schema that complements the Type 10BASE5 backbone in a hierarchical manner for intradepartment or work area CSMA/CD interconnections. Clause 7 and Clause 10 of the standard provide detailed specifications for the

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Physical Layers associated with Type 10BASE2 environments. The generic Physical Layer parameters are as follows:

Maximum unrepeatered cable segment185 m
Maximum number of MAUs per segment30
Connector typeType BNC “T”
Breakdown voltage, MAU function500 V ac rms
MTBF100 000 hours
Total Segment Resistance10 Ω
MAU separation0.5 m
Connection shunt capacitance8 pF
AUI functionalityDO, DI, CI

D.4 Type FOIRL and 10BASE-F applications; alternative fiber optic medium applications

D.4.1 Alternative fiber types

Table D–1 provides a listing of other fiber types that may be used in an FOIRL or a 10BASE-F Cable Link Segment. These fiber types have not been studied, and details for their use are not provided for in the main body of the standard. Therefore, using these fiber types may reduce the maximum achievable distance.

Table D–1—Alternative fiber types

Nominal Core diameter (µm) IEC 60793-2:1992	Nominal cladding diameter (µm) IEC 60793-2:1992	Nominal Numerical aperture IEC 60793-2:1992
50	125	0.2
50	125	0.21
50	125	0.22
85	125	0.26
100	140	0.29

D.4.1.1 Theoretical coupling losses

The body of the standard references a single fiber type to facilitate interoperability and conformance testing; however, other fiber types may also be used. The use of an alternate fiber type with a particular implementation may have the following consequences. At the transmit MDI, more or less light may be launched into the fiber, depending on whether the optics are optimized for a core size and a numerical aperture (NA) that are smaller or larger than that of the alternate fiber size. At the receive MDI, the sensitivity may be increased or decreased depending on the optimization of the collecting optics. Table D–2 summarizes the potential effects of the use of alternate fiber sizes and provides the loss budget remaining for cable plant attenuation. All adjustments are relative to an implementation using the minimum diameter and NA 62.5 µm core fiber as specified in IEC 60793-2:1992, Type A1b, Category ≤ 3.5 dB/km. This cable plant has a loss budget of 9 dB for FOIRL segments and 12.5 dB for 10BASE-FL and 10BASE-FB link segments.

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The worst-case loss budget in Table D–2 is calculated on the assumption that the transmitter and receiver core diameter and NA are 62.5 µm and 0.275, respectively. Launching into a smaller core diameter or NA will incur a loss. Launching into a larger core diameter or NA will not result in a gain.

Similarly, receiving from a larger core diameter or NA incurs a loss, but receiving from smaller core diameter or NA provides no gain.

The values for transmit powers assume a worst-case condition that no additional power is launched into an increased core diameter and NA link fiber when referred to the 62.5 µm core fiber. This assumption is valid for underfilled launch conditions such as may occur from a MAU containing a pigtailed or laser emitter.

Table D–2—Worst-case loss budget

Fiber type	Transmit loss (dB)	Receive loss (dB)	Loss budget remaining (dB)	
			FOIRL	10BASE-FB/L
50 µm/NA=0.20	5.7	0	3.3	6.8
50 µm/NA=0.21	5.2	0	3.8	7.3
50 µm/NA=0.22	4.8	0	4.2	7.7
85 µm/NA=0.26	1.6	2.6	4.8	8.3
100 µm/NA=0.29	0.5	4.5	4.0	7.5

D.4.1.2 Maximum launch power

When large core diameter and NA launch conditions are used in conjunction with a launch fiber of larger core diameter and NA than the 62.5 µm reference, significantly greater launch power can occur. For example, this is typically the case with wide area surface emitter LED devices that are directly aligned with a fiber in a device mount header.

Table D–3 summarizes the maximum launch power into fibers with larger core diameters than 62.5 µm and the corresponding excess power that can result with a receiver utilizing all the optical power from the fiber.

Table D–3—Worst-case launch power

Fiber type	Maximum transmit power (dBm)	Maximum excess power (dBm)
85 µm/NA=0.26	–6.1	2.9
100 µm/NA=0.29	–3.8	5.2

In this case, sufficient attenuation should be installed in the link segment to ensure that for FOIRL segments the peak received optical power does not exceed –9 dBm, and for 10BASE-F segments the average received optical power does not exceed the appropriate optical Receive Average Power (Max) in Table 15–1.

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D.4.2 Type 10BASE-FP applications using 50/125 µm fiber

It is recognized that, in some cases, designers are constrained to use fiber sizes other than 62.5/125 µm in LAN designs. Such LAN designs are beyond the scope of this standard but can operate properly if optical power and loss budgets are adjusted to compensate for the different fiber characteristics. The following guidance is provided for system implementers who are constrained to design LANs with the 50/125 µm fiber described in D.4.1.

WARNING

Interoperability of nonconforming implementations cannot be ensured. It is the responsibility of the designer(s) of nonconforming implementation(s) to assure LAN operation. The following is only advisory information for implementations outside the scope of this standard.

D.4.2.1 Coupled transmit power

As shown in D.4.1, reduction of coupled power introduces the greatest difference between LANs using 62.5/125 µm and those using 50/125 µm fiber. Typically, for an emitter technology that produces a uniform, overfilled launch condition, this difference will be 3.5 dB. Implementers of 50/125 µm systems may choose to deal with this by trying one of the following alternatives:

a) Selecting an emitter technology with coupled power that is less susceptible to variation with fiber size, or
b) Increasing receiver sensitivity and dynamic range, or
c) Reducing the star coupler loss to compensate for the reduction in coupled transmit power. This may be accomplished by reducing the number of ports on the star coupler, or
d) Reducing the connector losses in the system, either by reducing the number of in-line connectors or reducing the loss per connector.

D.4.2.2 Star coupler loss

Also in accordance with D.4.1, the transmission loss of 50/125 µm star couplers may be as much as 1 dB greater than their 62.5/125 µm counterparts. Implementers of 50/125 µm systems may choose to deal with this by trying one of the following alternatives:

a) Procurement—specification of coupler loss characteristics to be the same as those shown for 62.5/125 µm star couplers, per 16.5, or
b) Compensation—all items shown in D.4.2.1 a) to d) may be used to compensate for an increase in coupler loss.

For example, a passive-star coupler (with connectors) with 33 ports typically has the following losses:

Contributor	Loss (dB)
Splitting	–15
Connector (1)	–1
Excess	0 to –4
Total	–16 to –20

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If, in a LAN that used 50/125 µm fiber, the maximum allowable number of ports per passive-star coupler was reduced to 17, the appropriate losses would be as follows:

Contributor	Loss (dB)
Splitting:	–12
Connector (1):	–1
Excess:	0 to –3
Total:	–13 to –16

The 3.5 dB lost to the MDI OTD would then be recovered allowing this "reduced nodes" LAN to still operate at the proposed maximum of 500 m MAU to the star.

It should be noted that the MAU parameters remain unchanged.

D.4.2.3 Collision detection

Reliable collision detection requires that designers of systems using nonconforming fiber optic cable ensure that the optical power levels of all possible colliding signals on the LAN differ at the mixing element (passive-star coupler) by no more than that specified in 16.3.4.2. This requires that
$10 \times \text{abs}\,(\log((P_{Ti} - L_{Ti} - U_{Ti})/(P_{Tj} - L_{Tj} - U_{Tj}))) \leq$ that specified in 16.3.4.2.

for all i not equal j, and

where

P_{Tn} is coupled optical transmit power, MAU n
L_{Tn} is optical cable and connector and transmit fiber loss, from MAU n to star input port m
U_{Tm} is input port uniformity, port m

D.5 10BASE-T use of cabling systems with a nominal differential characteristic impedance of 120 Ω

Clause 14 specifies the use of 100 Ω link segments. This subclause specifies the conditions for the use of cabling with a nominal characteristic impedance of 120 Ω by 10BASE-T conformant stations.

The use of cables with a characteristic impedance outside the range specified in 14.4.2.2 will generally increase the mismatching effects in the link components, inducing additional jitter in the received signal.

In particular, the use of a homogeneous link segment having a characteristic impedance of 120 Ω ± 15 Ω over the frequency band 1 to 16 MHz may add from 0.15 ns (maximum-length segment) up to 0.63 ns (short-length segment) of additional jitter to the signal at the input of the receiver.

Consequently, in order to keep the overall jitter budget at the same value as for a 100 Ω link segment when using a 120 Ω link segment, the following modifications to the specifications of 14.4 apply:

a) The maximum medium timing jitter specified in 14.4.2.3 for a simplex link segment is increased from 5 ns to 5.5 ns.

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b) The NEXT loss values specified in 14.4.3 are increased by 3 dB, i.e., the applicable formulas are replaced by the following:

1) in 14.4.3.1.1 for 25-pair cables/binder groups: $33–15 \log_{10}(f/10)$ dB.
2) in 14.4.3.1.2 for 4-pair cables: $29–15 \log_{10}(f/10)$ dB.
3) in 14.4.3.2 for MDNEXT: $26–15 \log_{10}(f/10)$ dB.

NOTE—In addition to the case of 120 Ω homogeneous link segments, the above figures encompass the case where 100 Ω terminal cords are used in conjunction with 120 Ω premises cabling. This configuration results in adding up to 0.5 ns of jitter for a maximum-length segment (instead of 0.15 ns) and up to 1.3 ns for a short-length segment (instead of 0.63 ns).

The use of 100 Ω cords at any intermediate cross-connects on 120 Ω links as well as the use of cords with a characteristic impedance of 120 Ω ± 15 Ω in conjunction with 100 Ω ±15 Ω premises cabling is not allowed since it would result in worst-case jitter greater than that allowed in the standard.

D.6 10BASE-T use of cabling systems with a nominal differential characteristic impedance of 150 Ω

This subclause outlines the philosophy and methodology for allowing 10BASE-T stations to support transmission on 150 Ω balanced STP cabling, as specified by ISO/IEC 11801:1995, Clause 8, with the use of impedance matching transformers.

The 10BASE-T specification was designed to support Manchester signaling over a link segment consisting of 100 Ω cabling system. The MAU link interface specifications were designed to ensure that jitter due to impedance discontinuities were minimized as specified in 14.4.2.3. In theory and in practice, a 150 Ω cabling system may be used to provide the link segment function provided the proper impedance match (100 Ω) with the MAU over the frequency range of interest as specified in 14.4, and the resultant transmission characteristics of the cabling system used to provide the link segment function meet or exceed those specified in 14.4. Therefore, to ensure the jitter specification of 14.4.2.3 and the jitter budget of B.4.1 are met, the following approach is recommended when using 150 Ω balanced STP cabling (as specified in ISO/IEC 11801:1995):

a) The 150 Ω section included in the link segment shown in Figure D–1 meets the specifications of ISO/IEC 11801:1995, 7.2.

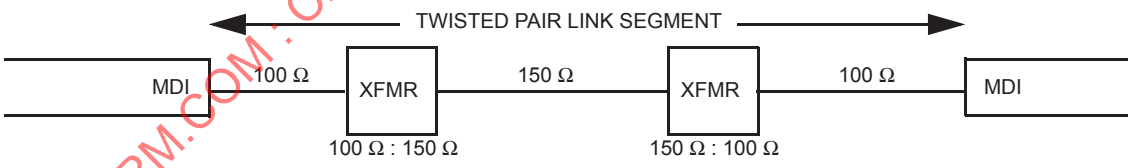

Figure D–1—Link segment incorporating 150 Ω cable section

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b) The link segment, including impedance matching transformers as shown in Figure D–2, meets all applicable specifications of 14.4.

c) A link test point is shown in Figure D–2. The transformers shown are the same as the ones shown in Figure D–1. The attaching cables between the MAU and the link test point should be the minimum required to attach the components. As tested in this configuration, the MAU transmitter requirements meet all applicable requirements for the MAU as specified in Clause 14, except for signal levels which may be up to 1.0 dB lower than that specified there.

NOTE—This 1.0 dB (0.5 dB per transformer) effectively requires the attenuation of the 150 Ω cable section of the twisted-pair link segment (see Figure D–1) to be less than or equal to 10.5 dB in order to meet the requirements of 14.4.2.

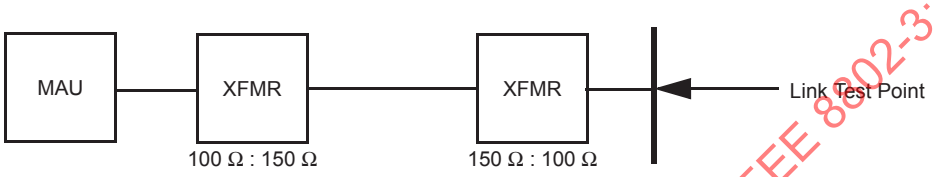

Figure D–2—Link test point for 150 Ω cabling

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Annex E

(informative)

Receiver wavelength design considerations (FOIRL)

NOTE—This annex relates to a clause that is not recommended for new installations. This annex is not recommended for new installations. Since March 2012, maintenance changes are no longer being considered for this annex.

The center wavelength of the optical source emission is specified in 9.9.4.1.1 to be between 790 nm and 860 nm. Although these limits are acceptable, it is currently recognized, through the examination of manufacturers' current data, that greater choices of emitters can be obtained by extending the allowable wavelength to 910 nm.

An upper limit of 910 nm allows the selection of devices nominally centered at a lower wavelength, for example, 880 nm. This allows a tolerance for manufacturing variations, for example, ±20 nm, and a tolerance for an operating temperature range (typically, 0.3 nm/°C).

It is anticipated that future fiber optic applications including Local Area Networks will use the 910 nm upper limit for first window systems. It is therefore recommended that implementers specify receiver sensitivity over a center wavelength range from 790 nm to 910 nm.

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Annex F

(normative)

Additional attributes required for systems

F.1 Introduction

During the development of Repeater Management, some attributes and operations were identified as items that were necessary to fill out the management of a complete intermediate system such as a repeater. These items are generic in the sense that they are required for managed systems in general. They are not normally specified as attributes of the lower layers. In repeater management, the entire system is at the lowest layers so there is no other group to turn to for systems management. The following items are defined to aid in the completeness of this standard, although it is recognized that they are outside the bounds of the definition area for a layer1/2 device.

F.1.1 Scope

This annex defines additional managed objects and attributes that have been identified by the IEEE 802.3 Repeater Management Task Force as being necessary to the management of an IEEE 802.3 repeater. These objects and attributes, while necessary to the management of an IEEE 802.3 repeater, are not specifically related to the CSMA/CD access method or to Clause 9 repeaters; rather, they are objects and attributes that are appropriate for any managed system.

This annex does not necessarily define the complete set of generic objects and attributes required to support a managed system. It contains only those objects and attributes that were identified in the process of developing the repeater management standard and were identified as not being uniquely appropriate to a CSMA/CD layer management standard.

When a generic systems management standard is available that is appropriate for managed systems of the complexity of a repeater, it is expected that this portion of the standard will no longer be appropriate and will be deprecated.

F.2 Objects/Attributes/Actions/Notifications

F.2.1 TimeSinceSystemReset attribute

```
aTimeSinceSystemReset          ATTRIBUTE
    DERIVED FROM               AttributeModule.ResettableCounter32;
    BEHAVIOUR                  bTimeSinceSystemReset;
    REGISTERED AS   {iso(1) member-body(2) us(840) 802dot3(10006) repeaterMgt(19) attribute(7)
                    sysResetTime(47)};
```

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bTimeSinceSystemReset **BEHAVIOUR**
DEFINED AS The time in tens of milliseconds since the last time that the system including network management was reset. This may have been caused by ResetSystemAction or other means. This counter has a value of 0 when initialized.

Though the count is reported in tens of milliseconds, the required resolution is to the nearest 100 ms. The clocking source for the counter shall be accurate to within 1% throughout the full counting range.;

NOTE—The approximate minimum time for counter rollover is 497 days.

F.2.2 RepeaterResetTimeStamp attribute

aRepeaterResetTimeStamp **ATTRIBUTE**
WITH ATTRIBUTE SYNTAX AttributeModule.Integer32;
BEHAVIOUR bRepeaterResetTimeStamp;
REGISTERED AS {iso(1) member-body(2) us(840) 802dot3(10006) repeaterMgt(19) attribute(7) repeaterResetTimeStamp(48)};

bRepeaterResetTimeStamp **BEHAVIOUR**
DEFINED AS Not a counter, this attribute provides the value of aTimeSinceSystemReset when the repeater was last reset. This value is recorded whenever the repeater enters the START state of Figure 9–2 in the 802.3 repeater standard. This value may never be greater than aTimeSinceSystemReset.;

F.2.3 ResetSystemAction action

acResetSystemAction **ACTION**
BEHAVIOUR acResetSystem;
MODE CONFIRMED;
REGISTERED AS {iso(1) member-body(2) us(840) 802dot3(10006) repeaterMgt(19) action(9) resetSystem(49)};

acResetSystem **BEHAVIOUR**
DEFINED AS This action initializes the resettable management counters of the system and also of all contained objects. The value of non-resettable counters may change as a result of this action.;

NOTE—This action may result in the loss of packets.

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Annex G

(normative)

Additional material required for conformance testing

NOTE—This annex relates to a clause that has been deprecated. Since March 2012, maintenance changes are no longer being considered for this annex.

G.1 Introduction

This material was generated during the development of Clause 19. It was felt that it was required to support the development of conformance test material that was not included in the charter of the development of the original repeater management standard.

G.1.1 Material in support of the aDataRateMismatches attribute

A vendor submitting equipment for conformance testing under Clause 19 shall provide minimum frequency difference data (two values) such that a test can be done for exertion and another test can be done for non-exertion of the aDataRateMismatch attribute (see 19.2.6.2).

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Annex H

(normative)

GDMO specifications for CSMA/CD managed objects

NOTE—GDMO specifications were moved to Annex B of IEEE Std 802.3.1-2011 and removed from this Annex in IEEE Std 802.3-2012.

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NOTE—This annex is numbered in correspondence to its associated clause; i.e., Annex 4A corresponds to Clause 4.

Annex 4A

(normative)

Simplified full duplex media access control

This annex is based on the Clause 4 MAC, with simplifications for use in networks that do not require the half duplex operational mode. Additional functionality is included for managing Physical Layer congestion and for support of interframe spacing outside this sublayer. This annex stands alone and does not rely on information within Clause 4 to be implemented.

4A.1 Functional model of the MAC method

4A.1.1 Overview

The architectural model described in Clause 1 is used in this clause to provide a functional description of the LAN full duplex MAC sublayer.

The MAC sublayer defines a medium-independent facility, built on the medium-dependent physical facility provided by the Physical Layer, and under the access-layer-independent LAN LLC sublayer (or other MAC client). It is applicable to a general class of media suitable for use with the full duplex media access discipline.

The LLC sublayer and the MAC sublayer together are intended to have the same function as that described in the OSI model for the Data Link Layer alone. The partitioning of functions presented in this standard requires two main functions generally associated with a data link control procedure to be performed in the MAC sublayer. They are as follows:

a) Data encapsulation (transmit and receive)
   1) Framing (frame boundary delimitation, frame synchronization)
   2) Addressing (handling of source and destination addresses)
   3) Error detection (detection of physical medium transmission errors)
b) Media access management (Physical Layer congestion)

This MAC does not support the *half duplex* mode of operation so there is no need for collision detection or handling. However, this MAC does have the ability to avoid congestion within the Physical Layer. Therefore, Media Access Management comprises the transmission of bits to the Physical Layer and optionally delaying any transmission for an interframe gap or for a longer period of time based on congestion within the Physical Layer.

An optional MAC control sublayer, architecturally positioned between LLC (or other MAC client) and the MAC, is specified in Clause 31 and Clause 64. This MAC Control sublayer is transparent to both the underlying MAC and its client (typically LLC). The MAC sublayer operates independently of its client; i.e., it is unaware whether the client is LLC or the MAC Control sublayer. This allows the MAC to be specified and implemented in one manner, whether or not the MAC Control sublayer is implemented. References to LLC as the MAC client in text and figures apply equally to the MAC Control sublayer, if implemented.

The remainder of this clause provides a functional model of this MAC method.

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4A.1.2 Full duplex operation

This subclause provides an overview of frame transmission and reception in terms of the functional model of the architecture. This overview is descriptive, rather than definitional; the formal specifications of the operations described here are given in 4A.2 and 4A.3. Specific implementations for full duplex mechanisms that meet this standard are given in 4A.4. Figure 1–1 provides the architectural model described functionally in the subclauses that follow.

The Physical Layer Signaling (PLS) component of the Physical Layer provides an interface to the MAC sublayer for the serial transmission of bits onto the physical media. For completeness, in the operational description that follows some of these functions are included as descriptive material. The concise specification of these functions is given in 4A.2 for the MAC functions and in Clause 7 for PLS.

Transmit frame operations are independent from receive frame operations and respond to different signals from the Physical Layer. The carrierSense signal indicates that the transmit function must defer because of congestion at the Physical Layer (see 4A.2.3.2.1). The receiveDataValid signal indicates the presence of incoming data to the receive function (see 4A.2.4.2).

4A.1.2.1 Transmission

When a MAC client requests the transmission of a frame, the Transmit Data Encapsulation component of the full duplex MAC sublayer constructs the frame from the client-supplied data. It prepends a preamble and a Start Frame Delimiter to the beginning of the frame. Using information provided by the client, the MAC sublayer also appends a Pad at the end of the MAC information field of sufficient length to ensure that the transmitted frame length satisfies a minimum frame-size requirement (see 4A.2.3.2.4). It also prepends destination and source addresses, the length/type field, and appends a frame check sequence to provide for error detection. If the MAC supports the use of client-supplied frame check sequence values, then it shall use the client-supplied value, when present. If the use of client-supplied frame check sequence values is not supported, or if the client-supplied frame check sequence value is not present, then the MAC shall compute this value. Frame transmission may be initiated once the carrierSense signal has been removed and after the interframe delay, regardless of the presence of receive activity.

The Physical Layer performs the task of generating the signals on the medium that represent the bits of the frame. Once the Physical Layer has indicated its readiness to transmit another frame by removing the carrierSense signal, it shall accept a complete frame from the MAC layer. A functional description of the Physical Layer is given in Clause 7 and beyond.

When transmission has completed, the MAC sublayer so informs the MAC client and awaits the next request for frame transmission.

4A.1.2.2 Reception

At each receiving station, the arrival of a frame is first detected by the Physical Layer, which responds by synchronizing with the incoming preamble, and by turning on the receiveDataValid signal. As the encoded bits arrive from the medium, they are decoded and translated back into binary data. The Physical Layer passes subsequent bits up to the MAC sublayer, where the leading bits are discarded, up to and including the end of the preamble and Start Frame Delimiter.

Meanwhile, the Receive Media Access Management component of the MAC sublayer, having observed receiveDataValid, has been waiting for the incoming bits to be delivered. Receive Media Access Management collects bits from the Physical Layer entity as long as the receiveDataValid signal remains on. When the receiveDataValid signal is removed, the frame is truncated to an octet boundary, if necessary, and passed to Receive Data Decapsulation for processing.

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Receive Data Decapsulation checks the frame's Destination Address field to decide whether the frame should be received by this station. If so, it passes the Destination Address (DA), the Source Address (SA), the Length/Type, the Data, and (optionally) the Frame Check Sequence (FCS) fields to the MAC client, along with an appropriate status code, as defined in 4A.3.2. It also checks for invalid MAC frames by inspecting the FCS to detect any damage to the frame enroute, and by checking for proper octet-boundary alignment of the end of the frame. Frames with a valid FCS may also be checked for proper octet-boundary alignment.

4A.1.3 Relationships to the MAC client and Physical Layers

The MAC sublayer provides services to the MAC client required for the transmission and reception of frames. Access to these services is specified in 4A.3. The MAC sublayer makes a best effort to transfer a serial stream of bits to the Physical Layer. Although certain errors are reported to the client, error recovery is not provided by MAC. Error recovery may be provided by the MAC client or higher (sub)layers.

4A.2 Media access control (MAC) method: precise specification

4A.2.1 Introduction

A precise algorithmic definition is given in this subclause, providing a procedural model for the MAC process with a program in the computer language Pascal. See references [B12] and [B23] for resource material. Note whenever there is any apparent ambiguity concerning the definition of some aspect of the MAC method, it is the Pascal procedural specification in 4A.2.7 through 4A.2.10 that should be consulted for the definitive statement. Subclauses 4A.2.2 through 4A.2.6 provide, in prose, a description of the access mechanism with the formal terminology to be used in the remaining subclauses.

4A.2.2 Overview of the procedural model

The functions of the MAC method are presented below, modeled as a program written in the computer language Pascal. This procedural model is intended as the primary specification of the functions to be provided in any MAC sublayer implementation. It is important to distinguish, however, between the model and a real implementation. The model is optimized for simplicity and clarity of presentation, while any realistic implementation shall place heavier emphasis on such constraints as efficiency and suitability to a particular implementation technology or computer architecture. In this context, several important properties of the procedural model shall be considered.

4A.2.2.1 Ground rules for the procedural model

a) First, it shall be emphasized that *the description of the MAC sublayer in a computer language is in no way intended to imply that procedures shall be implemented as a program executed by a computer.* The implementation may consist of any appropriate technology including hardware, firmware, software, or any combination.
b) Similarly, it shall be emphasized that it is the behavior of any MAC sublayer implementations that shall match the standard, not their internal structure. The internal details of the procedural model are useful only to the extent that they help specify that behavior clearly and precisely.
c) The handling of incoming and outgoing frames is rather stylized in the procedural model, in the sense that frames are handled as single entities by most of the MAC sublayer and are only serialized for presentation to the Physical Layer. In reality, many implementations will instead handle frames serially on a bit, octet or word basis. This approach has not been reflected in the procedural model, since this only complicates the description of the functions without changing them in any way.
d) The model consists of algorithms designed to be executed by a number of concurrent processes; these algorithms collectively implement the MAC procedure. The timing dependencies introduced by the need for concurrent activity are resolved in two ways:

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1) *Processes Versus External Events.* It is assumed that the algorithms are executed "very fast" relative to external events, in the sense that a process never falls behind in its work and fails to respond to an external event in a timely manner. For example, when a frame is to be received, it is assumed that the Media Access procedure ReceiveFrame is always called well before the frame in question has started to arrive.
2) *Processes Versus Processes.* Among processes, no assumptions are made about relative speeds of execution. This means that each interaction between two processes shall be structured to work correctly independent of their respective speeds. Note, however, that the timing of interactions among processes is often, in part, an indirect reflection of the timing of external events, in which case appropriate timing assumptions may still be made.

It is intended that the concurrency in the model reflect the parallelism intrinsic to the task of implementing the MAC client and MAC procedures, although the actual parallel structure of the implementations is likely to vary.

4A.2.2.2 Use of Pascal in the procedural model

Several observations need to be made regarding the method with which Pascal is used for the model. Some of these observations are as follows:

a) The following limitations of the language have been circumvented to simplify the specification:
   1) The elements of the program (variables and procedures, for example) are presented in logical groupings, in top-down order. Certain Pascal ordering restrictions have thus been circumvented to improve readability.
   2) The *process* and *cycle* constructs of Concurrent Pascal, a Pascal derivative, have been introduced to indicate the sites of autonomous concurrent activity. As used here, a process is simply a parameterless procedure that begins execution at "the beginning of time" rather than being invoked by a procedure call. A cycle statement represents the main body of a process and is executed repeatedly forever.
   3) The lack of variable array bounds in the language has been circumvented by treating frames as if they are always of a single fixed size (which is never actually specified). The size of a frame depends on the size of its data field, hence the value of the "pseudo-constant" frameSize should be thought of as varying in the long term, even though it is fixed for any given frame.
   4) The use of a variant record to represent a frame (as fields and as bits) follows the spirit but not the letter of the Pascal Report, since it allows the underlying representation to be viewed as two different data types.
b) The model makes no use of any explicit interprocess synchronization primitives. Instead, all interprocess interaction is done by way of carefully stylized manipulation of shared variables. For example, some variables are set by only one process and inspected by another process in such a manner that the net result is independent of their execution speeds. While such techniques are not generally suitable for the construction of large concurrent programs, they simplify the model and more nearly resemble the methods appropriate to the most likely implementation technologies (microcode, hardware state machines, etc.)

4A.2.2.3 Organization of the procedural model

The procedural model used here is based on five cooperating concurrent processes. The Frame Transmitter process and the Frame Receiver process are provided by the clients of the MAC sublayer (which may include the LLC sublayer) and make use of the interface operations provided by the MAC sublayer. The other three processes are defined to reside in the MAC sublayer. The five processes are as follows:

a) Frame Transmitter process
b) Frame Receiver process
c) Bit Transmitter process
d) Bit Receiver process
e) Deference process

This organization of the model is illustrated in Figure 4A–1 and reflects the fact that the communication of entire frames is initiated by the client of the MAC sublayer, while the timing of individual bit transfers is based on interactions between the MAC sublayer and the Physical-Layer-dependent bit time.

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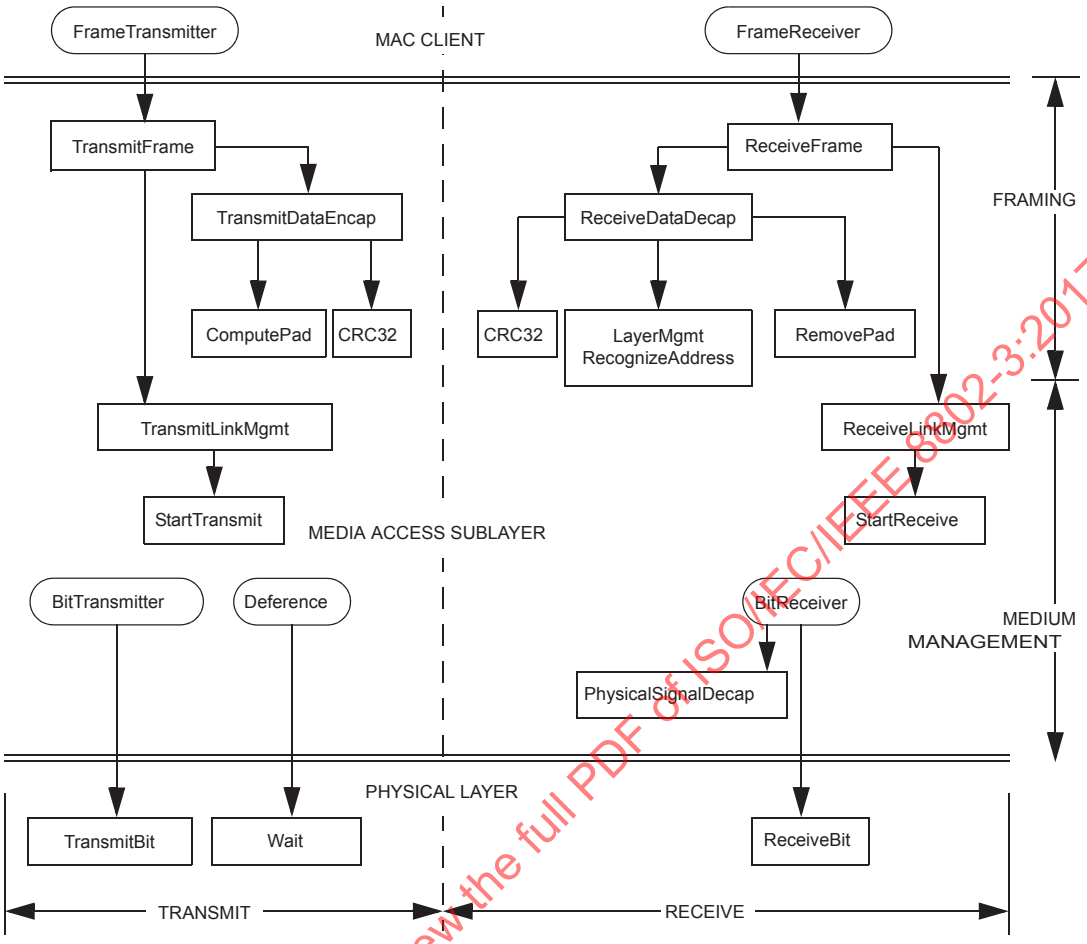

Figure 4A–1—Relationship among MAC procedures

Figure 4A–1 depicts the static structure of the procedural model, showing how the various processes and procedures interact by invoking each other. Figure 4A–2a, Figure 4A–2b, and Figure 4A–2c summarize the dynamic behavior of the model during transmission and reception, focusing on the steps that shall be performed, rather than the procedural structure that performs them. The usage of the shared state variables is not depicted in the figures, but is described in the comments and prose in the following subclauses.

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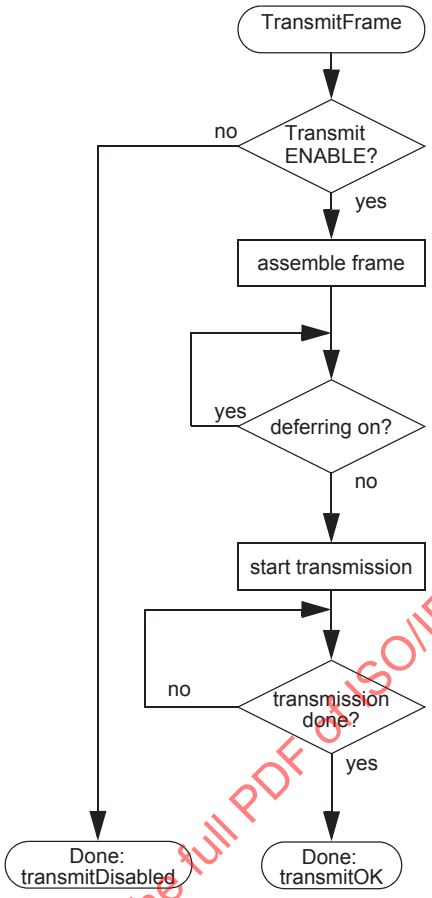

a) TransmitFrame

Figure 4A–2a—Control flow summary

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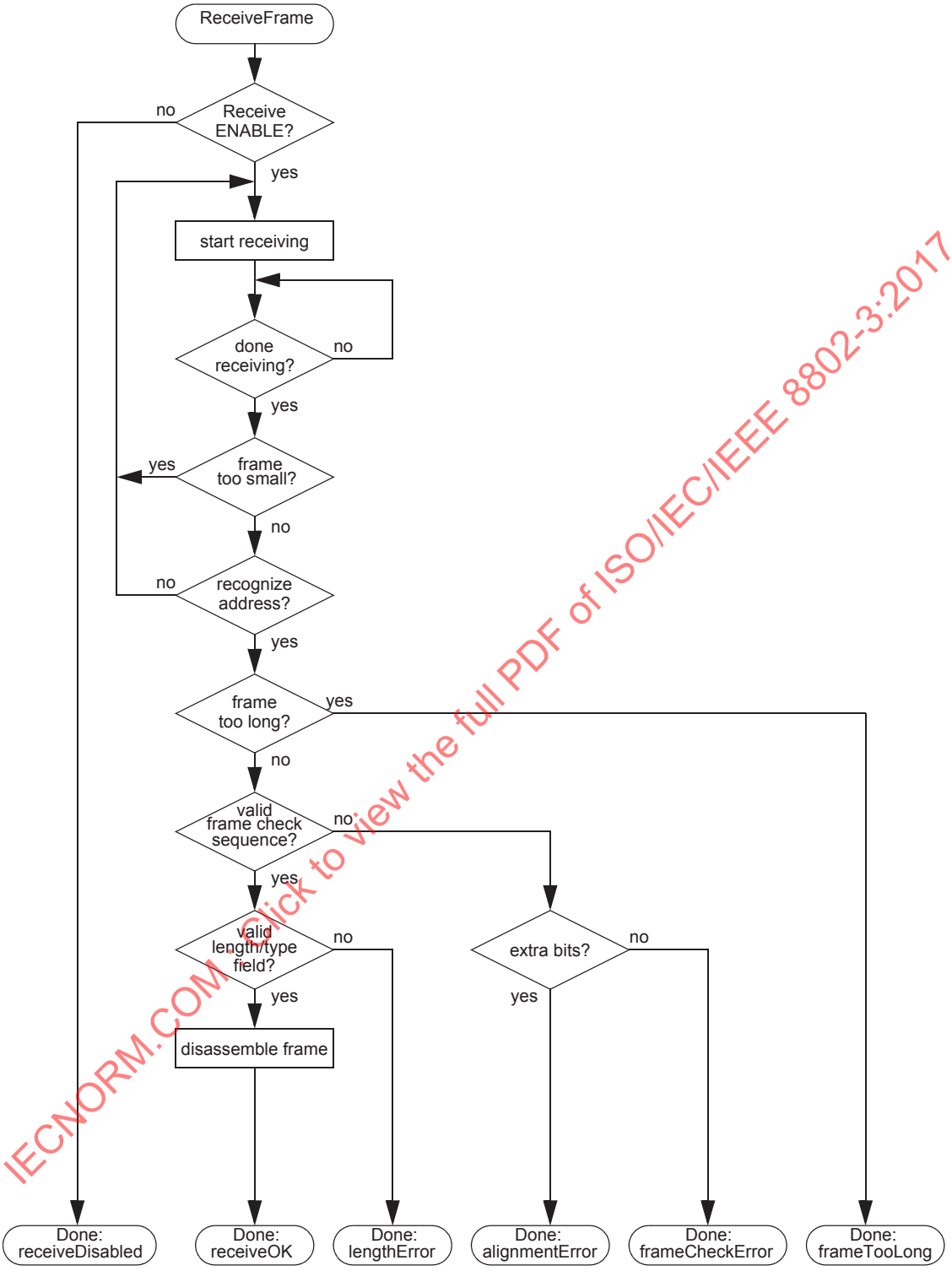

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b) ReceiveFrame

Figure 4A–2b—Control flow summary

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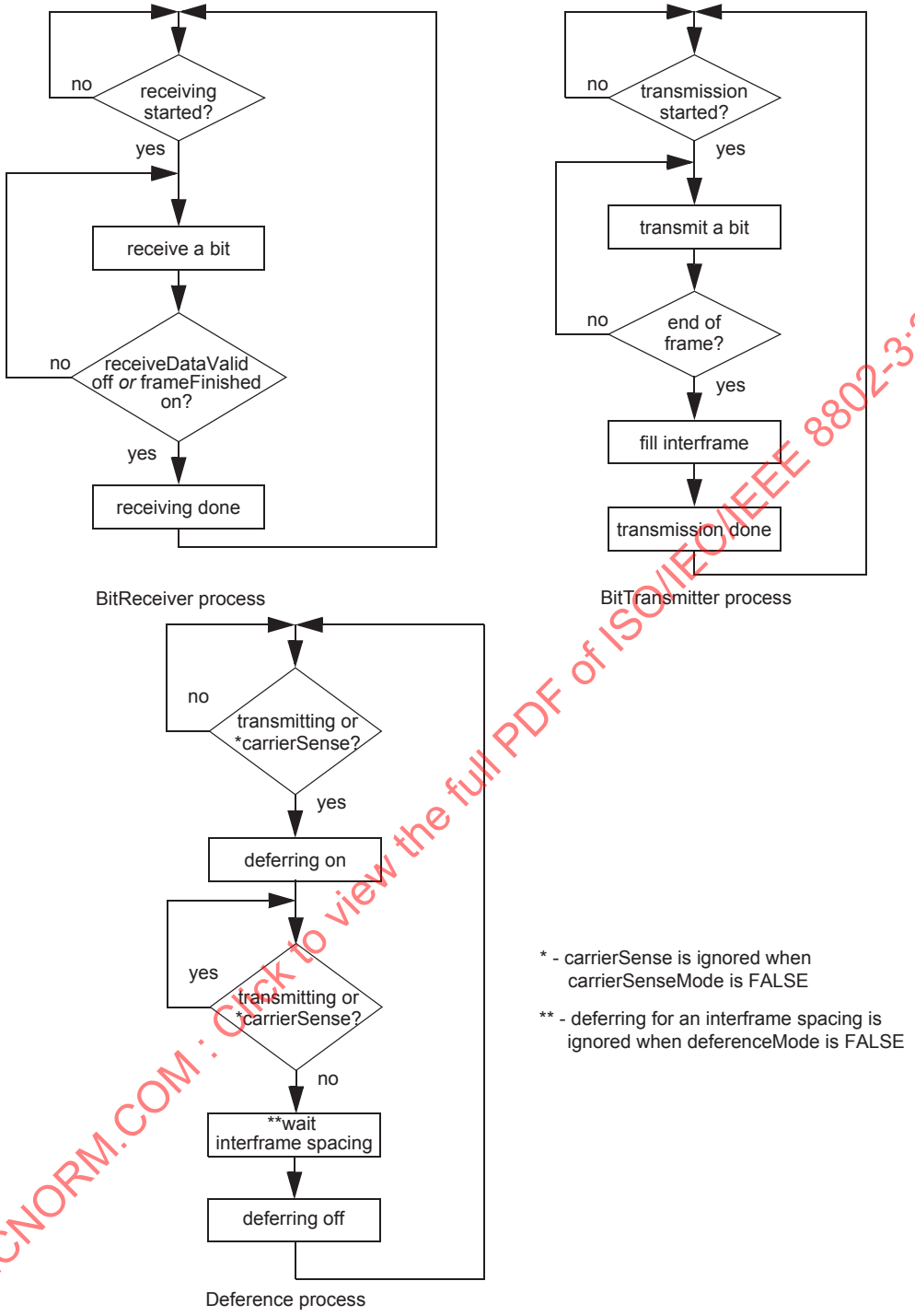

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c) MAC sublayer

Figure 4A–2c—Control flow

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4A.2.2.4 Layer management extensions to procedural model

In order to incorporate network management functions, this Procedural Model has been expanded. Network management functions have been incorporated in two ways. First, 4A.2.7–4A.2.10, 4A.3.2, Figure 4A–2a, and Figure 4A–2b have been modified and expanded to provide management services. Second, Layer Management procedures have been added as 5.2.4. The Pascal variables are shared between Annex 4A and Clause 5.

The Pascal procedural specification shall be consulted for the definitive statement when there is any apparent ambiguity concerning the definition of some aspect of the MAC access method.

The Layer Management facilities provided by the MAC and Physical Layer management definitions provide the ability to manipulate management counters and initiate actions within the layers. The managed objects within this standard are defined as sets of attributes, actions, notifications, and behaviours in accordance with IEEE Std 802.1F-1993, and ISO/IEC International Standards for network management.

4A.2.3 Packet transmission model

Packet transmission includes data encapsulation and Media Access management aspects:

a) Transmit Data Encapsulation includes the assembly of the outgoing packet (from the values provided by the MAC client) and frame check sequence generation.
b) Transmit Media Access Management includes carrier deference, interpacket gap and bit transmission.

4A.2.3.1 Transmit data encapsulation

The fields of the MAC frame are set to the values provided by the MAC client as arguments to the TransmitFrame operation (see 4A.3) with the following possible exceptions: the padding field and the frame check sequence. The padding field is necessary to enforce the minimum frame size. The frame check sequence field may be (optionally) provided as an argument to the MAC sublayer. It is optional for a MAC to support the provision of the frame check sequence in such an argument. If this field is provided by the MAC client, the padding field shall also be provided by the MAC client, if necessary. If this field is not provided by the MAC client, or if the MAC does not support the provision of the frame check sequence as an external argument, it is set to the CRC value as generated by the MAC sublayer, after appending the padding field, if necessary.

4A.2.3.2 Transmit media access management

4A.2.3.2.1 Deference

When a packet is submitted by the MAC client for transmission, the transmission is initiated as soon as possible, but in conformance with the following rules. The variable carrierSense is ignored in process Deference when the variable carrierSenseMode is FALSE.

The MAC sublayer monitors the transmitting variable, which indicates the MAC is transmitting data to the Physical Layer, as well as the carrierSense signal provided by the PLS, which indicates the Physical Layer is not ready for the next frame. When either transmitting or carrierSense is true, the MAC delays any pending transmission. When both are false, the MAC continues to defer for a proper interPacketGap (see 4A.2.3.2.2).

If, at the end of the interPacketGap, a packet is waiting to be transmitted, transmission is initiated. When transmission has completed (or immediately, if there was nothing to transmit) the MAC sublayer resumes its original monitoring of transmitting and carrierSense.

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4A.2.3.2.2 Interpacket gap

As defined in 4A.2.3.2.1, the rules for deferring ensure a minimum interpacket spacing of interPacketGap bit times. This is intended to provide interframe recovery time to aid in packet delineation on the physical medium.

Note that interPacketGap is the minimum value of the interpacket gap. If necessary for implementation reasons, a transmitting sublayer may use a larger value with a resulting decrease in its throughput. The larger value is determined by the parameters of the implementation, see 4A.4.

4A.2.3.2.3 Transmission

Transmissions may be initiated whenever the station has a frame queued, subject only to the Physical Layer congestion and interframe spacing required to allow recovery for the physical medium. In certain implementations, interframe spacing is accomplished outside this layer. These implementations are allowed to ignore the deference process and always initiate transmissions immediately, subject only to conditions enforced outside this sublayer.

4A.2.3.2.4 Minimum frame size

The MAC requires that a minimum frame length of minFrameSize bits be transmitted. If frameSize is less than minFrameSize, then the MAC sublayer shall append extra bits in units of octets (pad), after the end of the MAC client data field but prior to calculating, and appending, the FCS (if not provided by the MAC client). The number of extra bits shall be sufficient to ensure that the frame, from the DA field through the FCS field inclusive, is at least minFrameSize bits. If the FCS is (optionally) provided by the MAC client, the pad shall also be provided by the MAC client. The content of the pad is unspecified.

4A.2.4 Frame reception model

The MAC sublayer frame reception includes both data decapsulation and Media Access management aspects:

a) Receive data decapsulation comprises address recognition, frame check sequence validation, and frame disassembly to pass the fields of the received frame to the MAC client.

b) Receive media access management comprises recognition of collision fragments from incoming frames and truncation of frames to octet boundaries.

4A.2.4.1 Receive data decapsulation

4A.2.4.1.1 Address recognition

The MAC sublayer is capable of recognizing individual and group addresses.

a) *Individual Addresses.* The MAC sublayer recognizes and accepts any frame whose DA field contains the individual address of the station.

b) *Group Addresses.* The MAC sublayer recognizes and accepts any frame whose DA field contains the Broadcast address.

The MAC sublayer is capable of activating some number of group addresses as specified by higher layers. The MAC sublayer recognizes and accepts any frame whose Destination Address field contains an active group address. An active group address may be deactivated.

The MAC sublayer may also provide the capability of operating in the promiscuous receive mode. In this mode of operation, the MAC sublayer recognizes and accepts all valid frames, regardless of their Destination Address field values.

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4A.2.4.1.2 Frame check sequence validation

FCS validation is essentially identical to FCS generation. If the bits of the incoming frame (exclusive of the FCS field itself) do not generate a CRC value identical to the one received, an error has occurred and the frame is identified as invalid.

4A.2.4.1.3 Frame disassembly

Upon recognition of the Start Frame Delimiter at the end of the preamble sequence, the MAC sublayer accepts the frame. If there are no errors, the frame is disassembled and the fields are passed to the MAC client by way of the output parameters of the ReceiveFrame operation.

4A.2.4.2 Receive media access management

The MAC sublayer recognizes the boundaries of an incoming MAC frame by monitoring the receiveDataValid signal provided by the Physical Layer. Two possible length errors can occur that indicate ill-framed data: the MAC frame may be too long, or its length may not be an integer number of octets.

a) *Maximum Frame Size.* The receiving MAC sublayer is not required to enforce the MAC frame size limit, but it is allowed to truncate MAC frames longer than maxFrameSizeLimit octets (see 4.2.7.1). If optional layer management is implemented, such frames may be counted whether or not they are truncated. They may also be reported as an implementation-dependent error.

CAUTION

It is recommended that any implementation that truncates MAC frames should invalidate those frames as they may have severely weakened error protection and may cause serious problems if forwarded to the MAC client.

b) *Integer Number of Octets in Frame.* Since the format of a valid MAC frame specifies an integer number of octets, only a collision or an error can produce a MAC frame with a length that is not an integer multiple of 8 bits. Complete MAC frames (that is, not rejected for being too small) that do not contain an integer number of octets are truncated to the nearest octet boundary. If frame check sequence validation detects an error in such a MAC frame, the status code alignmentError is reported

4A.2.5 Preamble generation

In a LAN implementation, most of the Physical Layer components are allowed to provide valid output some number of bit times after being presented valid input signals. Thus it is necessary for a preamble to be sent before the start of data, to allow the PLS circuitry to reach its steady state. Upon request by TransmitLinkMgmt to transmit the first bit of a new frame, BitTransmitter shall first transmit the preamble, a bit sequence used for physical medium stabilization and synchronization, followed by the Start Frame Delimiter. The preamble pattern is:

10101010 10101010 10101010 10101010 10101010 10101010 10101010

The bits are transmitted in order, from left to right. The nature of the pattern is such that, for Manchester encoding, it appears as a periodic waveform on the medium that enables bit synchronization. It should be noted that the preamble ends with a 0.

4A.2.6 Start frame sequence

The receiveDataValid signal is the indication to the MAC that the frame reception process should begin. Upon reception of the sequence 10101011 following the assertion of receiveDataValid, PhysicalSignalDecap shall begin passing successive bits to ReceiveLinkMgmt for passing to the MAC client.

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4A.2.7 Global declarations

This subclause provides detailed formal specifications for the MAC sublayer. It is a specification of generic features and parameters to be used in systems implementing this media access method. 4A.4 provides values for these sets of parameters for recommended implementations of this media access mechanism.

4A.2.7.1 Common constants, types, and variables

The following declarations of constants, types and variables are used by the MAC frame transmission and reception sections of each MAC sublayer:

```
const
    addressSize = 48; {In bits, in compliance with 3.2.3}
    lengthOrTypeSize = 16; {In bits}
    clientDataSize = ...; {In bits, size of MAC Client Data; see 4A.2.2.2, a) 3)}
    padSize = ...; {In bits, = max (0, minFrameSize − (2 × addressSize + lengthOrTypeSize +
                                                        clientDataSize + crcSize))}
    dataSize = ...; {In bits, = clientDataSize + padSize}
    crcSize = 32; {In bits, 32-bit CRC}
    frameSize = ...; {In bits, = 2 × addressSize + lengthOrTypeSize + dataSize + crcSize; see 4A.2.2.2, a)}
    minFrameSize = ...; {In bits, see 4A.4}
    maxBasicFrameSize = 1518; {In octets, see 3.2.7, 4A.4}
    maxEnvelopeFrameSize = 2000; {In octets, see 3.2.7, 4A.4}
    qTagPrefixSize = 4; {In octets, length of Q-tag Prefix, see 3.2.7, 4A.4}
    maxFrameSizeLimit = maxBasicFrameSize or (maxBasicFrameSize + qTagPrefixSize) or
                        maxEnvelopeFrameSize ; {in octets}
    minTypeValue = 1536; {Minimum value of the Length/Type field for Type interpretation}
    maxBasicDataSize = 1500;
                        {In octets, the maximum length of the MAC Client Data field of the basic frame.}
    preambleSize = 56; {In bits, see 4A.2.5}
    sfdSize = 8; {In bits, Start Frame Delimiter}
    headerSize = 64; {In bits, sum of preambleSize and sfdSize}
type
    Bit = (0, 1);
    AddressValue = array [1..addressSize] of Bit;
    LengthOrTypeValue = array [1..lengthOrTypeSize] of Bit;
    DataValue = array [1..dataSize] of Bit; {Contains the portion of the MAC frame that starts with the first
                                             bit following the Length/Type field and ends with the last bit
                                             prior to the FCS field.
    CRCValue = array [1..crcSize] of Bit;
    PreambleValue = array [1..preambleSize] of Bit;
    SfdValue = array [1..sfdSize] of Bit;
    ViewPoint = (fields, bits); {Two ways to view the contents of a MAC frame}
    HeaderViewPoint = (headerFields, headerBits);
    Frame = record {Format of MAC frame}
        case view: ViewPoint of
            fields: (
                destinationField: AddressValue;
                sourceField: AddressValue;
                lengthOrTypeField: LengthOrTypeValue;
                dataField: DataValue;
                fcsField: CRCValue);
            bits: (contents: array [1..frameSize] of Bit)
        end; {MAC frame}
    Header = record {Format of Preamble and Start Frame Delimiter}
        case headerView: HeaderViewPoint of
```

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```
        headerFields: (
            preamble: PreambleValue;
            sfd: SfdValue);
        headerBits: (headerContents: array [1..headerSize] of Bit)
    end; {Defines header for MAC frame}
TransmitStatus = (transmitDisabled, transmitOK, excessiveCollisionError, lateCollisionErrorStatus);
ReceiveStatus = (receiveDisabled, receiveOK, frameTooLong, frameCheckError, lengthError,
                 alignmentError);
```

4A.2.7.2 Transmit state variables

The following items are specific to packet transmission. (See also 4A.4.)

```
const
    interPacketGap = ...; {In bit times, minimum gap between packets,
                           see 4A.4}
var
    outgoingFrame: Frame; {The frame to be transmitted}
    outgoingHeader: Header;
    currentTransmitBit, lastTransmitBit: 1..frameSize; {Positions of current and last outgoing bits in
                                                        outgoingFrame}
    lastHeaderBit: 1..headerSize;
    deferring: Boolean; {Implies any pending transmission must wait for the Physical Layer to be ready for
                         the next packet and for the interpacket gap}
    deferenceMode: Boolean; {Indicates the desired mode of operation, and enables waiting for
                             interpacket gap during the deference process}
    carrierSenseMode: Boolean; {Indicates the desired mode of operation, and enables using carrierSense
                                to extend deference due to congestion in the PHY}
```

4A.2.7.3 Receive state variables

The following items are specific to frame reception. (See also 4A.4.)

```
var
    incomingFrame: Frame; {The frame being received}
    receiving: Boolean; {Indicates that a frame reception is in progress}
    excessBits: 0..7; {Count of excess trailing bits beyond octet boundary}
    receiveSucceeding: Boolean; {Running indicator of whether reception is succeeding}
    validLength: Boolean; {Indicator of whether received frame has a length error}
    exceedsMaxLength: Boolean; {Indicator of whether received frame has a length longer than the
                                maximum permitted length}
    passReceiveFCSMode: Boolean; {Indicates the desired mode of operation, and enables passing of
                                  the frame check sequence field of all received frames from the
                                  MAC sublayer to the MAC client. passReceiveFCSMode is a
                                  static variable}
```

4A.2.7.4 State variable initialization

The procedure Initialize must be run when the MAC sublayer begins operation, before any of the processes begin execution. Initialize sets certain crucial shared state variables to their initial values. (All other global variables are appropriately reinitialized before each use.) Initialize then waits for the medium to be idle, and starts operation of the various processes.

NOTE—Care should be taken to ensure that the time from the completion of the Initialize process to when the first packet transmission begins is at least an interFrameGap.

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If Layer Management is implemented, the Initialize procedure shall only be called as the result of the initializeMAC action (30.3.1.2.1).

```
procedure Initialize;
begin
    deferring := false;
    transmitting := false; {An interface to Physical Layer; see below}
    receiving := false;
    passReceiveFCSMode := ...; {True when enabling the passing of the frame check sequence of all
                                received frames from the MAC sublayer to the MAC client is desired and
                                supported, false otherwise}
    deferenceMode := ...; {False for implementations that cannot rely on deference within the MAC to
                           provide an interframe gap, true otherwise}
    carrierSenseMode := ...; {True for implementations that use carrierSense to indicate congestion in the
                           PHY, false otherwise.}
    while ((carrierSenseMode and carrierSense) or receiveDataValid) do nothing
    {Start execution of all processes}
end; {Initialize}
```

4A.2.8 Frame transmission

The algorithms in this subclause define MAC sublayer frame transmission. The function TransmitFrame implements the frame transmission operation provided to the MAC client.

The TransmitFrame operation is synchronous. Its duration is the entire attempt to transmit the frame; when the operation completes, transmission has either succeeded or failed, as indicated by the TransmitStatus status code.

The transmitDisabled status code indicates that the transmitter is not enabled. Successful transmission is indicated by the status code transmitOK. The codes excessiveCollisionError and lateCollisionErrorStatus are artifacts of the CSMA/CD MAC and maintained here for historical purposes. These codes are never generated by this full duplex MAC. TransmitStatus is not used by the service interface defined in 2.3.1. TransmitStatus may be used in an implementation dependent manner.

```
function TransmitFrame (
    destinationParam: AddressValue;
    sourceParam: AddressValue;
    lengthOrTypeParam: LengthOrTypeValue;
    dataParam: DataValue;
    fcsParamValue: CRCValue;
    fcsParamPresent: Bit): TransmitStatus;
procedure TransmitDataEncap; {Nested procedure; see body below}
begin
    if transmitEnabled then
        begin
            TransmitDataEncap;
            TransmitFrame := TransmitLinkMgmt
        end
    else TransmitFrame := transmitDisabled
end; {TransmitFrame}
```

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If transmission is enabled, TransmitFrame calls the internal procedure TransmitDataEncap to construct the frame. Next, TransmitLinkMgmt is called to perform the actual transmission. The TransmitStatus returned indicates the success or failure of the transmission attempt.

TransmitDataEncap builds the frame and places the 32-bit CRC in the frame check sequence field:

```
procedure TransmitDataEncap;
begin
   with outgoingFrame do
      begin {Assemble frame}
         view := fields;
         destinationField := destinationParam;
         sourceField := sourceParam;
         lengthOrTypeField := lengthOrTypeParam;
         if fcsParamPresent then
            begin
               dataField := dataParam; {No need to generate pad if the FCS is passed from MAC client}
               fcsField := fcsParamValue {Use the FCS passed from MAC client}
            end
         else
            begin
               dataField := ComputePad(dataParam);
               fcsField := CRC32(outgoingFrame)
            end;
         view := bits
      end {Assemble frame}
   with outgoingHeader do
      begin
         headerView := headerFields;
         preamble := ...; {* '1010...10,' LSB to MSB*}
         sfd := ...; {* '10101011,' LSB to MSB*}
         headerView := headerBits
      end
end; {TransmitDataEncap}
```

If the MAC client chooses to generate the frame check sequence field for the frame, it passes this field to the MAC sublayer via the fcsParamValue parameter. If the fcsParamPresent parameter is true, TransmitDataEncap uses the fcsParamValue parameter as the frame check sequence field for the frame. Such a frame shall not require any padding, since it is the responsibility of the MAC client to ensure that the frame meets the minFrameSize constraint. If the fcsParamPresent parameter is false, the fcsParamValue parameter is unspecified. TransmitDataEncap first calls the ComputePad function, followed by a call to the CRC32 function to generate the padding (if necessary) and the frame check sequence field for the frame internally to the MAC sublayer.

ComputePad appends an array of arbitrary bits to the MAC client data to pad the frame to the minimum frame size:

```
function ComputePad(var dataParam: DataValue): DataValue;
begin
   ComputePad := {Append an array of size padSize of arbitrary bits to the MAC client dataField}
end; {ComputePad}
```

TransmitLinkMgmt attempts to transmit the frame. When deferenceMode is true, it first defers to the Physical Layer if it is not ready for the next packet and to ensure proper interframe spacing. When deferenceMode is false, it begins transmitting immediately:

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```
function TransmitLinkMgmt: TransmitStatus;
begin
    while deferring do nothing {Defer to Physical Layer congestion and IFS}
    StartTransmit;
    while transmitting do nothing
    LayerMgmtTransmitCounters; {Update transmit and transmit error counters in 5.2.4.2}
    TransmitLinkMgmt := transmitOK
end; {TransmitLinkMgmt}
```

Each time a frame transmission attempt is initiated, StartTransmit is called to alert the BitTransmitter process that bit transmission should begin:

```
procedure StartTransmit;
begin
    currentTransmitBit := 1;
    lastTransmitBit := frameSize;
    lastHeaderBit:= headerSize;
    transmitting := true
end; {StartTransmit}
```

The Deference process runs asynchronously to continuously compute the proper value for the variable deferring:

```
process Deference;
begin
    cycle {Main loop}
        while (not transmitting and not (carrierSenseMode and carrierSense)) do nothing; {Wait for the start
                                                                                          of transmission or congestion}
        deferring := true; {Inhibit future transmissions}
        while (transmitting or (carrierSenseMode and carrierSense)) do nothing; {Wait for the end of
                                                                                  transmission and congestion}
        if deferenceMode then Wait(interPacketGap);
                {Time out entire interpacket gap if enabled}
        deferring := false {Don't inhibit transmission}
    end {Main loop}
end; {Deference}
```

The BitTransmitter process runs asynchronously, transmitting bits at a rate determined by the Physical Layer's TransmitBit operation:

```
process BitTransmitter;
begin
    cycle {Outer loop}
        if transmitting then
            begin {Inner loop}
                while (currentTransmitBit ≤ lastHeaderBit) do
                    begin
                        TransmitBit(outgoingHeader[currentTransmitBit]);
                        currentTransmitBit := currentTransmitBit + 1
                    end;
                currentTransmitBit := 1;
                while transmitting do
                    begin
                        TransmitBit(outgoingFrame[currentTransmitBit]);
                        currentTransmitBit := currentTransmitBit + 1;
                        transmitting := (currentTransmitBit ≤ lastTransmitBit)
                    end
```

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```
            end {Inner loop}
        end {Outer loop}
    end; {BitTransmitter}
```

4A.2.9 Frame reception

The algorithms in this subclause define the MAC sublayer frame reception.

The function ReceiveFrame implements the frame reception operation provided to the MAC client.

The ReceiveFrame operation is synchronous. The operation does not complete until a frame has been received. The fields of the frame are delivered via the output parameters with the ReceiveStatus status code.

The receiveDisabled status indicates that the receiver is not enabled. Successful reception is indicated by the status code receiveOK. The frameTooLong error indicates that the last frame received had a frameSize beyond the maximum allowable frame size. The code frameCheckError indicates that the frame received was damaged by a transmission error. The lengthError indicates that the lengthOrTypeParam value was both consistent with a length interpretation of this field (i.e., its value was less than or equal to maxValidFrame), and inconsistent with the frameSize of the received frame. The code alignmentError indicates that the frame received was damaged, and that in addition, its length was not an integer number of octets. ReceiveStatus is not mapped to any MAC client parameter by the service interface defined in 2.3.2. ReceiveStatus may be used in an implementation dependent manner.

```
    function ReceiveFrame (
        var destinationParam: AddressValue;
        var sourceParam: AddressValue;
        var lengthOrTypeParam: LengthOrTypeValue;
        var dataParam: DataValue;
        var fcsParamValue: CRCValue;
        var fcsParamPresent: Bit): ReceiveStatus;

    function ReceiveDataDecap: ReceiveStatus; {Nested function; see body below}
    begin
        if receiveEnabled then
            repeat
                ReceiveLinkMgmt;
                ReceiveFrame := ReceiveDataDecap;
            until receiveSucceeding
        else ReceiveFrame := receiveDisabled
    end; {ReceiveFrame}
```

If enabled, ReceiveFrame calls ReceiveLinkMgmt to receive the next valid frame, and then calls the internal function ReceiveDataDecap to return the frame's fields to the MAC client if the frame's address indicates that it should do so. The returned ReceiveStatus indicates the presence or absence of detected transmission errors in the frame.

```
    function ReceiveDataDecap: ReceiveStatus;
        var status: ReceiveStatus; {Holds receive status information}
    begin
        with incomingFrame do
            begin
                view := fields;
                receiveSucceeding := LayerMgmtRecognizeAddress(destinationField);
                if receiveSucceeding then
```

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```
            begin {Disassemble MAC frame}
                destinationParam := destinationField;
                sourceParam := sourceField;
                lengthOrTypeParam := lengthOrTypeField;
                dataParam := RemovePad(lengthOrTypeField, dataField);
                fcsParamValue := fcsField;
                fcsParamPresent := passReceiveFCSMode;
                exceedsMaxLength := ...; {Check to determine if received MAC frame size exceeds
                                          maxFrameSizeLimit.
                                          MAC implementations use maxFrameSizeLimit to
                                          determine if management counts the frame as too long.
                                          It is recommended that new implementations support
                                          maxFrameSizeLimit = maxEnvelopeFrameSize )
                if exceedsMaxLength then status := frameTooLong
                else if fcsField = CRC32(incomingFrame) then
                        if validLength then status := receiveOK else status := lengthError
                else if excessBits = 0 then status := frameCheckError
                else status := alignmentError;
                LayerMgmtReceiveCounters(status); {Update receive counters in 5.2.4.3}
                view := bits
            end {Disassemble MAC frame}
        end; {With incomingFrame}
    ReceiveDataDecap := status
end; {ReceiveDataDecap}

function LayerMgmtRecognizeAddress(address: AddressValue): Boolean;
begin
    if {promiscuous receive enabled} then LayerMgmtRecognizeAddress := true;
    else if address = ... {MAC station address} then LayerMgmtRecognizeAddress := true;
    else if address = ... {Broadcast address} then LayerMgmtRecognizeAddress := true;
    else if address = ... {One of the addresses on the multicast list and multicast reception is enabled} then
                                                        LayerMgmtRecognizeAddress := true;
    else LayerMgmtRecognizeAddress := false
end; {LayerMgmtRecognizeAddress}
```

The function RemovePad strips any padding that was generated to meet the minFrameSize constraint, if possible. When the MAC sublayer operates in the mode that enables passing of the frame check sequence field of all received MAC frames to the MAC client (passReceiveFCSMode variable is true), it shall not strip the padding and it shall leave the data field of the MAC frame intact. Length checking is provided for Length interpretations of the Length/Type field. For Length/Type field values in the range between maxBasicDataSize and minTypeValue the behavior of the RemovePad function is unspecified:

```
function RemovePad(var lengthOrTypeParam: LengthOrTypeValue; dataParam: DataValue): DataValue;
begin
    if lengthOrTypeParam ≥ minTypeValue then
        begin
            validLength := true; {Don't perform length checking for Type interpretation}
            RemovePad := dataParam
        end
    else if lengthOrTypeParam ≤ maxBasicDataSize then
        begin
            validLength := {For length interpretations of the Length/Type field, check to determine if value
                            represented by Length/Type field matches the received clientDataSize};
            if validLength and not passReceiveFCSMode then
```

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```
            RemovePad := {Truncate the dataParam (when present) to the value represented by the
                          lengthOrTypeParam (in octets) and return the result}
        else RemovePad := dataParam
    end
end; {RemovePad}
```

ReceiveLinkMgmt attempts repeatedly to receive the bits of a frame, discarding any fragments smaller than the minimum valid frame size:

```
procedure ReceiveLinkMgmt;
begin
    repeat
        StartReceive;
        while receiving do nothing; {Wait for frame to finish arriving}
        excessBits := frameSize mod 8;
        frameSize := frameSize – excessBits; {Truncate to octet boundary}
        receiveSucceeding := (frameSize ≥ minFrameSize) {Reject frames too small}
    until receiveSucceeding
end; {ReceiveLinkMgmt}

procedure StartReceive;
begin
    receiving := true
end; {StartReceive}
```

The BitReceiver process runs asynchronously, receiving bits from the medium at the rate determined by the Physical Layer's ReceiveBit operation, partitioning them into frames, and optionally receiving them:

```
process BitReceiver;
    var   b: Bit;
          currentReceiveBit: 1..frameSize; {Position of current bit in incomingFrame}
begin
    cycle {Outer loop}
        if receiveEnabled then
            begin {Receive next frame from Physical Layer}
                currentReceiveBit := 1;
                PhysicalSignalDecap; {Skip idle, strip off preamble and sfd}
                while receiveDataValid do
                    begin {Inner loop to receive the rest of an incoming frame}
                        b := ReceiveBit; {Next bit from physical medium}
                        if receiving then {Append to frame}
                        begin
                            incomingFrame[currentReceiveBit] := b;
                            currentReceiveBit := currentReceiveBit + 1
                        end; {append bit to frame}
                        receiving := receiveDataValid
                    end; {Inner loop}
                frameSize := currentReceiveBit – 1
            end {Enabled}
    end {Outer loop}
end; {BitReceiver}

procedure PhysicalSignalDecap;
begin
    {Receive one bit at a time from physical medium until a valid sfd is detected, discard bits and return}
end; {PhysicalSignalDecap}
```

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4A.2.10 Common procedures

The function CRC32 is used by both the transmit and receive algorithms to generate a 32-bit CRC value:

```
function CRC32(f: Frame): CRCValue;
begin
    CRC32 := {The 32-bit CRC for the entire frame as defined in 3.2.9, excluding the FCS field (if
             present)}
end; {CRC32}
```

Purely to enhance readability, the following procedure is also defined:

procedure nothing; *begin end*;

The idle state of a process (that is, while waiting for some event) is cast as repeated calls on this procedure.

4A.3 Interfaces to/from adjacent layers

4A.3.1 Overview

The purpose of this clause is to provide precise definitions of the interfaces between the architectural layers defined in Clause 1 in compliance with the Media Access Service Specification given in Clause 2. In addition, the services required from the physical medium are defined.

The notation used here is the Pascal language, in keeping with the procedural nature of the precise MAC sublayer specification (see 4A.2). Each interface is described as a set of procedures or shared variables, or both, that collectively provide the only valid interactions between layers. The accompanying text describes the meaning of each procedure or variable and points out any implicit interactions among them.

The description of the interfaces in Pascal is a notational technique, and in no way implies that they can or should be implemented in software. This point is discussed more fully in 4A.2, that provides complete Pascal declarations for the data types used in the remainder of this clause. The synchronous (one frame at a time) nature of the frame transmission and reception operations is a property of the architectural interface between the MAC client and MAC sublayers, and need not be reflected in the implementation interface between a station and its sublayer.

4A.3.2 MAC service

The services provided to the MAC client by the MAC sublayer are transmission and reception of MAC frames using service primitives MA_DATA.request and MA_DATA.indication, as defined in Clause 2. For historical reasons the MAC sublayer definitions use two functions, TransmitFrame and ReceiveFrame, defined in 4A.2.8 and 4A.2.9. The relationship between these two functions and the service primitives is defined by the MAC client state diagrams in 4A.3.2.1 and 4A.3.2.2.

The state machines in 4A.3.2 follow the conventions in <XREFX>21.5.

4A.3.2.1 MAC client transmit interface state diagram

4A.3.2.1.1 Variables

data
: The value of mac_service_data_unit excluding the first two octets (Length/Type field).

destination_address
: The Destination Address field parsed from the client request.

fcsPresent
: Indicates whether the MA_DATA.request service primitive contained the frame_check_sequence field.

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frame_check_sequence
: The fcs field parsed from the client request.

lengthOrType
: The value of the first two octets at the start of the mac_service_data_unit.

mac_service_data_unit
: The concatenation of the lengthOrType field and the data field parsed from the client request.

source_address
: The Source Address field parsed from the client request

TransmitStatus
: Indicates the status of the transmitted MAC frame. See 4.2.8.

4A.3.2.1.2 Functions

TransmitFrame
: The MAC sublayer function invoked to transmit a MAC frame with the specified parameters. See 4A.2.8.

4A.3.2.1.3 Messages

MA_DATA.request
: The service primitive used to convey a MAC frame to be transmitted from the MAC client. See 2.3.1. The action invoked is not considered to end until the transmission of the frame by the MAC has concluded.

4A.3.2.1.4 MAC client transmit interface state diagram

Figure 4A–3 specifies the behavior of the transmit interface from the MAC client

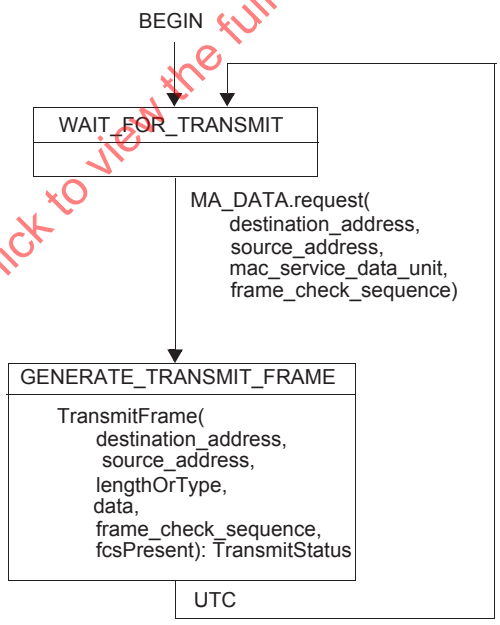

Figure 4A–3—MAC client transmit interface state diagram

4A.3.2.2 MAC client receive interface state diagram

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4A.3.2.2.1 Variables

destination_address
: The Destination Address field parsed from the received MAC frame.

source_address
: The Source Address field parsed from the received MAC frame.

lengthOrType
: The lengthOrType field parsed from the received MAC frame.

data
: The data payload field parsed from the received MAC frame.

fcsPresent
: A Boolean set by the MAC sublayer.

ReceiveStatus
: Indicates the status of the received MAC frame.

mac_service_data_unit
: The concatenation of the lengthOrType field and the data field parsed from the received MAC frame.

frame_check_sequence
: The fcs field parsed from the received MAC frame.

4A.3.2.2.2 Functions

ReceiveFrame
: The MAC sublayer function invoked to accept an incoming MAC frame with the specified parameters. See 4A.2.9.

4A.3.2.2.3 Messages

MA_DATA.indication
: The service primitive used to transfer an incoming MAC frame to the MAC client with the specified parameters. See 2.3.2.

4A.3.2.2.4 MAC client receive interface state diagram

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Figure 4A–4 specifies the behavior of the receive interface to the MAC client.

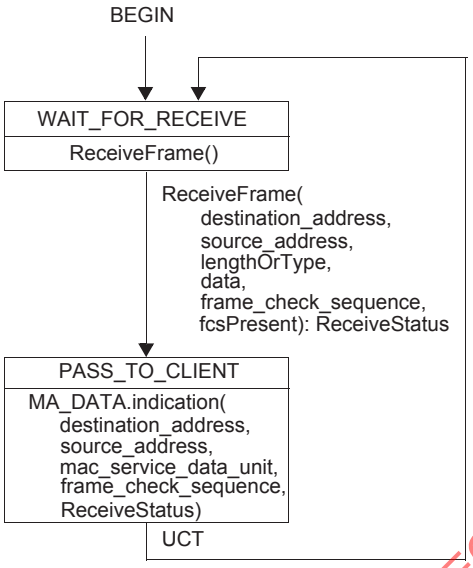

Figure 4A–4—MAC client receive interface state diagram

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4A.3.3 Services required from the Physical Layer

The interface through which the MAC sublayer uses the facilities of the Physical Layer consists of a function, a pair of procedures and four Boolean variables as described in Table 4A–1.

Table 4A–1—Full duplex MAC functions, procedures and variables

Function	Procedures	Variables
ReceiveBit	**TransmitBit**	**collisionDetect**
	Wait	**carrierSense**
		receiveDataValid
		transmitting

During transmission, the contents of an outgoing frame are passed from the MAC sublayer to the Physical Layer by way of repeated use of the TransmitBit operation:

procedure TransmitBit (bitParam: Bit);

Each invocation of TransmitBit passes one new bit of the outgoing frame to the Physical Layer. The TransmitBit operation is synchronous. The duration of the operation is the entire transmission of the bit. The operation completes when the Physical Layer is ready to accept the next bit and it transfers control to the MAC sublayer.

The overall event of data being transmitted is signaled to the Physical Layer by way of the variable transmitting:

var transmitting: Boolean;

Before sending the first bit of a frame, the MAC sublayer sets transmitting to true, to inform the Physical Layer that a stream of bits will be presented via the TransmitBit operation. After the last bit of the frame has been presented, the MAC sublayer sets transmitting to false to indicate the end of the frame.

The collisionDetect variable is not used by this full duplex MAC but maintained as an artifact of the CSMA/CD MAC's interface to the Physical Layer.

var collisionDetect: Boolean;

During reception, the contents of an incoming frame are retrieved from the Physical Layer by the MAC sublayer via repeated use of the ReceiveBit operation:

function ReceiveBit: Bit;

Each invocation of ReceiveBit retrieves one new bit of the incoming frame from the Physical Layer. The ReceiveBit operation is synchronous. Its duration is the entire reception of a single bit. Upon receiving a bit, the MAC sublayer shall immediately request the next bit until all bits of the frame have been received (see 4A.2 for details).

The overall event of data being received is signaled to the MAC sublayer by the variable receiveDataValid:

var receiveDataValid: Boolean;

When the Physical Layer sets receiveDataValid to true, the MAC sublayer shall immediately begin retrieving the incoming bits by the ReceiveBit operation. When receiveDataValid subsequently becomes false, the MAC sublayer can begin processing the received bits as a completed frame. If an invocation of ReceiveBit is pending when receiveDataValid becomes false, ReceiveBit returns an undefined value, which should be discarded by the MAC sublayer (see 4A.2 for details).

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The overall event of congestion at the Physical Layer, indicating that the Physical Layer is not ready to accept the next packet, is signaled to the MAC sublayer by the variable carrierSense:

var carrierSense: Boolean*;*

When the value of variable carrierSenseMode is set to TRUE, the MAC sublayer shall monitor the value of carrierSense to defer its own transmissions when the Physical Layer is busy. The Physical Layer sets carrierSense to true immediately upon congestion within the Physical Layer. After the congestion ceases, carrierSense is set to false. When the value of variable carrierSenseMode is set to FALSE, the carrierSense variable is ignored by the MAC.

While the label carrierSense does not accurately describe the condition presented by this variable, the name is maintained as an artifact of the CSMA/CD MAC interface to the Physical Layer.

The Physical Layer also provides the procedure Wait:

procedure Wait (bitTimes: integer)*;*

This procedure waits for the specified number of bit times. This allows the MAC sublayer to measure time intervals in units of the (physical-medium-dependent) bit time.

4A.4 Specific implementations

4A.4.1 Compatibility overview

To provide total compatibility at all levels of the standard, it is required that each network component implementing the MAC sublayer procedure adheres rigidly to these specifications. The information provided in 4A.4.2 provides design parameters for specific implementations of this access method. Variations from these values result in a system implementation that violates the standard. See the warning in 4A.4.2.

4A.4.2 MAC parameters

The parameter values shown in Table 4A–2 shall be used.

Table 4A–2—Full duplex MAC parameter values

Parameters	Values
interPacketGap	96 bits
maxBasicFrameSize	1518 octets
maxEnvelopeFrameSize	2000 octets
minFrameSize	512 bits (64 octets)

The minimum interPacketGap shall be enforced in this sublayer, when the deferenceMode variable is set to TRUE, or outside this sublayer, when the deferenceMode variable is set to FALSE.

NOTE 1—For 10 Mb/s operation, the spacing between two successive non-colliding packets, from start of idle at the end of the first packet to start of Preamble of the subsequent packet, can have a minimum value of 47 BT (bit times), at the AUI receive line of the DTE. This interpacket gap shrinkage is caused by variable network delays, added preamble bits, and clock skew.

NOTE 2—For 1 Gb/s operation, the spacing between two non-colliding packets, from the last bit of the FCS field of the first packet to the first bit of the Preamble of the second packet, can have a minimum value of 64 BT (bit times), as measured at the GMII receive signals at the DTE. This interpacket gap shrinkage may be caused by variable network delays, added preamble bits, and clock tolerances.

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NOTE 3—For 10 Gb/s operation, the spacing between two packets, from the last bit of the FCS field of the first packet to the first bit of the Preamble of the second packet, can have a minimum value of 40 BT (bit times), as measured at the XGMII receive signals at the DTE. This interpacket gap shrinkage may be caused by variable network delays and clock tolerances.

NOTE 4—For 40 Gb/s and 100 Gb/s operation, the received interpacket gap (the spacing between two packets, from thelast bit of the FCS field of the first packet to the first bit of the Preamble of the second packet) can have a minimum valueof 8 BT (bit times), as measured at the XLGMII or CGMII receive signals at the DTE due to clock tolerance and lanealignment requirements.

WARNING

Any deviation from the above specified values may affect proper operation of the network.

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IEEE Standard for Ethernet

SECTION TWO

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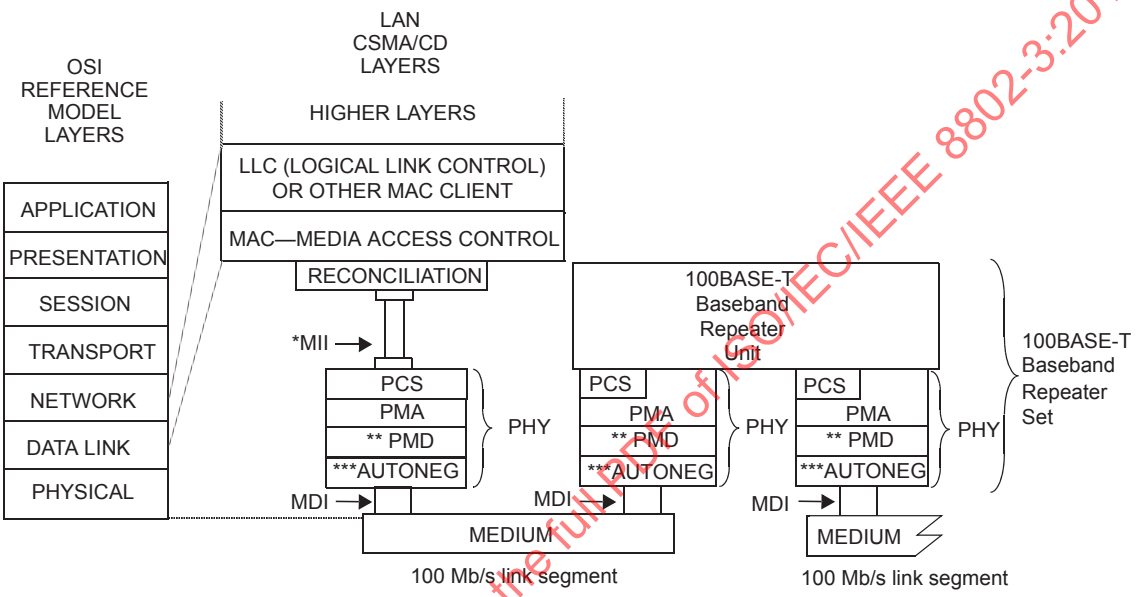
21. Introduction to 100 Mb/s baseband networks, type 100BASE-T

21.1 Overview

100BASE-T couples the IEEE 802.3 CSMA/CD MAC with a family of 100 Mb/s Physical Layers. While the MAC can be readily scaled to higher performance levels, new Physical Layer standards are required for 100 Mb/s operation.

The relationships between 100BASE-T, the existing IEEE 802.3 (CSMA/CD MAC), and the ISO/IEC Open System Interconnection (OSI) reference model is shown in Figure 21–1.



MDI = MEDIUM DEPENDENT INTERFACE
MII = MEDIA INDEPENDENT INTERFACE

PCS = PHYSICAL CODING SUBLAYER
PMA = PHYSICAL MEDIUM ATTACHMENT
PHY = PHYSICAL LAYER DEVICE
PMD = PHYSICAL MEDIUM DEPENDENT

* MII is optional for 10 Mb/s DTEs and for 100 Mb/s systems and is not specified for 1 Mb/s systems.
** PMD is specified for 100BASE-X only; 100BASE-T4 does not use this layer.
Use of MII between PCS and Baseband Repeater Unit is optional.
*** AUTONEG is optional.

Figure 21–1—Architectural positioning of 100BASE-T

100BASE-T uses the existing IEEE 802.3 MAC layer interface, connected through a Media-Independent Interface layer to a Physical Layer entity (PHY) sublayer such as 100BASE-T4, 100BASE-TX, or 100BASE-FX.

100BASE-T extends the IEEE 802.3 MAC to 100 Mb/s. The bit rate is faster, bit times are shorter, packet transmission times are reduced, and cable delay budgets are smaller—all in proportion to the change in bandwidth. This means that the ratio of packet duration to network propagation delay for 100BASE-T is the same as for 10BASE-T.

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21.1.1 Reconciliation Sublayer (RS) and Media Independent Interface (MII)

The Media Independent Interface (Clause 22) provides an interconnection between the Media Access Control (MAC) sublayer and Physical Layer entities (PHY) and between PHY Layer and Station Management (STA) entities. This MII is capable of supporting both 10 Mb/s and 100 Mb/s data rates through four bit wide (nibble wide) transmit and receive paths. The Reconciliation sublayer provides a mapping between the signals provided at the MII and the MAC/PLS service definition.

21.1.2 Physical Layer signaling systems

The following portion of this standard specifies a family of Physical Layer implementations. Typically 100BASE-TX (Clauses 24 and 25) uses two pairs of Category 5 balanced cabling as defined by ISO/IEC 11801, 100BASE-FX (Clauses 24 and 26) uses two multimode fibers. There are a number of other PHY types and their associated media.

21.1.3 Repeater

Repeater sets (Clause 27) are an integral part of any 100BASE-T network with more than two DTEs in a collision domain. They extend the physical system topology by coupling two or more segments. Multiple repeaters are permitted within a single collision domain to provide the maximum path length.

21.1.4 Auto-Negotiation

Auto-Negotiation (Clause 28) provides a linked device with the capability to detect the abilities (modes of operation) supported by the device at the other end of the link, determine common abilities, and configure for joint operation. Auto-Negotiation is performed out-of-band using a pulse code sequence that is compatible with the 10BASE-T link integrity test sequence.

21.1.5 Management

Managed objects, attributes, and actions are defined for all 100BASE-T components (Clause 30).

21.2 References

See 1.3.

21.3 Definitions

See 1.4.

21.4 Abbreviations

See 1.5.

21.5 State diagrams

State diagrams take precedence over text.

The conventions of 1.2 are adopted, with the following extensions.

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21.5.1 Actions inside state blocks

The actions inside a state block execute instantaneously. Actions inside state blocks are atomic (i.e., uninterruptible).

After performing all the actions listed in a state block one time, the state block then continuously evaluates its exit conditions until one is satisfied, at which point control passes through a transition arrow to the next block. While the state awaits fulfillment of one of its exit conditions, the actions inside do not implicitly repeat.

The characters • and [bracket] are *not* used to denote any special meaning.

Valid state actions may include .indication and .request messages.

No actions are taken outside of any state block.

21.5.2 State diagram variables

Once set, variables retain their values as long as succeeding blocks contain no references to them.

Setting the parameter of a formal interface message assures that, on the next transmission of that message, the last parameter value set will be transmitted.

Testing the parameter of a formal interface messages tests the value of that message parameter that was received on the last transmission of said message. Message parameters may be assigned default values that persist until the first reception of the relevant message.

21.5.3 State transitions

The following terms are valid transition qualifiers:

a) Boolean expressions
b) An event such as the expiration of a timer: timer_done
c) An event such as the reception of a message: PMA_UNITDATA.indication
d) An unconditional transition: UCT
e) A branch taken when other exit conditions are not satisfied: ELSE

Any open arrow (an arrow with no source block) represents a global transition. Global transitions are evaluated continuously whenever any state is evaluating its exit conditions. When a global transition becomes true, it supersedes all other transitions, including UCT, returning control to the block pointed to by the open arrow.

21.5.4 Operators

The state diagram operators are shown in Table 21–1.

Table 21–1—State diagram operators

Character	Meaning
*	Boolean AND
+	Boolean OR
^	Boolean XOR
!	Boolean NOT

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Table 21–1—State diagram operators *(continued)*

Character	Meaning
<	Less than
≤	Less than or equal to
=	Equals (a test of equality)
≠	Not equals
≥	Greater than or equal to
>	Greater than
( )	Indicates precedence
⇐	Assignment operator
∈	Indicates membership
∉	Indicates nonmembership
|	Catenate
ELSE	No other state condition is satisfied

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21.6 Protocol implementation conformance statement (PICS) proforma

21.6.1 Introduction

The supplier of a protocol implementation that is claimed to conform to any 100 Mb/s portion of this standard shall complete a protocol implementation conformance statement (PICS) proforma.

A completed PICS proforma is the PICS for the implementation in question. The PICS is a statement of which capabilities and options of the protocol have been implemented. A PICS is included at the end of each clause as appropriate. The PICS can be used for a variety of purposes by various parties, including the following:

a) As a checklist by the protocol implementer, to reduce the risk of failure to conform to the standard through oversight;
b) As a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard PICS proforma, by the supplier and acquirer, or potential acquirer, of the implementation;
c) As a basis for initially checking the possibility of interworking with another implementation by the user, or potential user, of the implementation (note that, while interworking can never be guaranteed, failure to interwork can often be predicted from incompatible PICS);
d) As the basis for selecting appropriate tests against which to assess the claim for conformance of the implementation, by a protocol tester.

21.6.2 Abbreviations and special symbols

The following symbols are used in the PICS proforma:

M	mandatory field/function
!	negation
O	optional field/function
O.<n>	optional field/function, but at least one of the group of options labeled by the same numeral <n> is required
O/<n>	optional field/function, but one and only one of the group of options labeled by the same numeral <n> is required
X	prohibited field/function
<item>:	simple-predicate condition, dependent on the support marked for <item>
<item1>*<item2>:	AND-predicate condition, the requirement must be met if both optional items are implemented

21.6.3 Instructions for completing the PICS proforma

The first part of the PICS proforma, Implementation Identification and Protocol Summary, is to be completed as indicated with the information necessary to identify fully both the supplier and the implementation.

The main part of the PICS proforma is a fixed-format questionnaire divided into subclauses, each containing a group of items. Answers to the questionnaire items are to be provided in the right-most column, either by simply marking an answer to indicate a restricted choice (usually Yes, No, or Not Applicable), or by entering a value or a set or range of values. (Note that there are some items where two or more choices from a set of possible answers can apply; all relevant choices are to be marked.)

Each item is identified by an item reference in the first column; the second column contains the question to be answered; the third column contains the reference or references to the material that specifies the item in the main body of the standard; the sixth column contains values and/or comments pertaining to the question

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to be answered. The remaining columns record the status of the items—whether the support is mandatory, optional or conditional—and provide the space for the answers.

The supplier may also provide, or be required to provide, further information, categorized as either Additional Information or Exception Information. When present, each kind of further information is to be provided in a further subclause of items labeled A<i> or X<i>, respectively, for cross-referencing purposes, where <i> is any unambiguous identification for the item (e.g., simply a numeral); there are no other restrictions on its format or presentation.

A completed PICS proforma, including any Additional Information and Exception Information, is the protocol implementation conformance statement for the implementation in question.

Note that where an implementation is capable of being configured in more than one way, according to the items listed under Major Capabilities/Options, a single PICS may be able to describe all such configurations. However, the supplier has the choice of providing more than one PICS, each covering some subset of the implementation's configuration capabilities, if that would make presentation of the information easier and clearer.

21.6.4 Additional information

Items of Additional Information allow a supplier to provide further information intended to assist the interpretation of the PICS. It is not intended or expected that a large quantity will be supplied, and the PICS can be considered complete without any such information. Examples might be an outline of the ways in which a (single) implementation can be set up to operate in a variety of environments and configurations; or a brief rationale, based perhaps upon specific application needs, for the exclusion of features that, although optional, are nonetheless commonly present in implementations.

References to items of Additional Information may be entered next to any answer in the questionnaire, and may be included in items of Exception Information.

21.6.5 Exceptional information

It may occasionally happen that a supplier will wish to answer an item with mandatory or prohibited status (after any conditions have been applied) in a way that conflicts with the indicated requirement. No preprinted answer will be found in the Support column for this; instead, the supplier is required to write into the Support column an X<i> reference to an item of Exception Information, and to provide the appropriate rationale in the Exception item itself.

An implementation for which an Exception item is required in this way does not conform to this standard.

Note that a possible reason for the situation described above is that a defect in the standard has been reported, a correction for which is expected to change the requirement not met by the implementation.

21.6.6 Conditional items

The PICS proforma contains a number of conditional items. These are items for which both the applicability of the item itself, and its status if it does apply—mandatory, optional, or prohibited—are dependent upon whether or not certain other items are supported.

Individual conditional items are indicated by a conditional symbol of the form "<item>:<s>" in the Status column, where "<item>" is an item reference that appears in the first column of the table for some other item, and "<s>" is a status symbol, M (Mandatory), O (Optional), or X (Not Applicable).

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If the item referred to by the conditional symbol is marked as supported, then 1) the conditional item is applicable, 2) its status is given by "<s>", and 3) the support column is to be completed in the usual way. Otherwise, the conditional item is not relevant and the Not Applicable (N/A) answer is to be marked.

Each item whose reference is used in a conditional symbol is indicated by an asterisk in the Item column.

21.7 MAC delay constraints (exposed MII)

100BASE-T makes the following assumptions about MAC performance. These assumptions apply to any MAC operating in half duplex mode with an exposed MII.

Table 21–2—MAC delay assumptions (exposed MII)

Sublayer measurement points	Event	Min (bits)	Max (bits)	Input timing reference	Output timing reference
MAC ⇔ MII	MAC transmit start to TX_EN sampled		4		TX_CLK rising
	CRS assert to MAC detect	0	8		
	CRS deassert to MAC detect	0	8		
	CRS assert to TX_EN sampled (worst case nondeferred transmit)		16		TX_CLK rising
	COL assert to MAC detect	0	8		
	COL deassert to MAC detect	0	8		
	COL assert to TXD = Jam sampled (worst-case collision response)		16		TX_CLK rising; first nibble of jam

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22. Reconciliation Sublayer (RS) and Media Independent Interface (MII)

22.1 Overview

This clause defines the logical, electrical, and mechanical characteristics for the Reconciliation Sublayer (RS) and Media Independent Interface (MII) between CSMA/CD media access controllers and various PHYs. Figure 22–1 shows the relationship of the Reconciliation sublayer and MII to the ISO/IEC OSI reference model.

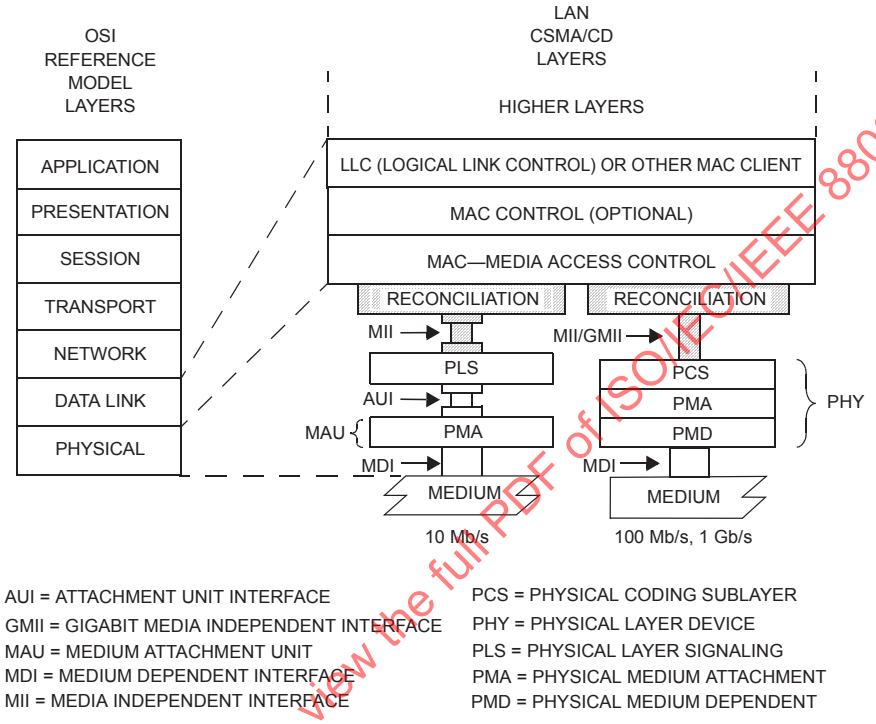

Figure 22–1—MII relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

The purpose of this interface is to provide a simple, inexpensive, and easy-to-implement interconnection between Media Access Control (MAC) sublayers and PHYs for data transfer at 10 Mb/s and 100 Mb/s, and between Station Management (STA) and PHYs.

This interface has the following characteristics:

a) It is capable of supporting 10 Mb/s and 100 Mb/s rates for data transfer, and management functions.
b) Data and delimiters are synchronous to clock references.
c) It provides independent four bit wide transmit and receive data paths.
d) It uses TTL signal levels, compatible with common digital CMOS ASIC processes.
e) It provides a simple management interface.
f) It is capable of driving a limited length of shielded cable.
g) It provides full duplex operation.

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22.1.1 Summary of major concepts

a) Each direction of data transfer is serviced with seven (making a total of 14) signals: Data (a four-bit bundle), Delimiter, Error, and Clock.
b) Two media status signals are provided. One indicates the presence of carrier, and the other indicates the occurrence of a collision.
c) A management interface comprised of two signals provides access to management parameters and services.
d) The Reconciliation sublayer maps the signal set provided at the MII to the PLS service definition specified in Clause 6.

22.1.2 Application

This clause applies to the interface between MAC sublayer and PHYs, and between PHYs and Station Management entities. The implementation of the interface may assume any of the following three forms:

a) A chip-to-chip (integrated circuit to integrated circuit) interface implemented with traces on a printed circuit board.
b) A motherboard to daughterboard interface between two or more printed circuit boards.
c) An interface between two printed circuit assemblies that are attached with a length of cable and an appropriate connector.

Figure 22–2 provides an example of the third application environment listed above. All MII conformance tests are performed at the mating surfaces of the MII connector, identified by the line A-A.

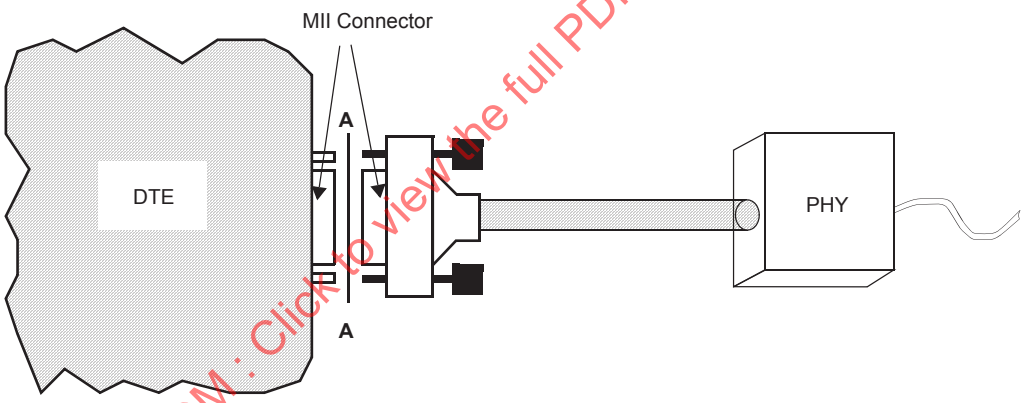

Figure 22–2—Example application showing location of conformance test

This interface is used to provide media independence for various forms of unshielded twisted-pair wiring, shielded twisted-pair wiring, fiber optic cabling, and potentially other media, so that identical media access controllers may be used with any of these media.

To allow for the possibility that multiple PHYs may be controlled by a single station management entity, the MII management interface has provisions to accommodate up to 32 PHYs, with the restriction that a maximum of one PHY may be attached to a management interface via the mechanical interface defined in 22.6.

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22.1.3 Rates of operation

The MII can support two specific data rates, 10 Mb/s and 100 Mb/s. The functionality is identical at both data rates, as are the signal timing relationships. The only difference between 10 Mb/s and 100 Mb/s operation is the nominal clock frequency.

PHYs that provide an MII are not required to support both data rates, and may support either one or both. PHYs must report the rates they are capable of operating at via the management interface, as described in 22.2.4.

22.1.4 Allocation of functions

The allocation of functions at the MII is such that it readily lends itself to implementation in both PHYs and MAC sublayer entities. The division of functions balances the need for media independence with the need for a simple and cost-effective interface.

While the Attachment Unit Interface (AUI) was defined to exist between the Physical Signaling (PLS) and Physical Media Attachment (PMA) sublayers for 10 Mb/s DTEs, the MII maximizes media independence by cleanly separating the Data Link and Physical Layers of the ISO (IEEE) seven-layer reference model. This allocation also recognizes that implementations can benefit from a close coupling of the PLS or PCS sublayer and the PMA sublayer.

22.1.5 Relationship of MII and GMII

The Gigabit Media Independent Interface (GMII) is similar to the MII. The GMII uses the MII Management Interface and register set specified in 22.2.4. These common elements of operation allow Station Management to determine PHY capabilities and configure the station based on those capabilities. In a station supporting both MII and GMII operation, configuration of the station would include enabling either the MII or GMII operation as appropriate for the data rate of the selected PHY.

Most of the MII and GMII signals use the same names, but the width of the RXD and TXD data bundles and the semantics of the associated control signals differ between MII and GMII operation. The GMII transmit path clocking also differs significantly from MII clocking. MII operation of these signals and clocks is specified within Clause 22 and GMII operation is specified within Clause 35.

22.2 Functional specifications

The MII is designed to make the differences among the various media absolutely transparent to the MAC sublayer. The selection of logical control signals and the functional procedures are all designed to this end. Additionally, the MII is designed to be easily implemented at minimal cost using conventional design techniques and manufacturing processes.

22.2.1 Mapping of MII signals to PLS service primitives and Station Management

The Reconciliation sublayer maps the signals provided at the MII to the PLS service primitives defined in Clause 6. The PLS service primitives provided by the Reconciliation sublayer behave in exactly the same manner as defined in Clause 6. The MII signals are defined in detail in 22.2.2.The mapping is changed if EEE capability is supported (see 78.3), as described in 22.7. EEE capability requires the use of the MAC defined in Annex 4A for simplified full duplex operation (with carrier sense deferral). This provides full duplex operation but uses the carrier sense signal to defer transmission when the PHY is in its low power state.

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Figure 22–3 depicts a schematic view of the Reconciliation sublayer inputs and outputs, and demonstrates that the MII management interface is controlled by the station management entity (STA).

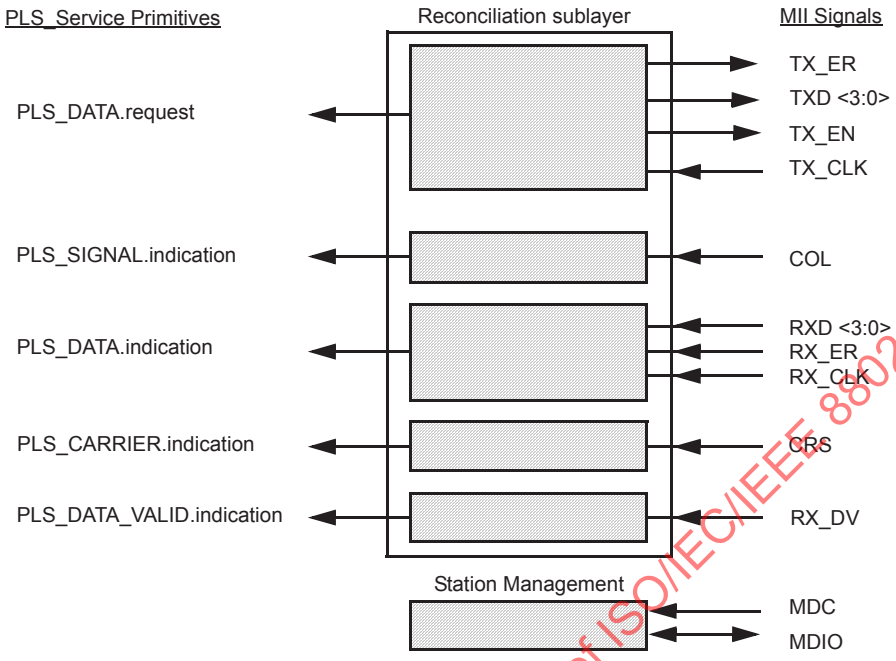

Figure 22–3—Reconciliation Sublayer (RS) inputs and outputs, and STA connections to MII

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22.2.1.1 Mapping of PLS_DATA.request

22.2.1.1.1 Function

Map the primitive PLS_DATA.request to the MII signals TXD<3:0>, TX_EN, and TX_CLK.

22.2.1.1.2 Semantics of the service primitive

PLS_DATA.request (OUTPUT_UNIT)

The OUTPUT_UNIT parameter can take one of three values: ONE, ZERO, or DATA_COMPLETE. It represents a single data bit. The values ONE and ZERO are conveyed by the signals TXD<3>, TXD<2>, TXD<1>, and TXD<0>, each of which conveys one bit of data while TX_EN is asserted. The value DATA_COMPLETE is conveyed by the deassertion of TX_EN. Synchronization between the Reconciliation sublayer and the PHY is achieved by way of the TX_CLK signal.

22.2.1.1.3 When generated

The TX_CLK signal is generated by the PHY. The TXD<3:0> and TX_EN signals are generated by the Reconciliation sublayer after every group of four PLS_DATA.request transactions from the MAC sublayer to request the transmission of four data bits on the physical medium or to stop transmission.

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22.2.1.2 Mapping of PLS_DATA.indication

22.2.1.2.1 Function

Map the primitive PLS_DATA.indication to the MII signals RXD<3:0>, RX_DV, RX_ER, and RX_CLK.

22.2.1.2.2 Semantics of the service primitive

PLS_DATA.indication (INPUT_UNIT)

The INPUT_UNIT parameter can take one of two values: ONE or ZERO. It represents a single data bit. The values ONE and ZERO are derived from the signals RXD<3>, RXD<2>, RXD<1>, and RXD<0>, each of which represents one bit of data while RX_DV is asserted.

The value of the data transferred to the MAC is controlled by the RX_ER signal, see 22.2.1.5, Response to RX_ER indication from MII.

Synchronization between the PHY and the Reconciliation sublayer is achieved by way of the RX_CLK signal.

22.2.1.2.3 When generated

This primitive is generated to all MAC sublayer entities in the network after a PLS_DATA.request is issued. Each nibble of data transferred on RXD<3:0> will result in the generation of four PLS_DATA.indication transactions.

22.2.1.3 Mapping of PLS_CARRIER.indication

22.2.1.3.1 Function

Map the primitive PLS_CARRIER.indication to the MII signal CRS, and the LPI assert function if the EEE capability supported (see 22.7.2).

22.2.1.3.2 Semantics of the service primitive

PLS_CARRIER.indication (CARRIER_STATUS)

The CARRIER_STATUS parameter can take one of two values: CARRIER_ON or CARRIER_OFF. The values CARRIER_ON and CARRIER_OFF are derived from the MII signal CRS.

22.2.1.3.3 When generated

The PLS_CARRIER.indication service primitive is generated by the Reconciliation sublayer whenever the CARRIER_STATUS parameter changes from CARRIER_ON to CARRIER_OFF or vice versa.

Any transition of the CRS signal from deasserted to asserted must cause a transition of CARRIER_STATUS from the CARRIER_OFF to the CARRIER_ON value, and any transition of the CRS signal from asserted to deasserted must cause a transition of CARRIER_STATUS from the CARRIER_ON to the CARRIER_OFF value.

NOTE—The behavior of the CRS signal is specified within this clause so that it can be mapped directly (with the appropriate implementation-specific synchronization) to the carrierSense variable in the MAC process Deference, which is described in 4.2.8. The behavior of the RX_DV signal is specified within this clause so that it can be mapped directly to

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the receiveDataValid variable in the MAC process BitReceiver, which is described in 4.2.9, provided that the MAC processBitReceiver is implemented to receive a nibble of data on each cycle through the inner loop.

For EEE capability, CARRIER_STATUS is overridden according to the behavior of the LPI transmit state diagram (see Figure 22–23). The signal CRS has no effect on CARRIER_STATUS while in states LPI_ASSERTED and LPI_WAIT. A transition to the LPI_ASSERTED state in the transmit LPI state diagram shall cause a transition of CARRIER_STATUS from the CARRIER_OFF to the CARRIER_ON value, and a transition to the LPI_DEASSERTED state in the transmit LPI state diagram shall cause a transition of CARRIER_STATUS from the CARRIER_ON to the CARRIER_OFF value.

22.2.1.4 Mapping of PLS_SIGNAL.indication

22.2.1.4.1 Function

Map the primitive PLS_SIGNAL.indication to the MII signal COL.

22.2.1.4.2 Semantics of the service primitive

PLS_SIGNAL.indication (SIGNAL_STATUS)

The SIGNAL_STATUS parameter can take one of two values: SIGNAL_ERROR or NO_SIGNAL_ERROR. SIGNAL_STATUS assumes the value SIGNAL_ERROR when the MII signal COL is asserted, and assumes the value NO_SIGNAL_ERROR when COL is deasserted.

22.2.1.4.3 When generated

The PLS_SIGNAL.indication service primitive is generated whenever SIGNAL_STATUS makes a transition from SIGNAL_ERROR to NO_SIGNAL_ERROR or vice versa.

22.2.1.5 Response to RX_ER indication from MII

If, during frame reception, both RX_DV and RX_ER are asserted, the Reconciliation sublayer shall ensure that the MAC will detect a FrameCheckError in that frame.

This requirement may be met by incorporating a function in the Reconciliation sublayer that produces a result that is guaranteed to be not equal to the CRC result, as specified by the algorithm in 3.2.9, of the sequence of nibbles comprising the received frame as delivered to the MAC sublayer. The Reconciliation sublayer must then ensure that the result of this function is delivered to the MAC sublayer at the end of the received frame in place of the last nibble(s) received from the MII.

Other techniques may be employed to respond to RX_ER, provided that the result is that the MAC sublayer behaves as though a FrameCheckError occurred in the received frame.

22.2.1.6 Conditions for generation of TX_ER

If, during the process of transmitting a frame, it is necessary to request that the PHY deliberately corrupt the contents of the frame in such a manner that a receiver will detect the corruption with the highest degree of probability, then the signal TX_ER may be generated.

For example, a repeater that detects an RX_ER during frame reception on an input port may propagate that error indication to its output ports by asserting TX_ER during the process of transmitting that frame.

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Since there is no mechanism in the definition of the MAC sublayer by which the transmit data stream can be deliberately corrupted, the Reconciliation sublayer is not required to generate TX_ER.

22.2.1.7 Mapping of PLS_DATA_VALID.indication

22.2.1.7.1 Function

Map the primitive PLS_DATA_VALID.indication to the MII signal RX_DV.

22.2.1.7.2 Semantics of the service primitive

PLS_DATA_VALID.indication (DATA_VALID_STATUS)

The DATA_VALID_STATUS parameter can take one of two values: DATA_VALID or DATA_NOT_VALID. DATA_VALID_STATUS assumes the value DATA_VALID when the MII signal RX_DV is asserted, and assumes the value DATA_NOT_VALID when RX_DV is deasserted.

22.2.1.7.3 When generated

The PLS_DATA_VALID.indication service primitive is generated by the Reconciliation sublayer whenever the DATA_VALID_STATUS parameter changes from DATA_VALID to DATA_NOT_VALID or vice versa.

22.2.2 MII signal functional specifications

22.2.2.1 TX_CLK (transmit clock)

TX_CLK (Transmit Clock) is a continuous clock that provides the timing reference for the transfer of the TX_EN, TXD, and TX_ER signals from the Reconciliation sublayer to the PHY. TX_CLK is sourced by the PHY.

The TX_CLK frequency shall be 25% of the nominal transmit data rate ± 100 ppm. For example, a PHY operating at 100 Mb/s must provide a TX_CLK frequency of 25 MHz, and a PHY operating at 10 Mb/s must provide a TX_CLK frequency of 2.5 MHz. The duty cycle of the TX_CLK signal shall be between 35% and 65% inclusive.

NOTE—See additional information in 22.2.4.1.5.

22.2.2.2 RX_CLK (receive clock)

RX_CLK is a continuous clock that provides the timing reference for the transfer of the RX_DV, RXD, and RX_ER signals from the PHY to the Reconciliation sublayer. RX_CLK is sourced by the PHY. The PHY may recover the RX_CLK reference from the received data or it may derive the RX_CLK reference from a nominal clock (e.g., the TX_CLK reference).

The minimum high and low times of RX_CLK shall be 35% of the nominal period under all conditions.

While RX_DV is asserted, RX_CLK shall be synchronous with recovered data, shall have a frequency equal to 25% of the data rate of the received signal, and shall have a duty cycle of between 35% and 65% inclusive.

When the signal received from the medium is continuous and the PHY can recover the RX_CLK reference and supply the RX_CLK on a continuous basis, there is no need to transition between the recovered clock reference and a nominal clock reference on a frame-by-frame basis. If loss of received signal from the

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medium causes a PHY to lose the recovered RX_CLK reference, the PHY shall source the RX_CLK from a nominal clock reference.

Transitions from nominal clock to recovered clock or from recovered clock to nominal clock shall be made only while RX_DV is deasserted. During the interval between the assertion of CRS and the assertion of RX_DV at the beginning of a frame or while the PHY is asserting LPI, the PHY may extend a cycle of RX_CLK by holding it in either the high or low condition until the PHY has successfully locked onto the recovered clock. Following the deassertion of RX_DV at the end of a frame, the PHY may extend a cycle of RX_CLK by holding it in either the high or low condition for an interval that shall not exceed twice the nominal clock period. For EEE capability, RX_CLK may be stopped by the PHY during LPI when the Clock stop enable bit is asserted (see 22.2.2.9 and 45.2.3.1.4).

NOTE—This standard neither requires nor assumes a guaranteed phase relationship between the RX_CLK and TX_CLK signals. See additional information in 22.2.4.1.5 and 22.2.2.9.

22.2.2.3 TX_EN (transmit enable)

TX_EN indicates that the Reconciliation sublayer is presenting nibbles on the MII for transmission. It shall be asserted by the Reconciliation sublayer synchronously with the first nibble of the preamble and shall remain asserted while all nibbles to be transmitted are presented to the MII. TX_EN shall be negated prior to the first TX_CLK following the final nibble of a frame. TX_EN is driven by the Reconciliation sublayer and shall transition synchronously with respect to the TX_CLK.

Figure 22–4 depicts TX_EN behavior during a frame transmission with no collisions.

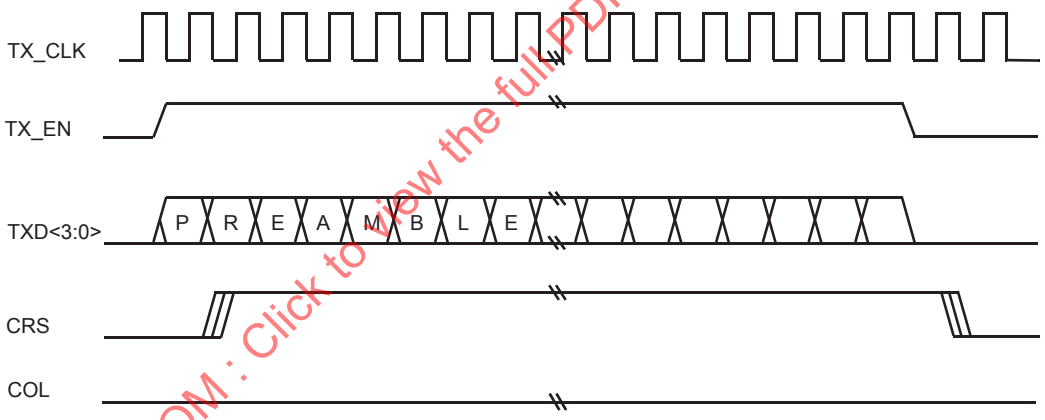

Figure 22–4—Transmission with no collision

22.2.2.4 TXD (transmit data)

TXD is a bundle of 4 data signals (TXD<3:0>) that are driven by the Reconciliation sublayer. TXD<3:0> shall transition synchronously with respect to the TX_CLK. For each TX_CLK period in which TX_EN is asserted, TXD<3:0> are accepted for transmission by the PHY. TXD<0 >is the least significant bit. While TX_EN and TX_ER are both deasserted, TXD<3:0> shall have no effect upon the PHY.

For EEE capability, the RS shall use the combination of TX_EN deasserted, TX_ER asserted, and TXD<3:0> equal to 0001 as shown in Table 22–1 as a request to enter, or remain in a low power state. Other values of TXD<3:0> with this combination of TX_EN and TX_ER shall have no effect upon the PHY.

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Figure 22–4 depicts TXD<3:0> behavior during the transmission of a frame.

Table 22–1 summarizes the permissible encodings of TXD<3:0>, TX_EN, and TX_ER.

Table 22–1—Permissible encodings of TXD<3:0>, TX_EN, and TX_ER

TX_EN	TX_ER	TXD<3:0>	Indication
0	0	0000 through 1111	Normal inter-frame
0	1	0000	Reserved
0	1	0001	Assert LPI
0	1	0010 through 1111	Reserved
1	0	0000 through 1111	Normal data transmission
1	1	0000 through 1111	Transmit error propagation

22.2.2.5 TX_ER (transmit coding error)

TX_ER shall transition synchronously with respect to the TX_CLK. When TX_ER is asserted for one or more TX_CLK periods while TX_EN is also asserted, the PHY shall emit one or more symbols that are not part of the valid data or delimiter set somewhere in the frame being transmitted. The relative position of the error within the frame need not be preserved.

Assertion of the TX_ER signal shall not affect the transmission of data when a PHY is operating at 10 Mb/s, or when TX_EN is deasserted.

Figure 22–5 shows the behavior of TX_ER during the transmission of a frame propagating an error.

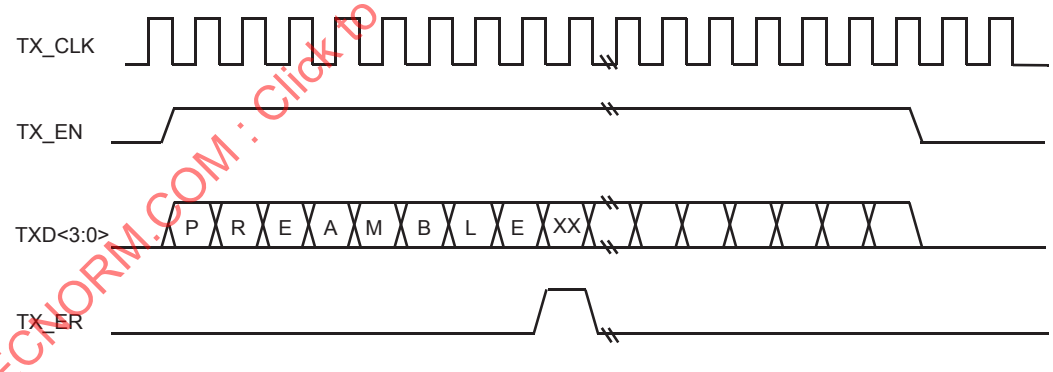

Figure 22–5—Propagating an error

Table 22–1 summarizes the permissible encodings of TXD<3:0>, TX_EN, and TX_ER.

The TX_ER signal shall be implemented at the MII of a PHY, may be implemented at the MII of a repeater that provides an MII port, and may be implemented in MAC sublayer devices. If a Reconciliation sublayer or a repeater with an MII port does not actively drive the TX_ER signal, it shall ensure that the TX_ER signal is pulled down to an inactive state at all times.

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22.2.2.6 Transmit direction LPI transition

When the transmit LPI state diagram is in state LPI_ASSERTED, the LPI client requests the PHY to transition to the LPI state by deasserting TX_EN, asserting TX_ER, and setting TXD<3:0> to 0001. The LPI client maintains the same state for these signals for the entire time that the PHY is to remain in the LPI state.

The LPI client requests the PHY to transition out of the LPI state by deasserting TX_ER and TXD. The LPI client should not assert TX_EN for valid transmit data until after the resolved wake up time specified for the PHY.

Figure 22–6 shows the behavior of TX_EN, TX_ER, and TXD<3:0> during the transition into and out of the LPI state.

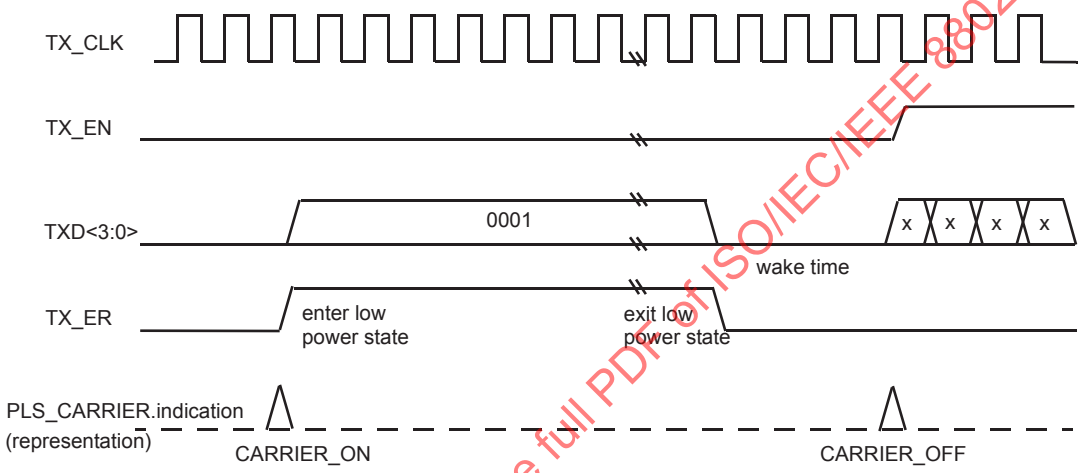

Figure 22–6—LPI transition

Table 22–1 summarizes the permissible encodings of TXD<3:0>, TX_EN, and TX_ER.

22.2.2.7 RX_DV (Receive Data Valid)

RX_DV (Receive Data Valid) is driven by the PHY to indicate that the PHY is presenting recovered and decoded nibbles on the RXD<3:0> bundle and that the data on RXD<3:0> is synchronous to RX_CLK. RX_DV shall transition synchronously with respect to the RX_CLK. RX_DV shall remain asserted continuously from the first recovered nibble of the frame through the final recovered nibble and shall be negated prior to the first RX_CLK that follows the final nibble. In order for a received frame to be correctly interpreted by the Reconciliation sublayer and the MAC sublayer, RX_DV must encompass the frame, starting no later than the Start Frame Delimiter (SFD) and excluding any End-of-Frame delimiter.

Figure 22–7 shows the behavior of RX_DV during frame reception.

22.2.2.8 RXD (receive data)

RXD is a bundle of four data signals (RXD<3:0>) that transition synchronously with respect to the RX_CLK. RXD<3:0> are driven by the PHY. For each RX_CLK period in which RX_DV is asserted, RXD<3:0> transfer four bits of recovered data from the PHY to the Reconciliation sublayer. RXD<0> is the least significant bit. While RX_DV is deasserted, RXD<3:0> shall have no effect on the Reconciliation sublayer.

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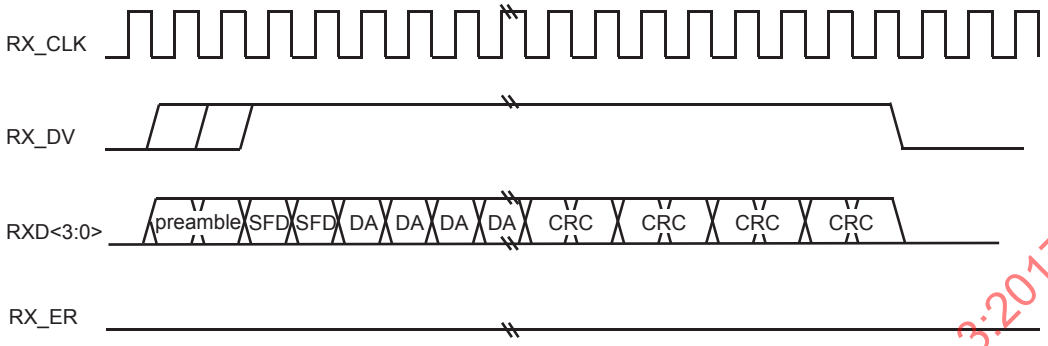

Figure 22–7—Reception with no errors

While RX_DV is deasserted, the PHY may provide a False Carrier indication by asserting the RX_ER signal while driving the value <1110> onto RXD<3:0>. See 22.2.4.4.2 for a description of the conditions under which a PHY will provide a False Carrier indication.

For EEE capability, the PHY indicates that it is receiving LPI by asserting the RX_ER signal and driving the value 0001 onto RXD<3:0> while RX_DV is deasserted.

In order for a frame to be correctly interpreted by the MAC sublayer, a completely formed SFD must be passed across the MII. In a DTE operating in half duplex mode, a PHY is not required to loop data transmitted on TXD<3:0> back to RXD<3:0> unless the loopback mode of operation is selected as defined in 22.2.4.1.2. In a DTE operating in full duplex mode, data transmitted on TXD <3:0> must not be looped back to RXD <3:0> unless the loopback mode of operation is selected.

Figure 22–7 shows the behavior of RXD<3:0> during frame reception.

Table 22–2 summarizes the permissible encoding of RXD<3:0>, RX_ER, and RX_DV, along with the specific indication provided by each code.

Table 22–2—Permissible encoding of RXD<3:0>, RX_ER, and RX_DV

RX_DV	RX_ER	RXD<3:0>	Indication
0	0	0000 through 1111	Normal inter-frame
0	1	0000	Normal inter-frame
0	1	0001	Assert LPI
0	1	0010 through 1101	Reserved
0	1	1110	False Carrier indication
0	1	1111	Reserved
1	0	0000 through 1111	Normal data reception
1	1	0000 through 1111	Data reception with errors

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22.2.2.9 Receive direction LPI transition

When the PHY receives signals from the link partner to indicate transition into the low power state, it indicates this to the LPI client by asserting RX_ER and setting RXD<3:0> to 0001 while keeping RX_DV deasserted. The PHY maintains these signals in this state while it remains in the low power state. When the PHY receives signals from the link partner to indicate transition out of the low power state, it indicates this to the LPI client by deasserting RX_ER and returning to a normal interframe state.

While the PHY device is indicating LPI, it may halt the RX_CLK at any time more than 9 clock cycles after the start of the low power state as shown in (Figure 22–8) if and only if the Clock stop enable bit is asserted (see 45.2.3.1.4). The PHY may restart RX_CLK at any time while it is asserting LPI, but shall restart RX_CLK so that at least one positive transition occurs before it deasserts LPI.

Figure 22–8 shows the behavior of RX_ER, RX_DV and RXD<3:0> during LPI transitions.

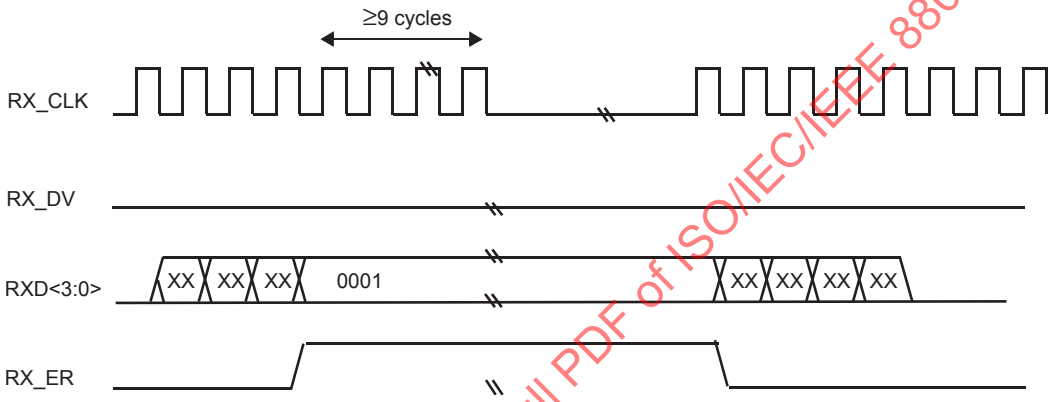

Figure 22–8—LPI transitions (receiver)

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22.2.2.10 RX_ER (receive error)

RX_ER (Receive Error) is driven by the PHY. RX_ER shall be asserted for one or more RX_CLK periods to indicate to the Reconciliation sublayer that an error (e.g., a coding error, or any error that the PHY is capable of detecting, and that may otherwise be undetectable at the MAC sublayer) was detected somewhere in the frame presently being transferred from the PHY to the Reconciliation sublayer. RX_ER shall transition synchronously with respect to RX_CLK. While RX_DV is deasserted, RX_ER shall have no effect on the Reconciliation sublayer.

While RX_DV is deasserted, the PHY may provide a False Carrier indication by asserting the RX_ER signal for at least one cycle of the RX_CLK while driving the appropriate value onto RXD<3:0>, as defined in 22.2.2.8. See 24.2.4.4.2 for a description of the conditions under which a PHY will provide a False Carrier indication.

The effect of RX_ER on the Reconciliation sublayer is defined in 22.2.1.5, Response to RX_ER indication from MII.

Figure 22–9 shows the behavior of RX_ER during the reception of a frame with errors.

Figure 22–10 shows the behavior of RX_ER, RX_DV and RXD<3:0> during a False Carrier indication.

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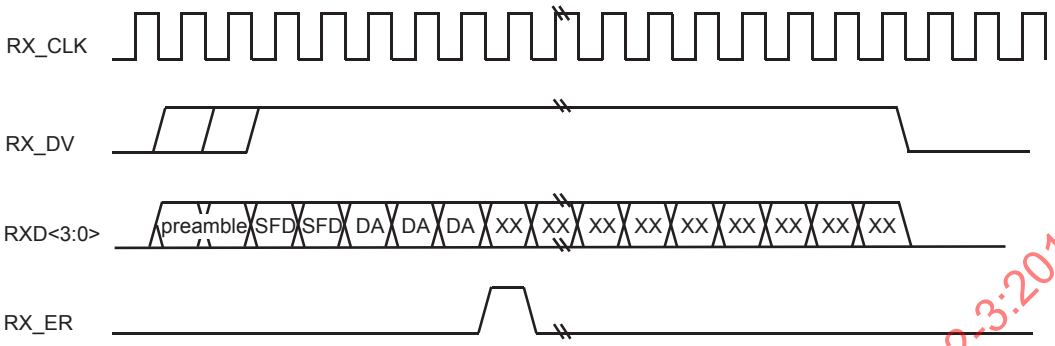

Figure 22–9—Reception with errors

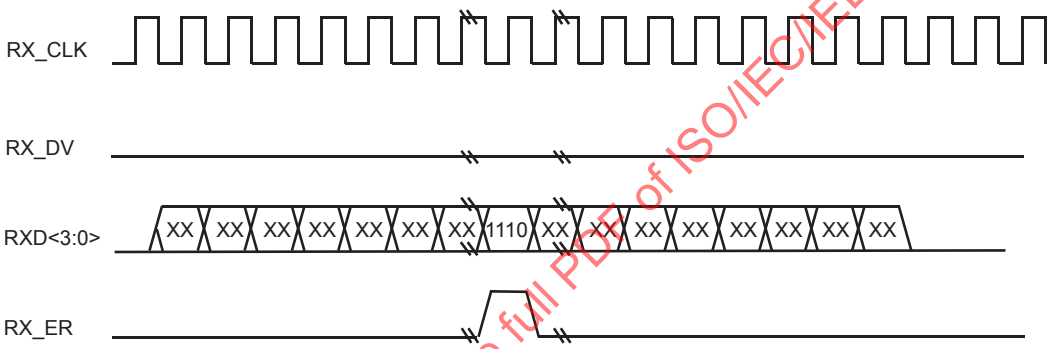

Figure 22–10—False Carrier indication

22.2.2.11 CRS (carrier sense)

CRS shall be asserted by the PHY when either the transmit or receive medium is nonidle. CRS shall be deasserted by the PHY when both the transmit and receive media are idle. The PHY shall ensure that CRS remains asserted throughout the duration of a collision condition.

CRS is not required to transition synchronously with respect to either the TX_CLK or the RX_CLK.

The behavior of the CRS signal is unspecified when the duplex mode bit 0.8 in the control register is set to a logic one, as described in 22.2.4.1.8, or when the Auto-Negotiation process selects a full duplex mode of operation.

Figure 22–4 shows the behavior of CRS during a frame transmission without a collision, while Figure 22–11 shows the behavior of CRS during a frame transmission with a collision.

22.2.2.12 COL (collision detected)

COL shall be asserted by the PHY upon detection of a collision on the medium, and shall remain asserted while the collision condition persists.

COL shall be asserted by a PHY that is operating at 10 Mb/s in response to a *signal_quality_error* message from the PMA.

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COL is not required to transition synchronously with respect to either the TX_CLK or the RX_CLK.

The behavior of the COL signal is unspecified when the duplex mode bit 0.8 in the control register is set to a logic one, as described in 22.2.4.1.8, or when the Auto-Negotiation process selects a full duplex mode of operation.

Figure 22–11 shows the behavior of COL during a frame transmission with a collision.

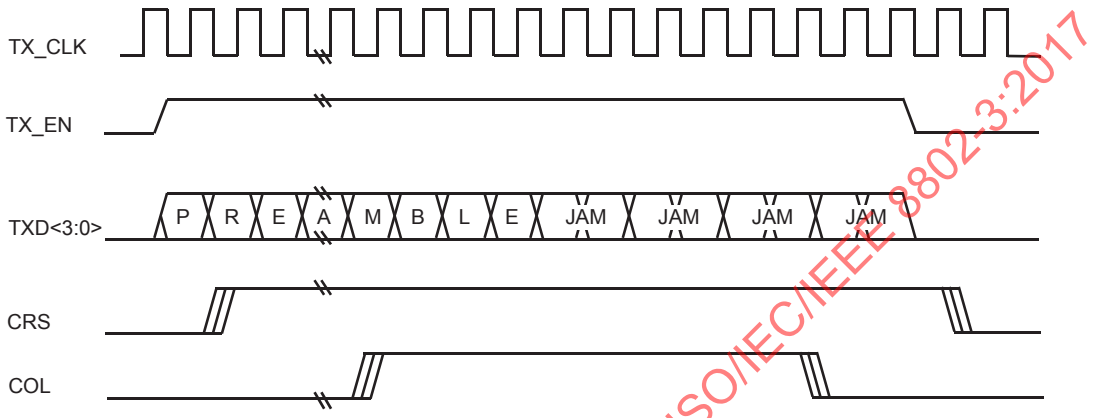

Figure 22–11—Transmission with collision

NOTE—The circuit assembly that contains the Reconciliation sublayer may incorporate a weak pull-up on the COL signal as a means of detecting an open circuit condition on the COL signal at the MII. The limit on the value of this pull-up is defined in 22.4.4.2.

22.2.2.13 MDC (management data clock)

MDC is sourced by the station management entity to the PHY as the timing reference for transfer of information on the MDIO signal. MDC is an aperiodic signal that has no maximum high or low times. The minimum high and low times for MDC shall be 160 ns each, and the minimum period for MDC shall be 400 ns, regardless of the nominal period of TX_CLK and RX_CLK.

22.2.2.14 MDIO (management data input/output)

MDIO is a bidirectional signal between the PHY and the STA. It is used to transfer control information and status between the PHY and the STA. Control information is driven by the STA synchronously with respect to MDC and is sampled synchronously by the PHY. Status information is driven by the PHY synchronously with respect to MDC and is sampled synchronously by the STA.

MDIO shall be driven through three-state circuits that enable either the STA or the PHY to drive the signal. A PHY that is attached to the MII via the mechanical interface specified in 22.6 shall provide a resistive pull-up to maintain the signal in a high state. The STA shall incorporate a resistive pull-down on the MDIO signal and thus may use the quiescent state of MDIO to determine if a PHY is connected to the MII via the mechanical interface defined in 22.6. The limits on the values of these pull-ups and pull-downs are defined in 22.4.4.2.

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22.2.3 MII data stream

Packets transmitted through the MII shall have the format shown in Figure 22–12.

<inter-frame><preamble><sfd><data><efd>

Figure 22–12—MII data stream

For the MII, transmission and reception of each octet of data shall be done a nibble at a time with the order of nibble transmission and reception as shown in Figure 22–13.

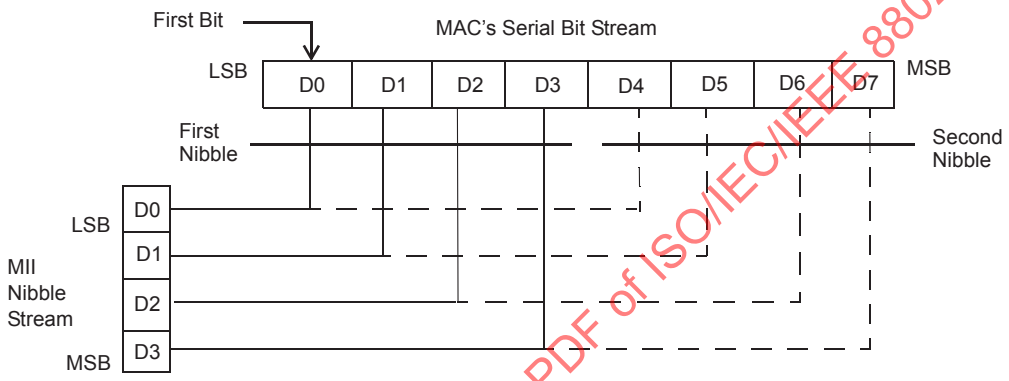

Figure 22–13—Octet/nibble transmit and receive order

The bits of each octet are transmitted and received as two nibbles, bits 0 through 3 of the octet corresponding to bits 0 through 3 of the first nibble transmitted or received, and bits 4 through 7 of the octet corresponding to bits 0 through 3 of the second nibble transmitted or received.

22.2.3.1 Inter-frame

The inter-frame period provides an observation window for an unspecified amount of time during which no data activity occurs on the MII. The absence of data activity is indicated by the deassertion of the RX_DV signal on the receive path, and the deassertion of the TX_EN signal on the transmit path. The MAC interFrameSpacing parameter defined in Clause 4 is measured from the deassertion of the CRS signal to the assertion of the CRS signal.

22.2.3.2 Preamble and start of frame delimiter

22.2.3.2.1 Transmit case

The preamble <preamble> begins a frame transmission. The bit value of the preamble field at the MII is unchanged from that specified in 7.2.3.2 and shall consist of 7 octets with the following bit values:

10101010 10101010 10101010 10101010 10101010 10101010 10101010

In the preceding example, the preamble is displayed using the bit order it would have if transmitted serially. This means that for each octet the leftmost l value represents the LSB of the octet, and the rightmost 0 value the octet MSB.

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The SFD (Start Frame Delimiter) <sfd> indicates the start of a frame and follows the preamble. The bit value of the SFD at the MII is unchanged from that specified in 7.2.3.3 and is the bit sequence:

10101011

The preamble and SFD shall be transmitted through the MII as nibbles starting from the assertion of TX_EN as shown in Table 22–3.

Table 22–3—Transmitted preamble and SFD

Signal	Bit values of nibbles transmitted through MII																		
TXD0	X	1[a]	1	1	1	1	1	1	1	1	1	1	1	1	1	1[b]	1	D0[c]	D4[d]
TXD1	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	D1	D5
TXD2	X	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	D2	D6
TXD3	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	D3	D7
TX_EN	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

[a]1st preamble nibble transmitted.
[b]1st SFD nibble transmitted.
[c]1st data nibble transmitted.
[d]D0 through D7 are the first eight bits of the data field from the Protocol Data Unit (PDU).

22.2.3.2.2 Receive case

The conditions for assertion of RX_DV are defined in 22.2.2.7.

The alignment of the received SFD and data at the MII shall be as shown in Table 22–4 and Table 22–5. Table 22–4 depicts the case where no preamble nibbles are conveyed across the MII, and Table 22–5 depicts the case where the entire preamble is conveyed across the MII.

Table 22–4—Start of receive with no preamble preceding SFD

Signal	Bit values of nibbles received through MII										
RXD0	X	X	X	X	X	X	X	1[a]	1	D0[b]	D4[c]
RXD1	X	X	X	X	X	X	X	0	0	D1	D5
RXD2	X	X	X	X	X	X	X	1	1	D2	D6
RXD3	X	X	X	X	X	X	X	0	1	D3	D7
RX_DV	0	0	0	0	0	0	0	1	1	1	1

[a]1st SFD nibble received.
[b]1st data nibble received.
[c]D0 through D7 are the first eight bits of the data field from the PDU.

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Table 22–5—Start of receive with entire preamble preceding SFD

Signal	Bit values of nibbles received through MII																		
RXD0	X	1[a]	1	1	1	1	1	1	1	1	1	1	1	1	1	1[b]	1	D0[c]	D4[d]
RXD1	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	D1	D5
RXD2	X	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	D2	D6
RXD3	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	D3	D7
RX_DV	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

[a]1st preamble nibble received.
[b]1st SFD nibble received.
[c]1st data nibble received.
[d]D0 through D7 are the first eight bits of the data field from the PDU.

22.2.3.3 Data

The data in a well formed frame shall consist of N octets of data transmitted as 2N nibbles. For each octet of data the transmit order of each nibble is as specified in Figure 22–13. Data in a collision fragment may consist of an odd number of nibbles.

22.2.3.4 End-of-Frame delimiter (EFD)

Deassertion of the TX_EN signal constitutes an End-of-Frame delimiter for data conveyed on TXD<3:0>, and deassertion of RX_DV constitutes an End-of-Frame delimiter for data conveyed on RXD<3:0>.

22.2.3.5 Handling of excess nibbles

An excess nibble condition occurs when an odd number of nibbles is conveyed across the MII beginning with the SFD and including all nibbles conveyed until the End-of-Frame delimiter. Reception of a frame containing a non-integer number of octets shall be indicated by the PHY as an excess nibble condition.

Transmission of an excess nibble may be handled by the PHY in an implementation-specific manner. No assumption should be made with regard to truncation, octet padding, or exact nibble transmission by the PHY.

22.2.4 Management functions

The management interface specified here provides a simple, two-wire, serial interface to connect a management entity and a managed PHY for the purposes of controlling the PHY and gathering status from the PHY. This interface is referred to as the MII Management Interface.

The MII Management Interface consists of a pair of signals that physically transport the management information across the MII or GMII, a frame format and a protocol specification for exchanging management frames, and a register set that can be read and written using these frames. The register definition specifies a basic register set with an extension mechanism. The MII uses two basic registers. The GMII also uses the same two basic registers and adds a third basic register.

The MII basic register set consists of two registers referred to as the Control register (Register 0) and the Status register (Register 1). All PHYs that provide an MII Management Interface shall incorporate the basic register set. All PHYs that provide a GMII shall incorporate an extended basic register set consisting of the Control register (Register 0), Status register (Register 1), and Extended Status register (Register 15). The

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status and control functions defined here are considered basic and fundamental to 100 Mb/s and 1000 Mb/s PHYs. Registers 2 through 14 are part of the extended register set. The format of Registers 4 through 10 are defined for the specific Auto-Negotiation protocol used (Clause 28 or Clause 37). The format of these registers is selected by the bit settings of Registers 1 and 15.

The full set of management registers is listed in Table 22–6.

Table 22–6—MII management register set

Register address	Register name	Basic/Extended	
		MII	GMII
0	Control	B	B
1	Status	B	B
2,3	PHY Identifier	E	E
4	Auto-Negotiation Advertisement	E	E
5	Auto-Negotiation Link Partner Base Page Ability	E	E
6	Auto-Negotiation Expansion	E	E
7	Auto-Negotiation Next Page Transmit	E	E
8	Auto-Negotiation Link Partner Received Next Page	E	E
9	MASTER-SLAVE Control Register	E	E
10	MASTER-SLAVE Status Register	E	E
11	PSE Control register	E	E
12	PSE Status register	E	E
13	MMD Access Control Register	E	E
14	MMD Access Address Data Register	E	E
15	Extended Status	Reserved	B
16 through 31	Vendor Specific	E	E

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22.2.4.1 Control register (Register 0)

The assignment of bits in the Control Register is shown in Table 22–7. The default value for each bit of the Control Register should be chosen so that the initial state of the PHY upon power up or reset is a normal operational state without management intervention.

22.2.4.1.1 Reset

Resetting a PHY is accomplished by setting bit 0.15 to a logic one. This action shall set the status and control registers to their default states. As a consequence this action may change the internal state of the PHY and the state of the physical link associated with the PHY. This bit is self-clearing, and a PHY shall return a value of one in bit 0.15 until the reset process is completed. A PHY is not required to accept a write transaction to the control register until the reset process is completed, and writes to bits of the control register other than 0.15 may have no effect until the reset process is completed. The reset process shall be completed within 0.5 s from the setting of bit 0.15.

The default value of bit 0.15 is zero.

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Table 22–7—Control register bit definitions

Bit(s)	Name	Description	R/W[a]
0.15	Reset	1 = PHY reset 0 = normal operation	R/W SC
0.14	Loopback	1 = enable loopback mode 0 = disable loopback mode	R/W
0.13	Speed Selection (LSB)	0.6 0.13 1 1 = Reserved 1 0 = 1000 Mb/s 0 1 = 100 Mb/s 0 0 = 10 Mb/s	R/W
0.12	Auto-Negotiation Enable	1 = enable Auto-Negotiation process 0 = disable Auto-Negotiation process	R/W
0.11	Power Down	1 = power down 0 = normal operation[b]	R/W
0.10	Isolate	1 = electrically Isolate PHY from MII or GMII 0 = normal operation[b]	R/W
0.9	Restart Auto-Negotiation	1 = restart Auto-Negotiation process 0 = normal operation	R/W SC
0.8	Duplex Mode	1 = full duplex 0 = half duplex	R/W
0.7	Collision Test	1 = enable COL signal test 0 = disable COL signal test	R/W
0.6	Speed Selection (MSB)	0.6 0.13 1 1 = Reserved 1 0 = 1000 Mb/s 0 1 = 100 Mb/s 0 0 = 10 Mb/s	R/W
0.5	Unidirectional enable	When bit 0.12 is one or bit 0.8 is zero, this bit is ignored. When bit 0.12 is zero and bit 0.8 is one: 1 = Enable transmit from media independent interface regardless of whether the PHY has determined that a valid link has been established 0 = Enable transmit from media independent interface only when the PHY has determined that a valid link has been established	R/W
0.4:0	Reserved	Write as 0, ignore on read	R/W

[a]R/W = Read/Write, SC = Self-clearing.
[b]For normal operation, both 0.10 and 0.11 must be cleared to zero; see 22.2.4.1.5.

NOTE—This operation may interrupt data communication.

22.2.4.1.2 Loopback

The PHY shall be placed in a loopback mode of operation when bit 0.14 is set to a logic one. When bit 0.14 is set, the PHY receive circuitry shall be isolated from the network medium, and the assertion of TX_EN at the MII or GMII shall not result in the transmission of data on the network medium. When bit 0.14 is set, the PHY shall accept data from the MII or GMII transmit data path and return it to the MII or GMII receive data path in response to the assertion of TX_EN. When bit 0.14 is set, the delay from the assertion of TX_EN to

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the assertion of RX_DV shall be less than 512 BT. When bit 0.14 is set, the COL signal shall remain deasserted at all times, unless bit 0.7 is set, in which case the COL signal shall behave as described in 22.2.4.1.9. Clearing bit 0.14 to zero allows normal operation.

The default value of bit 0.14 is zero.

NOTE—The signal path through the PHY that is exercised in the loopback mode of operation is implementation specific, but it is recommended that the signal path encompass as much of the PHY circuitry as is practical. The intention of providing this loopback mode of operation is to permit a diagnostic or self-test function to perform the transmission and reception of a PDU, thus testing the transmit and receive data paths. Other loopback signal paths through a PHY may be enabled via the extended register set, in an implementation-specific fashion.

22.2.4.1.3 Speed selection

Link speed can be selected via either the Auto-Negotiation process, or manual speed selection. Manual speed selection is allowed when Auto-Negotiation is disabled by clearing bit 0.12 to zero. When Auto-Negotiation is disabled and bit 0.6 is cleared to a logic zero, setting bit 0.13 to a logic one configures the PHY for 100 Mb/s operation, and clearing bit 0.13 to a logic zero configures the PHY for 10 Mb/s operation. When Auto-Negotiation is disabled and bit 0.6 is set to a logic one, clearing bit 0.13 to a logic zero selects 1000 Mb/s operation. The combination of both bits 0.6 and 0.13 set to a logic one is reserved for future standardization. When Auto-Negotiation is enabled, bits 0.6 and 0.13 can be read or written, but the state of bits 0.6 and 0.13 have no effect on the link configuration, and it is not necessary for bits 0.6 and 0.13 to reflect the operating speed of the link when it is read. If a PHY reports via bits 1.15:9 and bits 15.15:12 that it is not able to operate at all speeds, the value of bits 0.6 and 0.13 shall correspond to a speed at which the PHY can operate, and any attempt to change the bits to an invalid setting shall be ignored.

The default value of bits 0.6 and 0.13 are the encoding of the highest data rate at which the PHY can operate as indicated by bits 1.15:9 and 15.15:12.

22.2.4.1.4 Auto-Negotiation enable

The Auto-Negotiation process shall be enabled by setting bit 0.12 to a logic one. If bit 0.12 is set to a logic one, then bits 0.13, 0.8, and 0.6 shall have no effect on the link configuration, and station operation other than that specified by the Auto-Negotiation protocol. If bit 0.12 is cleared to a logic zero, then bits 0.13, 0.8, and 0.6 will determine the link configuration, regardless of the prior state of the link configuration and the Auto-Negotiation process.

If a PHY reports via bit 1.3 that it lacks the ability to perform Auto-Negotiation, the PHY shall return a value of zero in bit 0.12. If a PHY reports via bit 1.3 that it lacks the ability to perform Auto-Negotiation, bit 0.12 should always be written as zero, and any attempt to write a one to bit 0.12 shall be ignored.

The default value of bit 0.12 is one, unless the PHY reports via bit 1.3 that it lacks the ability to perform Auto-Negotiation, in which case the default value of bit 0.12 is zero.

22.2.4.1.5 Power down

The PHY may be placed in a low-power consumption state by setting bit 0.11 to a logic one. Clearing bit 0.11 to zero allows normal operation. The specific behavior of a PHY in the power-down state is implementation specific. While in the power-down state, the PHY shall respond to management transactions. During the transition to the power-down state and while in the power-down state, the PHY shall not generate spurious signals on the MII or GMII.

A PHY is not required to meet the RX_CLK and TX_CLK signal functional requirements when either bit 0.11 or bit 0.10 is set to a logic one. A PHY shall meet the RX_CLK and TX_CLK signal functional requirements defined in 22.2.2 within 0.5 s after both bit 0.11 and 0.10 are cleared to zero.

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The default value of bit 0.11 is zero.

22.2.4.1.6 Isolate

The PHY may be forced to electrically isolate its data paths from the MII or GMII by setting bit 0.10 to a logic one. Clearing bit 0.10 allows normal operation. When the PHY is isolated from the MII or GMII it shall not respond to the TXD data bundle, TX_EN, TX_ER and GTX_CLK inputs, and it shall present a high impedance on its TX_CLK, RX_CLK, RX_DV, RX_ER, RXD data bundle, COL, and CRS outputs. When the PHY is isolated from the MII or GMII it shall respond to management transactions.

A PHY that is connected to the MII via the mechanical interface defined in 22.6 shall have a default value of one for bit 0.10 so as to avoid the possibility of having multiple MII output drivers actively driving the same signal path simultaneously.

NOTE—This clause neither requires nor assumes any specific behavior at the MDI resulting from setting bit 0.10 to a logic one.

22.2.4.1.7 Restart Auto-Negotiation

If a PHY reports via bit 1.3 that it lacks the ability to perform Auto-Negotiation, or if Auto-Negotiation is disabled, the PHY shall return a value of zero in bit 0.9. If a PHY reports via bit 1.3 that it lacks the ability to perform Auto-Negotiation, or if Auto-Negotiation is disabled, bit 0.9 should always be written as zero, and any attempt to write a one to bit 0.9 shall be ignored.

Otherwise, the Auto-Negotiation process shall be restarted by setting bit 0.9 to a logic one. This bit is self-clearing, and a PHY shall return a value of one in bit 0.9 until the Auto-Negotiation process has been initiated. The Auto-Negotiation process shall not be affected by writing a zero to bit 0.9.

The default value of bit 0.9 is zero.

22.2.4.1.8 Duplex mode

The duplex mode can be selected via either the Auto-Negotiation process, or manual duplex selection. Manual duplex selection is allowed when Auto-Negotiation is disabled by clearing bit 0.12 to zero. When Auto-Negotiation is disabled, setting bit 0.8 to a logic one configures the PHY for full duplex operation, and clearing bit 0.8 to a logic zero configures the PHY for half duplex operation. When Auto-Negotiation is enabled, bit 0.8 can be read or written, but the state of bit 0.8 has no effect on the link configuration. If a PHY reports via bits 1.15:9 and 15.15:12 that it is able to operate in only one duplex mode, the value of bit 0.8 shall correspond to the mode in which the PHY can operate, and any attempt to change the setting of bit 0.8 shall be ignored.

When a PHY is placed in the loopback mode of operation via bit 0.14, the behavior of the PHY shall not be affected by the state of bit 0.8.

The default value of bit 0.8 is zero, unless a PHY reports via bits 1.15:9 and 15.15:12 that it is able to operate only in full duplex mode, in which case the default value of bit 0.8 is one.

22.2.4.1.9 Collision test

The COL signal at the MII or GMII may be tested by setting bit 0.7 to a logic one. When bit 0.7 is set to one, the PHY shall assert the COL signal within 512 BT in response to the assertion of TX_EN. While bit 0.7 is set to one, the PHY shall deassert the COL signal within 4 BT when connected to an MII, or 16 BT when connected to a GMII, in response to the deassertion of TX_EN. Clearing bit 0.7 to zero allows normal operation.

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The default value of bit 0.7 is zero.

NOTE—It is recommended that the Collision Test function be used only in conjunction with the loopback mode of operation defined in 22.2.4.1.2.

22.2.4.1.10 Speed selection

Bit 0.6 is used in conjunction with bits 0.13 and 0.12 to select the speed of operation as described in 22.2.4.1.3.

22.2.4.1.11 Reserved bits

Bits 0.4:0 are reserved for future standardization. They shall be written as zero and shall be ignored when read; however, a PHY shall return the value zero in these bits.

22.2.4.1.12 Unidirectional enable

If a PHY reports via bit 1.7 that it lacks the ability to encode and transmit data from the media independent interface regardless of whether the PHY has determined that a valid link has been established, the PHY shall return a value of zero in bit 0.5, and any attempt to write a one to bit 0.5 shall be ignored.

The ability to encode and transmit data from the media independent interface regardless of whether the PHY has determined that a valid link has been established is controlled by bit 0.5 as well as the status of Auto-Negotiation Enable bit 0.12 and the Duplex Mode bit 0.8 as this ability can only be supported if Auto-Negotiation is disabled and the PHY is operating in full-duplex mode. If bit 0.5 is set to a logic one, bit 0.12 to logic zero and bit 0.8 to logic one, encoding and transmitting data from the media independent interface shall be enabled regardless of whether the PHY has determined that a valid link has been established. If bit 0.5 is set to a logic zero, bit 0.12 to logic one or bit 0.8 to logic zero, encoding and transmitting data from the media independent interface shall be dependent on whether the PHY has determined that a valid link has been established. When bit 0.12 is one or bit 0.8 is zero, bit 0.5 shall be ignored.

A management entity shall set bit 0.5 to a logic one only after it has enabled an associated OAM sublayer (see Clause 57) or if this device is a 1000BASE-PX-D PHY. A management entity shall clear bit 0.5 to a logic zero prior to it disabling an associated OAM sublayer when this device is not a 1000BASE-PX-D PHY. To avoid collisions, a management entity should not set bit 0.5 of a 1000BASE-PX-U PHY to a logic one.

The default value of bit 0.5 is zero, except for 1000BASE-PX-D, where it is one.

22.2.4.2 Status register (Register 1)

The assignment of bits in the Status register is shown in Table 22–8. All of the bits in the Status register are read only, a write to the Status register shall have no effect.

22.2.4.2.1 100BASE-T4 ability

When read as a logic one, bit 1.15 indicates that the PHY has the ability to perform link transmission and reception using the 100BASE-T4 signaling specification. When read as a logic zero, bit 1.15 indicates that the PHY lacks the ability to perform link transmission and reception using the 100BASE-T4 signaling specification.

22.2.4.2.2 100BASE-X full duplex ability

When read as a logic one, bit 1.14 indicates that the PHY has the ability to perform full duplex link transmission and reception using the 100BASE-X signaling specification. When read as a logic zero, bit

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Table 22–8—Status register bit definitions

Bit(s)	Name	Description	R/W[a]
1.15	100BASE-T4	1 = PHY able to perform 100BASE-T4 0 = PHY not able to perform 100BASE-T4	RO
1.14	100BASE-X Full Duplex	1 = PHY able to perform full duplex 100BASE-X 0 = PHY not able to perform full duplex 100BASE-X	RO
1.13	100BASE-X Half Duplex	1 = PHY able to perform half duplex 100BASE-X 0 = PHY not able to perform half duplex 100BASE-X	RO
1.12	10 Mb/s Full Duplex	1 = PHY able to operate at 10 Mb/s in full duplex mode 0 = PHY not able to operate at 10 Mb/s in full duplex mode	RO
1.11	10 Mb/s Half Duplex	1 = PHY able to operate at 10 Mb/s in half duplex mode 0 = PHY not able to operate at 10 Mb/s in half duplex mode	RO
1.10	100BASE-T2 Full Duplex	1 = PHY able to perform full duplex 100BASE-T2 0 = PHY not able to perform full duplex 100BASE-T2	RO
1.9	100BASE-T2 Half Duplex	1 = PHY able to perform half duplex 100BASE-T2 0 = PHY not able to perform half duplex 100BASE-T2	RO
1.8	Extended Status	1 = Extended status information in Register 15 0 = No extended status information in Register 15	RO
1.7	Unidirectional ability	1 = PHY able to transmit from media independent interface regardless of whether the PHY has determined that a valid link has been established 0 = PHY able to transmit from media independent interface only when the PHY has determined that a valid link has been established	RO
1.6	MF Preamble Suppression	1 = PHY will accept management frames with preamble suppressed 0 = PHY will not accept management frames with preamble suppressed	RO
1.5	Auto-Negotiation Complete	1 = Auto-Negotiation process completed 0 = Auto-Negotiation process not completed	RO
1.4	Remote Fault	1 = remote fault condition detected 0 = no remote fault condition detected	RO/ LH
1.3	Auto-Negotiation Ability	1 = PHY is able to perform Auto-Negotiation 0 = PHY is not able to perform Auto-Negotiation	RO
1.2	Link Status	1 = link is up 0 = link is down	RO/ LL
1.1	Jabber Detect	1 = jabber condition detected 0 = no jabber condition detected	RO/ LH
1.0	Extended Capability	1 = extended register capabilities 0 = basic register set capabilities only	RO

[a]RO = Read only, LL = Latching low, LH = Latching high

1.14 indicates that the PHY lacks the ability to perform full duplex link transmission and reception using the 100BASE-X signaling specification.

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22.2.4.2.3 100BASE-X half duplex ability

When read as a logic one, bit 1.13 indicates that the PHY has the ability to perform half duplex link transmission and reception using the 100BASE-X signaling specification. When read as a logic zero, bit 1.13 indicates that the PHY lacks the ability to perform half duplex link transmission and reception using the 100BASE-X signaling specification.

22.2.4.2.4 10 Mb/s full duplex ability

When read as a logic one, bit 1.12 indicates that the PHY has the ability to perform full duplex link transmission and reception while operating at 10 Mb/s. When read as a logic zero, bit 1.12 indicates that the PHY lacks the ability to perform full duplex link transmission and reception while operating at 10 Mb/s.

22.2.4.2.5 10 Mb/s half duplex ability

When read as a logic one, bit 1.11 indicates that the PHY has the ability to perform half duplex link transmission and reception while operating at 10 Mb/s. When read as a logic zero, bit 1.11 indicates that the PHY lacks the ability to perform half duplex link transmission and reception while operating at 10 Mb/s.

22.2.4.2.6 100BASE-T2 full duplex ability

When read as a logic one, bit 1.10 indicates that the PHY has the ability to perform full duplex link transmission and reception using the 100BASE-T2 signaling specification. When read as a logic zero, bit 1.10 indicates that the PHY lacks the ability to perform full duplex link transmission and reception using the 100BASE-T2 signaling specification.

22.2.4.2.7 100BASE-T2 half duplex ability

When read as a logic one, bit 1.9 indicates that the PHY has the ability to perform half duplex link transmission and reception using the 100BASE-T2 signaling specification. When read as a logic zero, bit 1.9 indicates that the PHY lacks the ability to perform half duplex link transmission and reception using the 100BASE-T2 signaling specification.

22.2.4.2.8 Unidirectional ability

When read as a logic one, bit 1.7 indicates that the PHY has the ability to encode and transmit data from the media independent interface regardless of whether the PHY has determined that a valid link has been established. When read as a logic zero, bit 1.7 indicates the PHY is able to transmit data from the media independent interface only when the PHY has determined that a valid link has been established.

A PHY shall return a value of zero in bit 1.7 if it is not a 100BASE-X PHY using the PCS and PMA specified in 66.1 or a 1000BASE-X PHY using the PCS and PMA specified in 66.2.

22.2.4.2.9 MF preamble suppression ability

When read as a logic one, bit 1.6 indicates that the PHY is able to accept management frames regardless of whether they are or are not preceded by the preamble pattern described in 22.2.4.5.2. When read as a logic zero, bit 1.6 indicates that the PHY is not able to accept management frames unless they are preceded by the preamble pattern described in 22.2.4.5.2.

22.2.4.2.10 Auto-Negotiation complete

When read as a logic one, bit 1.5 indicates that the Auto-Negotiation process has been completed, and that the contents of the extended registers implemented by the Auto-Negotiation protocol (either Clause 28 or

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Clause 37) are valid. When read as a logic zero, bit 1.5 indicates that the Auto-Negotiation process has not been completed, and that the contents of the extended registers are as defined by the current state of the Auto-Negotiation protocol, or as written for manual configuration. A PHY shall return a value of zero in bit 1.5 if Auto-Negotiation is disabled by clearing bit 0.12. A PHY shall also return a value of zero in bit 1.5 if it lacks the ability to perform Auto-Negotiation.

22.2.4.2.11 Remote fault

When read as a logic one, bit 1.4 indicates that a remote fault condition has been detected. The type of fault as well as the criteria and method of fault detection is PHY specific. The Remote Fault bit shall be implemented with a latching function, such that the occurrence of a remote fault will cause the Remote Fault bit to become set and remain set until it is cleared. The Remote Fault bit shall be cleared each time Register 1 is read via the management interface, and shall also be cleared by a PHY reset.

If a PHY has no provision for remote fault detection, it shall maintain bit 1.4 in a cleared state. Further information regarding the remote fault indication can be found in 37.2.1.5, 22.2.1.2, and 24.3.2.1.

22.2.4.2.12 Auto-Negotiation ability

When read as a logic one, bit 1.3 indicates that the PHY has the ability to perform Auto-Negotiation. When read as a logic zero, bit 1.3 indicates that the PHY lacks the ability to perform Auto-Negotiation.

22.2.4.2.13 Link Status

When read as a logic one, bit 1.2 indicates that the PHY has determined that a valid link has been established. When read as a logic zero, bit 1.2 indicates that the link is not valid. The criteria for determining link validity is PHY specific. The Link Status bit shall be implemented with a latching function, such that the occurrence of a link failure condition will cause the Link Status bit to become cleared and remain cleared until it is read via the management interface. This status indication is intended to support the management attribute defined in 30.5.1.1.4, aMediaAvailable.

22.2.4.2.14 Jabber detect

When read as a logic one, bit 1.1 indicates that a jabber condition has been detected. This status indication is intended to support the management attribute defined in 30.5.1.1.6, aJabber, and the MAU notification defined in 30.5.1.3.1, nJabber. The criteria for the detection of a jabber condition is PHY specific. The Jabber Detect bit shall be implemented with a latching function, such that the occurrence of a jabber condition will cause the Jabber Detect bit to become set and remain set until it is cleared. The Jabber Detect bit shall be cleared each time Register 1 is read via the management interface, and shall also be cleared by a PHY reset.

PHYs specified for 100 Mb/s operation or above do not incorporate a Jabber Detect function, as this function is defined to be performed in the repeater unit at these speeds. Therefore, PHYs specified for 100 Mb/s operation and above shall always return a value of zero in bit 1.1.

22.2.4.2.15 Extended capability

When read as a logic one, bit 1.0 indicates that the PHY provides an extended set of capabilities which may be accessed through the extended register set. When read as a logic zero, bit 1.0 indicates that the PHY provides only the basic register set.

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22.2.4.2.16 Extended status

When read as a logic one, bit 1.8 indicates that the base register status information is extended into Register 15. All PHYs supporting 1000 Mb/s operation shall have this bit set to a logic one. When read as a logic zero, bit 1.8 indicates that the extended status is not implemented.

22.2.4.3 Extended capability registers

In addition to the basic register set defined in 22.2.4.1 and 22.2.4.2, PHYs may provide an extended set of capabilities that may be accessed and controlled via the MII management interface. Thirteen registers have been defined within the extended address space for the purpose of providing a PHY-specific identifier to layer management, to provide control and monitoring for the Auto-Negotiation process, and to provide control and monitoring of power sourcing equipment, and to provide MDIO Manageable Device (MMD) register access.

If an attempt is made to perform a read transaction to a register in the extended register set, and the PHY being read does not implement the addressed register, the PHY shall not drive the MDIO line in response to the read transaction. If an attempt is made to perform a write transaction to a register in the extended register set, and the PHY being written does not implement the addressed register, the write transaction shall be ignored by the PHY.

22.2.4.3.1 PHY Identifier (Registers 2 and 3)

Registers 2 and 3 provide a 32-bit value, which shall constitute a unique identifier for a particular type of PHY. A PHY may return a value of zero in each of the 32 bits of the PHY Identifier.

Bit 2.15 shall be the MSB of the PHY Identifier, and bit 3.0 shall be the LSB of the PHY Identifier.

The PHY Identifier shall be composed of the third through 24th bits of the Organizationally Unique Identifier (OUI) assigned to the PHY manufacturer by the IEEE,[1] plus a six-bit manufacturer's model number, plus a four-bit manufacturer's revision number. The PHY Identifier is intended to provide sufficient information to support the oResourceTypeID object as required in 30.1.2.

The third bit of the OUI is assigned to bit 2.15, the fourth bit of the OUI is assigned to bit 2.14, and so on. Bit 2.0 contains the eighteenth bit of the OUI. Bit 3.15 contains the nineteenth bit of the OUI, and bit 3.10 contains the twenty-fourth bit of the OUI. Bit 3.9 contains the MSB of the manufacturer's model number. Bit 3.4 contains the LSB of the manufacturer's model number. Bit 3.3 contains the MSB of the manufacturer's revision number, and bit 3.0 contains the LSB of the manufacturer's revision number.

NOTE—The use of only 22 bits of the OUI as described here has been deprecated by the IEEE Registration Authority. The definition of vendor-specific device identifiers for other applications is expected to use the full 24 bits to accommodate the use of either an OUI or Company ID.

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[1]Interested applicants should contact the IEEE Standards Department, Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA.

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Figure 22–14 depicts the mapping of this information to the bits of Registers 2 and 3. Additional detail describing the format of OUIs can be found in IEEE Std 802.

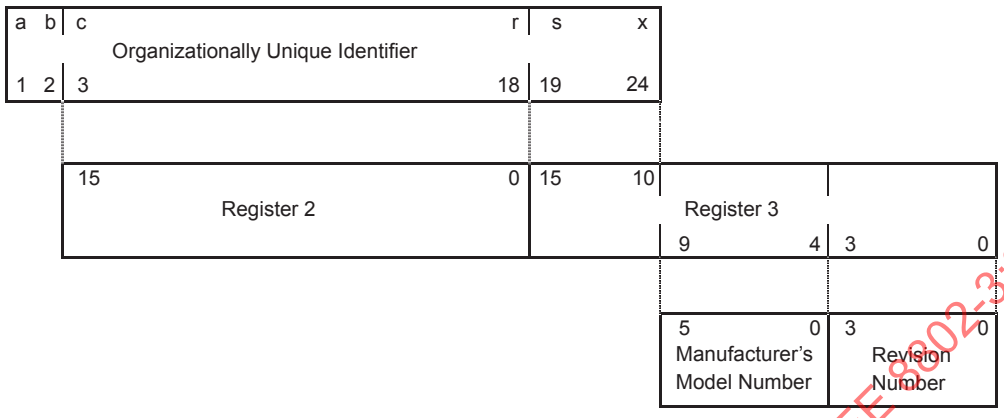

Figure 22–14—Format of PHY Identifier

22.2.4.3.2 Auto-Negotiation advertisement (Register 4)

Register 4 provides 16 bits that are used by the Auto-Negotiation process. See 28.2.4.1 and 37.2.5.1.

22.2.4.3.3 Auto-Negotiation link partner ability (Register 5)

Register 5 provides 16 bits that are used by the Auto-Negotiation process. See 28.2.4.1 and 37.2.5.1.

22.2.4.3.4 Auto-Negotiation expansion (Register 6)

Register 6 provides 16 bits that are used by the Auto-Negotiation process. See 28.2.4.1 and 37.2.5.1.

22.2.4.3.5 Auto-Negotiation Next Page (Register 7)

Register 7 provides 16 bits that are used by the Auto-Negotiation process. See 28.2.4.1 and 37.2.5.1.

22.2.4.3.6 Auto-Negotiation link partner Received Next Page (Register 8)

Register 8 provides 16 bits that are used by the Auto-Negotiation process. See 32.5.1 and 37.2.5.1.

22.2.4.3.7 MASTER-SLAVE control register (Register 9)

Register 9 provides bit values by 100BASE-T2 (as specified in 32.5) and 1000BASE-T (as specified in 40.5).

22.2.4.3.8 MASTER-SLAVE status register (Register 10)

Register 10 provides bit values by 100BASE-T2 (as specified in 32.5) and 1000BASE-T (as specified in 40.5).

22.2.4.3.9 PSE Control register (Register 11)

Register 11 provides control bits that are used by a PSE. See 33.5.1.1.

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22.2.4.3.10 PSE Status register (Register 12)

Register 12 provides status bits that are supplied by a PSE. See 33.5.1.2.

22.2.4.3.11 MMD access control register (Register 13)

The assignment of bits in the MMD access control register is shown in Table 22–9. The MMD access control register is used in conjunction with the MMD access address data register (Register 14) to provide access to the MMD address space using the interface and mechanisms defined in 22.2.4.

Table 22–9—MMD access control register bit definitions

Bit(s)	Name	Description	R/W[a]
13.15:14	Function	13.1513.14 00= address 01= data, no post increment 10= data, post increment on reads and writes 11= data, post increment on writes only	R/W
13.13:5	Reserved	Write as 0, ignore on read	R/W
13.4:0	DEVAD	Device address	R/W

[a]R/W = Read/Write

Each MMD maintains its own individual address register as described in 45.2.8. The DEVAD field directs any accesses of Register 14 to the appropriate MMD as described in 45.2. If the access of Register 14 is an address access (bits 13.15:14 = 00) then it is directed to the address register within the MMD associated with the value in the DEVAD field (bits 13.4:0). Otherwise, both the DEVAD field and that MMD's address register direct the Register 14 data accesses to the appropriate registers within that MMD.

The Function field can be set to any of four values:

a) When set to 00, accesses to Register 14 access the MMD's individual address register. This address register should always be initialized before attempting any accesses to other MMD registers.
b) When set to 01, accesses to Register 14 access the register within the MMD selected by the value in the MMD's address register.
c) When set to 10, accesses to Register 14 access the register within the MMD selected by the value in the MMD's address register. After that access is complete, for both read and write accesses, the value in the MMD's address field is incremented.
d) When set to 11, accesses to Register 14 access the register within the MMD selected by the value in the MMD's address register. After that access is complete, for write accesses only, the value in the MMD's address field is incremented. For read accesses, the value in the MMD's address field is not modified.

For additional insight into the operation and usage of this register, see Annex 22D.

22.2.4.3.12 MMD access address data register (Register 14)

The assignment of bits in the MMD access address data register is shown in Table 22–10. The MMD access address data register is used in conjunction with the MMD access control register (Register 13) to provide access to the MMD address space using the interface and mechanisms defined in 22.2.4. Accesses to this

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register are controlled by the value of the fields in Register 13 and the contents of the MMD's individual address field as described in 22.2.4.3.11.

Table 22–10—MMD access address data register bit definitions

Bit(s)	Name	Description	R/W[a]
14.15:0	Address Data	If 13.15:14 = 00, MMD DEVAD's address register. Otherwise, MMD DEVAD's data register as indicated by the contents of its address register	R/W

[a]R/W = Read/Write

For additional insight into the operation and usage of this register, see Annex 22D.

22.2.4.3.13 PHY specific registers

A particular PHY may provide additional registers beyond those defined above. Register addresses 16 through 31 (decimal) may be used to provide vendor-specific functions or abilities. The definition of Registers 4 through 14 are dependent on the version (Clause 28 or Clause 37) of Auto-Negotiation protocol used by the PHY.

22.2.4.4 Extended Status register (Register 15)

The Extended Status register is implemented for 1000BASE-T PHYs and all PHYs using the 1000BASE-X signaling specifications. The assignment of bits in the Extended Status register is shown in Table 22–11. All of the bits in the Extended Status register are read only; a write to the Extended Status register shall have no effect.

Table 22–11—Extended Status register bit definitions

Bit(s)	Name	Description	R/W[a]
15.15	1000BASE-X Full Duplex	1 = PHY able to perform full duplex 1000BASE-X 0 = PHY not able to perform full duplex 1000BASE-X	RO
15.14	1000BASE-X Half Duplex	1 = PHY able to perform half duplex 1000BASE-X 0 = PHY not able to perform half duplex 1000BASE-X	RO
15.13	1000BASE-T Full Duplex	1 = PHY able to perform full duplex 1000BASE-T 0 = PHY not able to perform full duplex 1000BASE-T	RO
15.12	1000BASE-T Half Duplex	1 = PHY able to perform half duplex 1000BASE-T 0 = PHY not able to perform half duplex 1000BASE-T	RO
15.11:0	Reserved	Ignore when read	RO

[a]RO = Read only

22.2.4.4.1 1000BASE-X full duplex ability

When read as a logic one, bit 15.15 indicates that the PHY has the ability to perform full duplex link transmission and reception using the 1000BASE-X signaling specification. When read as a logic zero, the

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bit 15.15 indicates that the PHY lacks the ability to perform full duplex link transmission and reception using the 1000BASE-X signaling specification.

22.2.4.4.2 1000BASE-X half duplex ability

When read as a logic one, bit 15.14 indicates that the PHY has the ability to perform half duplex link transmission and reception using the 1000BASE-X signaling specification. When read as a logic zero, the bit 15.14 indicates that the PHY lacks the ability to perform half duplex link transmission and reception using the 1000BASE-X signaling specification.

22.2.4.4.3 1000BASE-T full duplex ability

When read as a logic one, bit 15.13 indicates that the PHY has the ability to perform full duplex link transmission and reception using the 1000BASE-T signaling specification. When read as a logic zero, the bit 15.13 indicates that the PHY lacks the ability to perform full duplex link transmission and reception using the 1000BASE-T signaling specification.

22.2.4.4.4 1000BASE-T half duplex ability

When read as a logic one, bit 15.12 indicates that the PHY has the ability to perform half duplex link transmission and reception using the 1000BASE-T signaling specification. When read as a logic zero, the bit 15.12 indicates that the PHY lacks the ability to perform half duplex link transmission and reception using the 1000BASE-T signaling specification.

22.2.4.4.5 Reserved bits

Bits 15:11:0 are reserved for future standardization. They shall be written as zero and shall be ignored when read; however, a PHY shall return the value zero in these bits.

22.2.4.5 Management frame structure

Frames transmitted on the MII Management Interface shall have the frame structure shown in Table 22–12. The order of bit transmission shall be from left to right.

Table 22–12—Management frame format

	Management frame fields							
	PRE	ST	OP	PHYAD	REGAD	TA	DATA	IDLE
READ	1...1	01	10	AAAAA	RRRRR	Z0	DDDDDDDDDDDDDDDD	Z
WRITE	1...1	01	01	AAAAA	RRRRR	10	DDDDDDDDDDDDDDDD	Z

22.2.4.5.1 IDLE (IDLE condition)

The IDLE condition on MDIO is a high-impedance state. All three state drivers shall be disabled and the PHY's pull-up resistor will pull the MDIO line to a logic one.

22.2.4.5.2 PRE (preamble)

At the beginning of each transaction, the station management entity shall send a sequence of 32 contiguous logic one bits on MDIO with 32 corresponding cycles on MDC to provide the PHY with a pattern that it can

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use to establish synchronization. A PHY shall observe a sequence of 32 contiguous one bits on MDIO with 32 corresponding cycles on MDC before it responds to any transaction.

If the STA determines that every PHY that is connected to the MDIO signal is able to accept management frames that are not preceded by the preamble pattern, then the STA may suppress the generation of the preamble pattern, and may initiate management frames with the ST (Start of Frame) pattern.

22.2.4.5.3 ST (start of frame)

The start of frame is indicated by a <01> pattern. This pattern assures transitions from the default logic one line state to zero and back to one.

22.2.4.5.4 OP (operation code)

The operation code for a read transaction is <10>, while the operation code for a write transaction is <01>.

22.2.4.5.5 PHYAD (PHY Address)

The PHY Address is five bits, allowing 32 unique PHY addresses. The first PHY address bit transmitted and received is the MSB of the address. A PHY that is connected to the station management entity via the mechanical interface defined in 22.6 shall always respond to transactions addressed to PHY Address zero <00000>. A station management entity that is attached to multiple PHYs must have prior knowledge of the appropriate PHY Address for each PHY.

22.2.4.5.6 REGAD (Register Address)

The Register Address is five bits, allowing 32 individual registers to be addressed within each PHY. The first Register Address bit transmitted and received is the MSB of the address. The register accessed at Register Address zero <00000> shall be the control register defined in 22.2.4.1, and the register accessed at Register Address one <00001> shall be the status register defined in 22.2.4.2.

22.2.4.5.7 TA (turnaround)

The turnaround time is a 2 bit time spacing between the Register Address field and the Data field of a management frame to avoid contention during a read transaction. For a read transaction, both the STA and the PHY shall remain in a high-impedance state for the first bit time of the turnaround. The PHY shall drive a zero bit during the second bit time of the turnaround of a read transaction. During a write transaction, the STA shall drive a one bit for the first bit time of the turnaround and a zero bit for the second bit time of the turnaround. Figure 22–15 shows the behavior of the MDIO signal during the turnaround field of a read transaction.

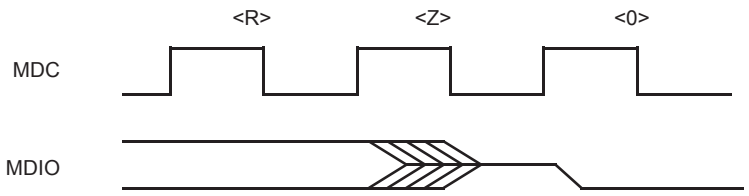

Figure 22–15—Behavior of MDIO during TA field of a read transaction

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22.2.4.5.8 DATA (data)

The data field is 16 bits. The first data bit transmitted and received shall be bit 15 of the register being addressed.

22.3 Signal timing characteristics

All signal timing characteristics shall be measured using the techniques specified in Annex 22C. The signal threshold potentials $V_{ih(min)}$ and $V_{il(max)}$ are defined in 22.4.4.1.

The HIGH time of an MII signal is defined as the length of time that the potential of the signal is greater than or equal to $V_{ih(min)}$. The LOW time of an MII signal is defined as the length of time that the potential of the signal is less than or equal to $V_{il(max)}$.

The setup time of an MII signal relative to an MII clock edge is defined as the length of time between when the signal exits and remains out of the switching region and when the clock enters the switching region. The hold time of an MII signal relative to an MII clock edge is defined as the length of time between when the clock exits the switching region and when the signal enters the switching region.

The propagation delay from an MII clock edge to a valid MII signal is defined as the length of time between when the clock exits the switching region and when the signal exits and remains out of the switching region.

22.3.1 Signals that are synchronous to TX_CLK

Figure 22–16 shows the timing relationship for the signals associated with the transmit data path at the MII connector. The clock to output delay shall be a minimum of 0 ns and a maximum of 25 ns.

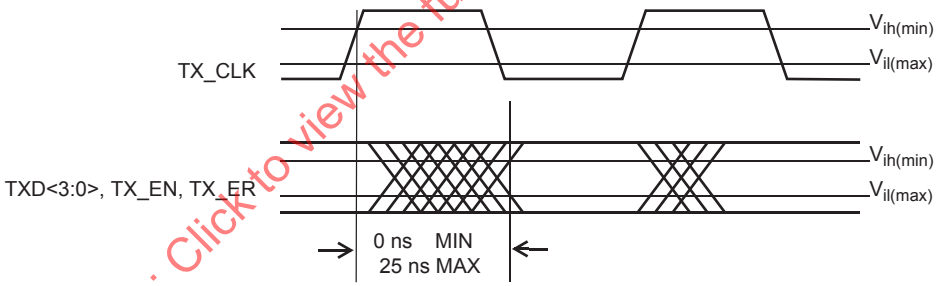

Figure 22–16—Transmit signal timing relationships at the MII

22.3.1.1 TX_EN

TX_EN is transitioned by the Reconciliation sublayer synchronously with respect to the TX_CLK rising edge with the timing as shown in Figure 22–16.

22.3.1.2 TXD<3:0>

TXD<3:0> is transitioned by the Reconciliation sublayer synchronously with respect to the TX_CLK rising edge with the timing as depicted in Figure 22–16.

22.3.1.3 TX_ER

TX_ER is transitioned synchronously with respect to the rising edge of TX_CLK as shown in Figure 22–16.

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22.3.2 Signals that are synchronous to RX_CLK

Figure 22–17 shows the timing relationship for the signals associated with the receive data path at the MII connector. The timing is referenced to the rising edge of the RX_CLK. The input setup time shall be a minimum of 10 ns and the input hold time shall be a minimum of 10 ns.

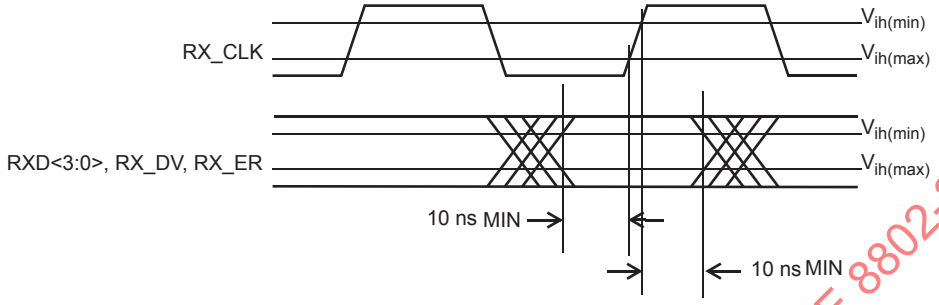

Figure 22–17—Receive signal timing relationships at the MII

22.3.2.1 RX_DV

RX_DV is sampled by the Reconciliation sublayer synchronously with respect to the rising edge of RX_CLK with the timing shown in Figure 22–17.

22.3.2.2 RXD<3:0>

RXD<3:0> is sampled by the Reconciliation sublayer synchronously with respect to the rising edge of RX_CLK as shown in Figure 22–17. The RXD<3:0> timing requirements must be met at all rising edges of RX_CLK.

22.3.2.3 RX_ER

RX_ER is sampled by the Reconciliation sublayer synchronously with respect to the rising edge of RX_CLK as shown in Figure 22–17. The RX_ER timing requirements must be met at all rising edges of RX_CLK.

22.3.3 Signals that have no required clock relationship

22.3.3.1 CRS

CRS is driven by the PHY. Transitions on CRS have no required relationship to either of the clock signals provided at the MII.

22.3.3.2 COL

COL is driven by the PHY. Transitions on COL have no required relationship to either of the clock signals provided at the MII.

22.3.4 MDIO timing relationship to MDC

MDIO (Management Data Input/Output) is a bidirectional signal that can be sourced by the Station Management Entity (STA) or the PHY. When the STA sources the MDIO signal, the STA shall provide a

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minimum of 10 ns of setup time and a minimum of 10 ns of hold time referenced to the rising edge of MDC, as shown in Figure 22–18, measured at the MII connector.

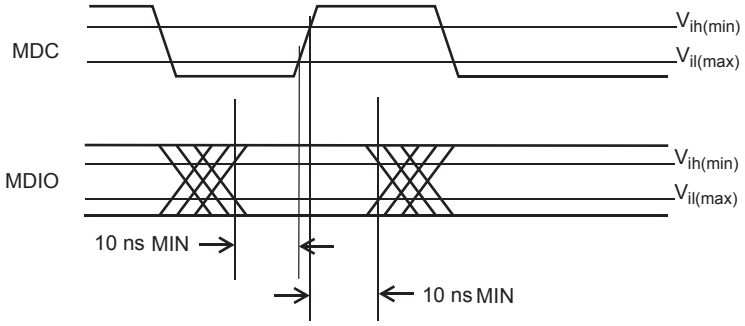

Figure 22–18—MDIO sourced by STA

When the MDIO signal is sourced by the PHY, it is sampled by the STA synchronously with respect to the rising edge of MDC. The clock to output delay from the PHY, as measured at the MII connector, shall be a minimum of 0 ns, and a maximum of 300 ns, as shown in Figure 22–19.

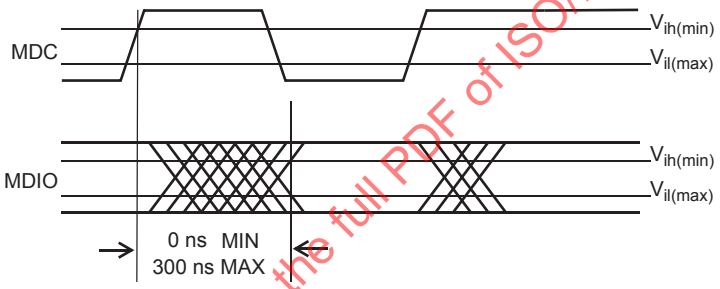

Figure 22–19—MDIO sourced by PHY

22.4 Electrical characteristics

The electrical characteristics of the MII are specified such that the three application environments described in 22.1 are accommodated. The electrical specifications are optimized for the integrated circuit to integrated circuit application environment, but integrated circuit drivers and receivers that are implemented in compliance with the specification will also support the mother board to daughter board and short cable application environments, provided those environments are constrained to the limits specified in this clause.

NOTE—The specifications for the driver and receiver characteristics can be met with TTL compatible input and output buffers implemented in a digital CMOS ASIC process.

22.4.1 Signal levels

The MII uses TTL signal levels, which are compatible with devices operating at a nominal supply voltage of either 5.0 V or 3.3 V.

NOTE—Care should be taken to ensure that all MII receivers can tolerate dc input potentials from 0.00 V to 5.50 V, referenced to the COMMON signal, and transient input potentials as high as 7.3 V, or as low as –1.8 V, referenced to the COMMON signal, which can occur when MII signals change state. The transient duration will not exceed 15 ns. The dc

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source impedance will be no less than $R_{oh(min)}$. The transient source impedance will be no less than (68 × 0.85 = 57.8 Ω) .

22.4.2 Signal paths

MII signals can be divided into two groups: signals that go between the STA and the PHY, and signals that go between the Reconciliation sublayer and the PHY.

Signals between the STA and the PHY may connect to one or more PHYs. When a signal goes between the STA and a single PHY, the signal's path is a point-to-point transmission path. When a signal goes between the STA and multiple PHYs, the signal's transmission path has drivers and receivers attached in any order along the length of the path and is not considered a point-to-point transmission path.

Signals between the Reconciliation sublayer and the PHY may also connect to one or more PHYs. However, the transmission path of each of these signals shall be either a point-to-point transmission path or a sequence of point-to-point transmission paths connected in series.

All connections to a point-to-point transmission path are at the path ends. The simplest point-to-point transmission path has a driver at one end and a receiver at the other. Point-to-point transmission paths can also have more than one driver and more than one receiver if the drivers and receivers are lumped at the ends of the path, and if the maximum propagation delay between the drivers and receivers at a given end of the path is a very small fraction of the 10%–90% rise/fall time for signals driven onto the path.

The MII shall use unbalanced signal transmission paths. The characteristic impedance Z_o of transmission paths is not specified for electrically short paths where transmission line reflections can be safely ignored.

The characteristic impedance Z_o of electrically long transmission paths or path segments shall be 68 Ω ± 15%.

The output impedance of the driver shall be used to control transmission line reflections on all electrically long point-to-point signal paths.

NOTE—In the context of this clause, a transmission path whose round-trip propagation delay is less than half of the 10%–90% rise/fall time of signals driven onto the path is considered an electrically short transmission path.

22.4.3 Driver characteristics

The driver characteristics defined in this clause apply to all MII signal drivers. The driver characteristics are specified in terms of both their ac and dc characteristics.

NOTE—Rail-to-rail drivers that comply with the driver output V-I diagrams in Annex 22B will meet the following ac and dc characteristics.

22.4.3.1 DC characteristics

The high (one) logic level output potential V_{oh} shall be no less than 2.40 V at an output current I_{oh} of –4.0 mA. The low (zero) logic level output potential V_{ol} shall not be greater than 0.40 V at an output current I_{ol} of 4.0 mA.

22.4.3.2 AC characteristics

Drivers must also meet certain ac specifications in order to ensure adequate signal quality for electrically long point-to-point transmission paths. The ac specifications shall guarantee the following performance requirements.

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The initial incident potential change arriving at the receiving end of a point-to-point MII signal path plus its reflection from the receiving end of the path must switch the receiver input potential monotonically from a valid high (one) level to $V_{il} \leq V_{il(max)} - 200$ mV, or from a valid low (zero) level to $V_{ih} \geq V_{ih(min)} + 200$ mV.

Subsequent incident potential changes arriving at the receiving end of a point-to-point MII signal path plus their reflections from the receiving end of the path must not cause the receiver input potential to reenter the range $V_{il(max)} - 200$ mV $< V_i < V_{ih(min)} + 200$ mV except when switching from one valid logic level to the other. Such subsequent incident potential changes result from a mismatch between the characteristic impedance of the signal path and the driver output impedance.

22.4.4 Receiver characteristics

The receiver characteristics are specified in terms of the threshold levels for the logical high (one) and logical low (zero) states. In addition, receivers must meet the input current and capacitance limits.

22.4.4.1 Voltage thresholds

An input potential V_i of 2.00 V or greater shall be interpreted by the receiver as a logical high (one). Thus, $V_{ih(min)} = 2.00$ V. An input potential V_i of 0.80 V or less shall be interpreted by the receiver as a logical low (zero). Thus, $V_{il(max)} = 0.80$ V. The switching region is defined as signal potentials greater than $V_{il(max)}$ and less than $V_{ih(min)}$. When the input signal potential is in the switching region, the receiver output is undefined.

22.4.4.2 Input current

The input current requirements shall be measured at the MII connector and shall be referenced to the +5 V supply and COMMON pins of the connector. The input current requirements shall be met across the full range of supply voltage specified in 22.5.1.

The bidirectional signal MDIO has two sets of input current requirements. The MDIO drivers must be disabled when the input current measurement is made.

The input current characteristics for all MII signals shall fall within the limits specified in Table 22–13.

NOTE—These limits for dc input current allow the use of weak resistive pull-ups or pull-downs on the input of each MII signal. They allow the use of weak resistive pull-downs on the signals other than COL, MDC, and MDIO. They allow the use of a weak resistive pull-up on the signal COL. They allow the use of a resistive pull-down of 2 kΩ ± 5% on the MDIO signal in the STA. They require a resistive pull-up of 1.5 kΩ ± 5% on the MDIO signal in a PHY that is attached to the MII via the mechanical interface specified in 22.6. The limits on MDC and MDIO allow the signals to be "bused" to several PHYs that are contained on the same printed circuit assembly, with a single PHY attached via the MII connector.

22.4.4.3 Input capacitance

For all signals other than MDIO, the receiver input capacitance C_i shall not exceed 8 pF.

For the MDIO signal, the transceiver input capacitance shall not exceed 10 pF.

22.4.5 Cable characteristics

The MII cable consists of a bundle of individual twisted pairs of conductors with an overall shield covering this bundle. Each twisted pair shall be composed of a conductor for an individual signal and a return path dedicated to that signal.

NOTE—It is recommended that the signals RX_CLK and TX_CLK be connected to pairs that are located in the center of the cable bundle.

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Table 22–13—Input current limits

Symbol	Parameter	Condition	Signal(s)	Min (µA)	Max (µA)
I_{ih}	Input high current	V_i=5.25 V	All except COL, MDC, MDIO[a]	—	200
			COL[b]	—	20
			MDC[c]	—	20
			MDIO[d]	—	3000
			MDIO[e]	—	20
I_{il}	Input low current	V_i=0.00 V	All except COL, MDC, MDIO[a]	–20	—
			COL[b]	–200	—
			MDC[c]	–20	—
			MDIO[d]	–180	—
			MDIO[e]	–3800	—
I_{iq}	Input quiescent current	V_i=2.4 V	MDIO[d]	—	1450
			MDIO[e]	–1450	—

[a]Measured at input of Reconciliation sublayer for CRS, RXD<3:0>, RX_CLK, RX_DV, RX_ER, and TX_CLK. Measured at inputs of PHY for TXD<3:0>, TX_EN, and TX_ER.
[b]Measured at input of Reconciliation sublayer.
[c]Measured at input of PHY.
[d]Measured at input of STA.
[e]Measured at input of PHY, which can be attached via the mechanical interface specified in 22.6.

22.4.5.1 Conductor size

The specifications for dc resistance in 22.4.5.6 and characteristic impedance in 22.4.5.2 assume a conductor size of 0.32 mm (28 AWG).

22.4.5.2 Characteristic impedance

The single-ended characteristic impedance of each twisted pair shall be 68 Ω ± 10%. The characteristic impedance measurement shall be performed with the return conductor connected to the cable's overall shield at both ends of the cable.

22.4.5.3 Delay

The propagation delay for each twisted pair, measured from the MII connector to the PHY, shall not exceed 2.5 ns. The measurement shall be made with the return conductor of the pair connected to the cable's overall shield at both ends of the cable. The propagation delay shall be measured at a frequency of 25 MHz.

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22.4.5.4 Delay variation

The variation in the propagation delay of the twisted pairs in a given cable bundle, measured from the MII connector to the PHY, shall not exceed 0.1 ns. The measurement shall be made with the return conductor of the pair connected to the cable's overall shield at both ends of the cable.

22.4.5.5 Shielding

The overall shield must provide sufficient shielding to meet the requirements of protection against electromagnetic interference.

The overall shield shall be terminated to the connector shell as defined in 22.6.2. A double shield, consisting of both braid and foil shielding, is strongly recommended.

22.4.5.6 DC resistance

The dc resistance of each conductor in the cable, including the contact resistance of the connector, shall not exceed 150 mΩ measured from the MII connector to the remote PHY.

22.4.6 Hot insertion and removal

The insertion or removal of a PHY from the MII with power applied (hot insertion or removal) shall not damage the devices on either side of the MII. In order to prevent contention between multiple output buffers driving the PHY output signals, a PHY that is attached to the MII via the mechanical interface defined in 22.6 shall ensure that its output buffers present a high impedance to the MII during the insertion process, and shall ensure that this condition persists until the output buffers are enabled via the Isolate control bit in the management interface basic register.

NOTE—The act of inserting or removing a PHY from an operational system may cause the loss of one or more packets or management frames that may be in transit across the MII or MDI.

22.5 Power supply

When the mechanical interface defined in 22.6 is used to interconnect printed circuit subassemblies, the Reconciliation sublayer shall provide a regulated power supply for use by the PHY.

The power supply shall use the following MII lines:

+5 V: The plus voltage output to the PHY.
COMMON: The return to the power supply.

22.5.1 Supply voltage

The regulated supply voltage to the PHY shall be 5 Vdc ± 5% at the MII connector with respect to the COMMON circuit at the MII over the range of load current from 0 mA to 750 mA. The method of over/under voltage protection is not specified; however, under no conditions of operation shall the source apply a voltage to the +5 V circuit of less than 0 V or greater than +5.25 Vdc.

Implementations that provide a conversion from the MII to the Attachment Unit Interface (AUI) to support connection to 10 Mb/s Medium Attachment Units (MAUs) will require a supplemental power source in order to meet the AUI power supply requirements specified in 7.5.2.5.

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22.5.2 Load current

The sum of the currents carried on the +5 V lines shall not exceed 750 mA, measured at the MII connector. The surge current drawn by the PHY shall not exceed 5 A peak for a period of 10 ms. The PHY shall be capable of powering up from 750 mA current limited sources.

22.5.3 Short-circuit protection

Adequate provisions shall be made to ensure protection of the power supply from overload conditions, including a short circuit between the +5 V lines and the COMMON lines.

22.6 Mechanical characteristics

When the MII is used to interconnect two printed circuit assemblies via a short length of cable, the cable shall be connected to the circuit assembly that implements the Reconciliation sublayer by means of the mechanical interface defined in this clause.

22.6.1 Definition of mechanical interface

A 40-pole connector having the mechanical mateability dimensions as specified in IEC 61076-3-101:1997 shall be used for the MII connector. The circuit assembly that contains the MAC sublayer and Reconciliation sublayer shall have a female connector with screw locks, and the mating cable shall have a male connector with jack screws.

No requirements are imposed on the mechanical interface used to connect the MII cable to the PHY circuit assembly when the MII cable is permanently attached to the PHY circuit assembly, as shown in Figure 22–2. If the cable is not permanently attached to the PHY circuit assembly, then a male connector with jack screws shall be used for the MII connector at the PHY circuit assembly.

NOTE—All MII conformance tests are performed at the mating surfaces of the MII connector at the Reconciliation sublayer end of the cable. If a PHY circuit assembly does not have a permanently attached cable, the vendor must ensure that all of the requirements of this clause are also met when a cable that meets the requirements of 22.4.5 is used to attach the PHY circuit assembly to the circuit assembly that contains the Reconciliation sublayer.

22.6.2 Shielding effectiveness and transfer impedance

The shells of these connectors shall be plated with conductive material to ensure the integrity of the current path from the cable shield to the chassis. The transfer impedance of this path shall not exceed the values listed in Table 22–14, after a minimum of 500 cycles of mating and unmating. The shield transfer impedance values listed in the table are measured in accordance with the procedure defined in Annex L of IEEE Std 1394-1995 [B45].[2]

All additions to provide for female shell to male shell conductivity shall be on the shell of the connector with male contacts. There should be multiple contact points around the sides of this shell to provide for shield continuity.

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[2]The numbers in brackets correspond to those of the bibliography in Annex A in Section One of this standard.

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Table 22–14—Transfer impedance performance requirements

Frequency	Value
30 MHz	–26 dBΩ
159 MHz	–13 dBΩ
500 MHz	–5 dBΩ

22.6.3 Connector pin numbering

Figure 22–20 depicts the MII connector pin numbering, as seen looking into the contacts of a female connector from the mating side.

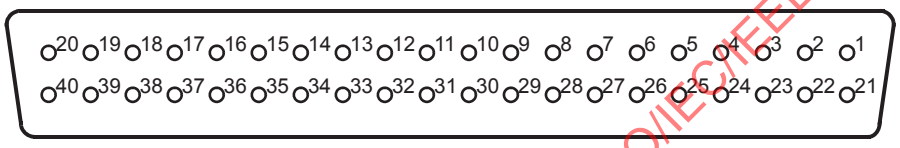

Figure 22–20—MII connector pin numbering

22.6.4 Clearance dimensions

The circuit assembly that contains the MAC sublayer and Reconciliation sublayer shall provide sufficient clearance around the MII connector to allow the attachment of cables that use die cast metal backshells and overmold assemblies. This requirement may be met by providing the clearance dimensions shown in Figure 22–21.

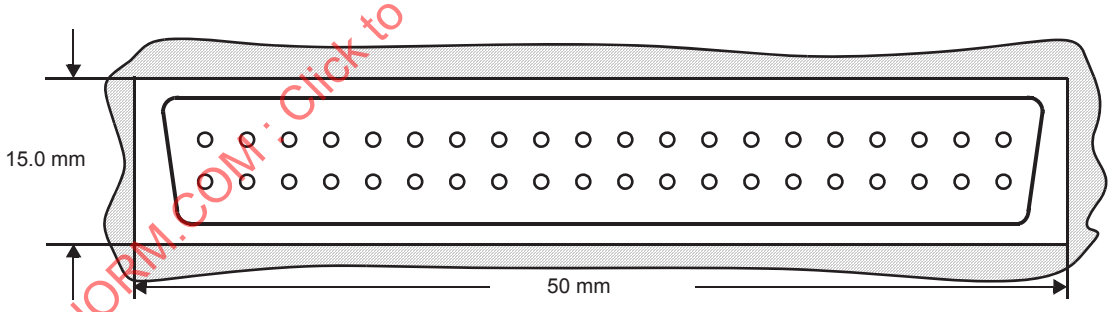

Figure 22–21—MII connector clearance dimensions

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22.6.5 Contact assignments

Table 22–15 shows the assignment of circuits to connector contacts.

Table 22–15—MII connector contact assignments

Contact	Signal name	Contact	Signal name
1	+5 V	21	+5 V
2	MDIO	22	COMMON
3	MDC	23	COMMON
4	RXD<3>	24	COMMON
5	RXD<2>	25	COMMON
6	RXD<1>	26	COMMON
7	RXD<0>	27	COMMON
8	RX_DV	28	COMMON
9	RX_CLK	29	COMMON
10	RX_ER	30	COMMON
11	TX_ER	31	COMMON
12	TX_CLK	32	COMMON
13	TX_EN	33	COMMON
14	TXD<0>	34	COMMON
15	TXD<1>	35	COMMON
16	TXD<2>	36	COMMON
17	TXD<3>	37	COMMON
18	COL	38	COMMON
19	CRS	39	COMMON
20	+5 V	40	+5 V

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22.7 LPI assertion and detection

Certain PHYs support Energy-Efficient Ethernet (EEF) (see Clause 78). PHYs with EEE capability support LPI assertion and detection. LPI operation and the LPI client are described in 78.1. LPI signaling allows the LPI client to signal to the PHY and to the link partner that an interruption in the data stream is expected and components may use this information to enter power-saving modes that require additional time to resume normal operation. Similarly, it allows the LPI client to understand that the link partner has sent such an indication. LPI signaling on the MII is specified only for 100 Mb/s operation.

The LPI assertion and detection mechanism fits conceptually between the PLS Service Primitives and the MII signals as shown in Figure 22–22.

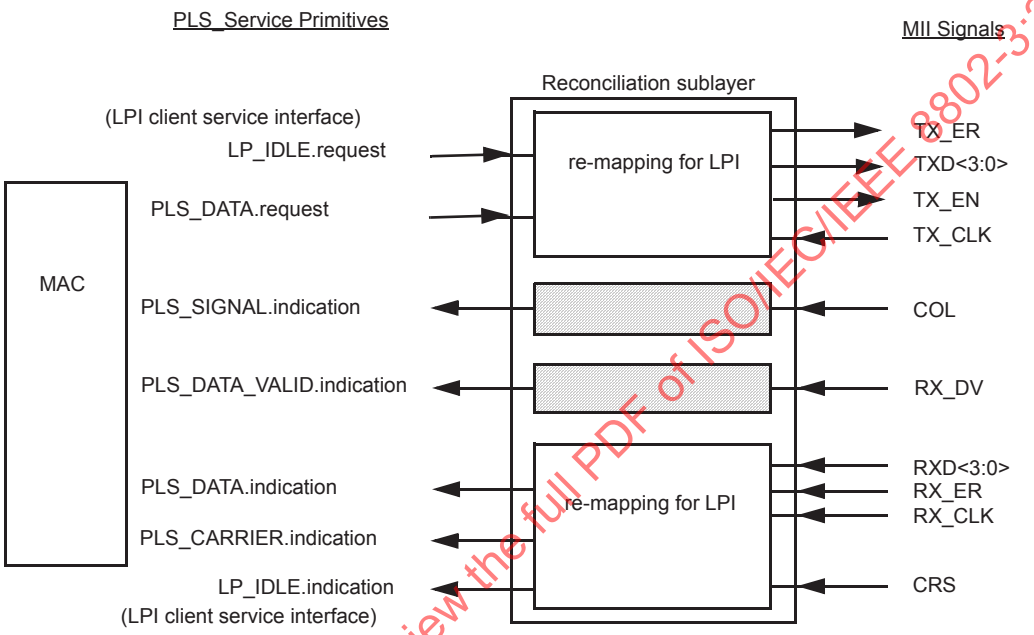

Figure 22–22—LPI assertion and detection mechanism

The definition of TX_EN, TX_ER and TXD<3:0> is derived from the state of PLS_DATA.request (22.2.1.1), except when it is overridden by an assertion of LP_IDLE.request. Similarly, RX_ER and RXD<3:0> are mapped to PLS_DATA.indication except when LP_IDLE is detected. CRS is mapped to PLS_CARRIER.indication except when LP_IDLE.request is asserted or the wake timer has yet to expire. The timing of PLS_CARRIER.indication when used for the LPI function is controlled by the LPI transmit state diagram.

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22.7.1 LPI messages

LP_IDLE.indication(LPI_INDICATION)

A primitive that indicates to the LPI client that the PHY has detected the assertion or deassertion of LPI from the link partner.

Values:DEASSERT: The link partner is operating with normal interframe behavior (default).

ASSERT: The link partner has asserted LPI.

LP_IDLE.request(LPI_REQUEST)

The LPI_REQUEST parameter can take one of two values: ASSERT or DEASSERT. ASSERT initiates the signaling of LPI to the link partner. DEASSERT stops the signaling of LPI to the link partner. The effect of receipt of this primitive is undefined if link_status is not OK (see 28.2.6.1.1) or if LPI_REQUEST=ASSERT within 1 second of the change of link_status to OK.

22.7.2 Transmit LPI state diagram

The operation of LPI in the PHY requires that the MAC does not send valid data for a time after LPI has been deasserted as governed by resolved Transmit T_{w_sys} defined in 78.4.2.3.

This wake up time is enforced by the transmit LPI state diagram and the rules mapping CARRIER_SENSE.indication defined in 22.2.1.3. The implementation shall conform to the behavior described by the transmit LPI state diagram shown in Figure 22–23.

22.7.2.1 Conventions

The notation used in the state diagram follows the conventions of 21.5.

22.7.2.2 Variables and counters

The transmit LPI state diagram uses the following variables and counters:

power_on

Condition that is true until such time as the power supply for the device that contains the RS has reached the operating region.

Values:FALSE: The device is completely powered (default).

TRUE: The device has not been completely powered.

rs_reset

Used by management to control the resetting of the RS.

Values:FALSE: Do not reset the RS (default).

TRUE: Reset the RS.

tw_timer

A timer that counts the time since the deassertion of LPI. The terminal count of the timer shall be the value of the resolved $T_{w_sys_tx}$ as defined in 78.2 and 78.4. The minimum value of $T_{w_sys_tx}$ shall be 30 µs for 100BASE-TX. Signal tw_timer_done is asserted on reaching its terminal count.

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22.7.2.3 State diagram

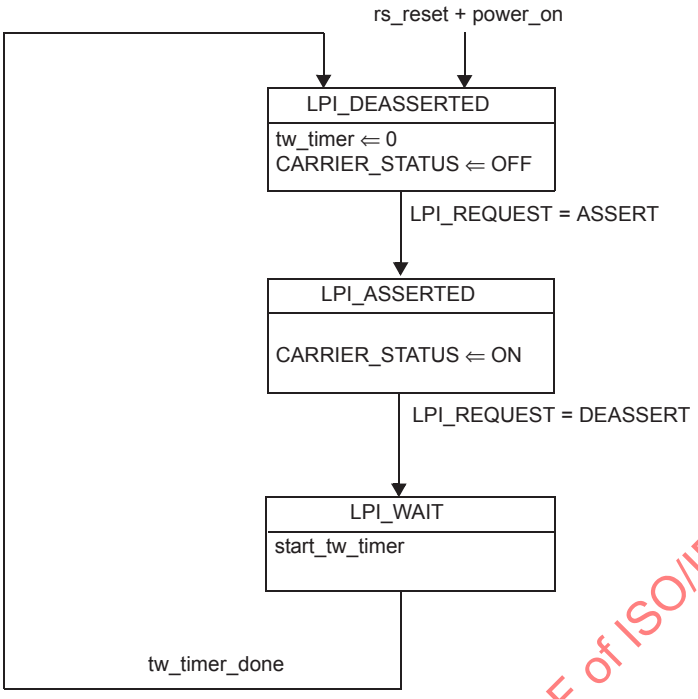

Figure 22–23—Transmit LPI state diagram

22.7.3 Considerations for transmit system behavior

The transmit system should expect that egress data flow will be halted for at least resolved $T_{w_sys_tx}$ (see 78.2) time, in microseconds, after it requests the deassertion of LPI. Buffering and queue management should be designed to accommodate this.

22.7.3.1 Considerations for receive system behavior

The mapping function of the Reconciliation Sublayer shall continue to signal IDLE on PLS_DATA.indicate while it is detecting LPI_IDLE on the MII. The receive system should be aware that data frames may arrive at the MII following the deassertion of LPI_INDICATION with a delay corresponding to the link partner's resolved $T_{w_sys_rx}$ (as specified in 78.5) time, in microseconds.

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22.8 Protocol implementation conformance statement (PICS) proforma for Clause 22, Reconciliation Sublayer (RS) and Media Independent Interface (MII)[3]

22.8.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 22, Reconciliation Sublayer (RS) and Media Independent Interface (MII), shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

22.8.2 Identification

22.8.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

22.8.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-201x, Clause 22, Reconciliation Sublayer (RS) and Media Independent Interface (MII)
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-201x.)	No [ ] Yes [ ]

Date of Statement	

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[3]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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22.8.2.3 Major capabilities/options

Item	Feature	Subclause	Status	Support	Value/Comment
*GM	Implementation of GMII	22.2.4	O		
*MUNI	Implementation of unidirectional PCS	22.2.4	O		
*LPI	Implementation of LPI	22.7	O		

22.8.3 PICS proforma tables for reconciliation sublayer and media independent interface

22.8.3.1 Mapping of PLS service primitives

Item	Feature	Subclause	Status	Support	Value/Comment
PL1	Response to RX_ER	22.2.1.5	M		Must produce FrameCheckError at MAC

22.8.3.2 MII signal functional specifications

Item	Feature	Subclause	Status	Support	Value/Comment
SF1	TX_CLK frequency	22.2.2.1	M		25% of transmitted data rate (25 MHz or 2.5 MHz)
SF2	TX_CLK duty cycle	22.2.2.1	M		35% to 65%
SF3	RX_CLK min high/low time	22.2.2.2	M		35% of nominal period
SF4	RX_CLK synchronous to recovered data	22.2.2.2	M		
SF5	RX_CLK frequency	22.2.2.2	M		25% of received data rate (25 MHz or 2.5 MHz)
SF6	RX_CLK duty cycle	22.2.2.2	M		35% to 65%
SF7	RX_CLK source due to loss of signal	22.2.2.2	M		Nominal clock reference (e.g., TX_CLK reference)
SF8	RX_CLK transitions only while RX_DV deasserted	22.2.2.2	M		
SF9	RX_CLK max high/low time following deassertion of RX_DV	22.2.2.2	M		Max 2 times the nominal period
SF10	TX_EN assertion	22.2.2.3	M		On first nibble of preamble
SF11	TX_EN remains asserted	22.2.2.3	M		Stay asserted while all nibbles are transmitted over MII
SF12	TX_EN transitions	22.2.2.3	M		Synchronous with TX_CLK
SF13	TX_EN negation	22.2.2.3	M		Before first TX_CLK after final nibble of frame

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22.8.3.2 MII signal functional specifications *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
SF14	TXD<3:0> transitions	22.2.2.4	M		Synchronous with TX_CLK
SF15	TXD<3:0> effect on PHY while TX_EN is deasserted	22.2.2.4	M		No effect
SF16	TX_ER transitions	22.2.2.5	M		Synchronous with TX_CLK
SF17	TX_ER effect on PHY while TX_EN is asserted	22.2.2.5	M		Cause PHY to emit invalid symbol
SF18	TX_ER effect on PHY while operating at 10 Mb/s, or when TX_EN is deasserted	22.2.2.5	M		No effect on PHY
SF19	TX_ER implementation	22.2.2.5	M		At MII of a PHY
SF20	TX_ER pulled down if not actively driven	22.2.2.5	M		At MII of a repeater or MAC/RS only
SF21	RX_DV transitions	22.2.2.7	M		Synchronous with RX_CLK
SF22	RX_DV assertion	22.2.2.7	M		From first recovered nibble to final nibble of a frame per Figure 22–7
SF23	RX_DV negation	22.2.2.7	M		Before the first RX_CLK follows the final nibble per Figure 22–7
SF24	RXD<3:0> effect on Reconciliation sublayer while RX_DV is deasserted	22.2.2.8	M		No effect
SF25	RX_ER assertion	22.2.2.10	M		By PHY to indicate error
SF26	RX_ER transitions	22.2.2.10	M		Synchronous with RX_CLK
SF27	RX_ER effect on Reconciliation sublayer while RX_DV is deasserted	22.2.2.10	M		No effect
SF28	CRS assertion	22.2.2.11	M		By PHY when either transmit or receive is NON-IDLE

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22.8.3.2 MII signal functional specifications *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
SF29	CRS deassertion	22.2.2.11	M		By PHY when both transmit and receive are IDLE
SF30	CRS assertion during collision	22.2.2.11	M		Remain asserted throughout
SF31	COL assertion	22.2.2.12	M		By PHY upon detection of collision on medium
SF32	COL remains asserted while collision persists	22.2.2.12	M		
SF33	COL response to SQE	22.2.2.12	M		Assertion by PHY
SF34	MDC min high/low time	22.2.2.13	M		160 ns
SF35	MDC min period	22.2.2.13	M		400 ns
SF36	MDIO uses three-state drivers	22.2.2.14	M		
SF37	PHY pull-up on MDIO	22.2.2.14	M		1.5 kΩ ± 5% (to +5 V)
SF38	STA pull-down on MDIO	22.2.2.14	M		2 kΩ ± 5% (to 0 V)

22.8.3.3 LPI functions

Item	Feature	Subclause	Status	Support	Value/Comment
L1	Transitions to LPI_ASSERTED and LPI_DEASSERTED reflected in CARRIER_STATUS	22.2.1.3.3	LPI:M		
L2	RX_CLK max high/low time while the PHY is asserting LPI	22.2.2.2	LPI:M		Max 2 times the nominal period
L3	Assertion of LPI as defined in Table 22–1	22.2.2.4	LPI:M		
L4	RX_CLK stoppable during LPI	22.2.2.9	LPI:O		At least 9 cycles after LPI assertion
L5	RX_CLK restart before LPI deasserted	22.2.2.9	LPI:O		At least 1 positive edge before LPI deassertion
L6	Behavior matches the transmit LPI state diagram	22.7.2	LPI:M		
L7	Terminal count for tw_timer	22.7.2.2	LPI:M		Based on resolved $T_{w_sys_tx}$
L8	RS continues to indicate IDLE on PLS_DATA.indicate	22.7.3.1	LPI:M		

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22.8.3.4 Frame structure

Item	Feature	Subclause	Status	Support	Value/Comment
FS1	Format of transmitted frames	22.2.3	M		Per Figure 22–12
FS2	Nibble transmission order	22.2.3	M		Per Figure 22–13
FS3	Preamble 7 octets long	22.2.3.2.1	M		10101010 10101010 10101010 10101010 10101010 10101010 10101010
FS4	Preamble and SFD transmission	22.2.3.2.1	M		Per Table 22–3
FS5	Preamble and SFD reception	22.2.3.2.2	M		Per Table 22–4, Table 22–5
FS6	N octets transmitted as 2N nibbles	22.2.3.3	M		Per Figure 22–13
FS7	Indication of excess nibbles	22.2.3.5	M		Frame contains non-integer number of octets is received

22.8.3.5 Management functions

Item	Feature	Subclause	Status	Support	Value/Comment
MF1	Incorporate of basic register set	22.2.4	M		Two 16-bit registers as Control register (Register 0) and Status register (Register 1)
MF2	Action on reset	22.2.4.1.1	M		Reset the entire PHY including Control and Status to default value and set bit 0.15 = 1
MF3	Return 1 until reset completed	22.2.4.1.1	M		Yes (when reset is done, 0.15 is self-clearing)
MF4	Reset completes within 0.5 s	22.2.4.1.1	M		
MF5	Loopback mode	22.2.4.1.2	M		Whenever 0.14 is 1
MF6	Receive circuitry isolated from network in loopback mode	22.2.4.1.2	M		
MF7	Effect of assertion of TX_EN in loopback mode	22.2.4.1.2	M		No transmission
MF8	Propagation of data in loopback mode	22.2.4.1.2	M		PHY accepts transmit data and return it as receive data
MF9	Delay from TX_EN to RX_DV in loopback mode	22.2.4.1.2	M		Less than 512 BT
MF10	Behavior of COL in loopback mode	22.2.4.1.2	M		Deasserted (for 0.7 = 0)
MF11	Behavior of COL in loopback mode	22.2.4.1.2	M		If 0.7 = 1, see MF33 and MF34
MF12	Value of speed selection bits	22.2.4.1.3	M		Set to match a valid PHY speed

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22.8.3.5 Management functions *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
MF13	Ignore writes to speed selection bits for unsupported speed	22.2.4.1.3	M		
MF14	Auto-Negotiation enable	22.2.4.1.4	M		By setting 0.12 = 1
MF15	Duplex mode, speed selection have no effect when Auto-Negotiation is enabled	22.2.4.1.4	M		If 0.12=1, bits 0.13, 0.8 and 0.6 have no effect on link configuration
MF16	PHY without Auto-Negotiation returns value of zero	22.2.4.1.4	M		Yes (if 1.3=0, then 0.12=0)
MF17	PHY without Auto-Negotiation ignores writes to enable bit	22.2.4.1.4	M		Yes (if 1.3=0, 0.12 always = 0 and cannot be changed)
MF18	Response to management transactions in power down	22.2.4.1.5	M		Remains active
MF19	Spurious signals in power down	22.2.4.1.5	M		None (not allowed)
MF20	TX_CLK and RX_CLK stabilize within 0.5 s	22.2.4.1.5	M		Yes (after both bits 0.11 and 0.10 are cleared to zero)
MF21	PHY Response to input signals while isolated	22.2.4.1.6	M		NONE
MF22	High impedance on PHY output signals while isolated	22.2.4.1.6	M		Yes (TX_CLK, RX_CLK, RX_DV, RX_ER, RXD bundle, COL, and CRS)
MF23	Response to management transactions while isolated	22.2.4.1.6	M		Remains active
MF24	Default value of isolate	22.2.4.1.6	M		0.10 =1
MF25	PHY without Auto-Negotiation returns value of zero	22.2.4.1.7	M		0.9 = 0 if 1.3 = 0 or 0.12 = 0
MF26	PHY without Auto-Negotiation ignores writes to restart bit	22.2.4.1.7	M		0.9 = 0, cannot be changed if 1.3 = 0 or 0.12 = 0
MF27	Restart Auto-Negotiation	22.2.4.1.7	M		When 0.9 = 1 if 0.12 = 1 and 1.3 = 1
MF28	Return 1 until Auto-Negotiation initiated	22.2.4.1.7	M		0.9 is self-clearing to 0
MF29	Auto-Negotiation not effected by clearing bit	22.2.4.1.7	M		
MF30	Value of duplex mode bit for PHYs with one duplex mode	22.2.4.1.8	M		Set 0.8 to match the correct PHY duplex mode
MF31	PHY with one duplex mode ignores writes to duplex bit	22.2.4.1.8	M		Yes (0.8 remains unchanged)

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22.8.3.5 Management functions *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
MF32	Loopback not affected by duplex mode	22.2.4.1.8	M		Yes (0.8 has no effect on PHY when 0.14 = 1)
MF33	Assertion of COL in collision test mode	22.2.4.1.9	M		Within 512 BT after TX_EN is asserted
MF34	deassertion of COL in collision test mode	22.2.4.1.9	M		After TX_EN is deasserted within: MII = 4 BT, GMII = 16 BT
MF35	Reserved bits written as zero	22.2.4.1.11	M		
MF36	Reserved bits ignored when read	22.2.4.1.11	M		
MF37	PHY returns 0 in reserved bits	22.2.4.1.11	M		
MF38	PHY without unidirectional ability	22.2.4.1.12	M		PHY returns a value of 0 in 0.5 if 1.7=0
MF39	PHY without unidirectional ability	22.2.4.1.12	M		PHY always maintains a value of 0 in 0.5 if 1.7=0
MF40	Unidirectional enable	22.2.4.1.12	MUNI:M		By setting 0.12 = 0, 0.8 = 1 and 0.5 = 1
MF41	Unidirectional disable	22.2.4.1.12	MUNI:M		By setting 0.12 = 1, 0.8 = 0 or 0.5 = 0
MF42	Ignore bit 0.5	22.2.4.1.12	MUNI:M		Ignore 0.5 when 0.12 = 1 or 0.8 = 0
MF43	Enable unidirectional mode	22.2.4.1.12	MUNI:M		Enable only when OAM sublayer is enabled or when part of 1000BASE-PX-D PHY
MF44	Disable unidirectional mode	22.2.4.1.12	MUNI:M		Unidirectional mode is disabled before disabling OAM sublayer when not part of 1000BASE-PX-D PHY
MF45	Unidirectional ability	22.2.4.2.8	M		Bit 1.7 = 0 for all PHYs except those using 66.1 and 66.2
MF46	Effect of write on status register	22.2.4.2	M		No effect
MF47	Reserved bits ignored when read	22.2.4.2.8	M		
MF48	PHY returns 0 in reserved bits	22.2.4.2.8	M		
MF49	PHY returns 0 if Auto-Negotiation disabled	22.2.4.2.10	M		Yes (1.5 = 0 when 0.12 = 0)
MF50	PHY returns 0 if it lacks ability to perform Auto-Negotiation	22.2.4.2.10	M		Yes (1.5 = 0 when 1.3 = 0)
MF51	Remote fault has latching function	22.2.4.2.11	M		Yes (once set will remain set until cleared)
MF52	Remote fault cleared on read	22.2.4.2.11	M		Yes

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22.8.3.5 Management functions *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
MF53	Remote fault cleared on reset	22.2.4.2.11	M		Yes (when 0.15 = 1)
MF54	PHY without remote fault returns value of zero	22.2.4.2.11	M		Yes (1.4 always 0)
MF55	Link status has latching function	22.2.4.2.13	M		Yes (once cleared by link failure will remain cleared until read by MII)
MF56	Jabber detect has latching function	22.2.4.2.14	M		Yes (once set will remain set until cleared)
MF57	Jabber detect cleared on read	22.2.4.2.14	M		
MF58	Jabber detect cleared on reset	22.2.4.2.14	M		
MF59	All PHYs operating at rates of 100 Mb/s or above return 0 for jabber detect	22.2.4.2.14	M		Yes (1.1 always = 0 for all PHYs operating at rates of 100 Mb/s or above)
MF60	MDIO not driven if register read is unimplemented	22.2.4.3	M		Yes (MDIO remain high impedance)
MF61	Write has no effect if register written is unimplemented	22.2.4.3	M		
MF62	Registers 2 and 3 constitute unique identifier for PHY type	22.2.4.3.1	M		
MF63	MSB of PHY identifier is 2.15	22.2.4.3.1	M		
MF64	LSB of PHY identifier is 3.0	22.2.4.3.1	M		
MF65	Composition of PHY identifier	22.2.4.3.1	O		22-bit OUI, 6-bit model, 4-bit version per Figure 22–14
MF66	Format of management frames	22.2.4.5	M		Per Table 22–11
MF67	Idle condition on MDIO	22.2.4.5.1	M		High impedance state
MF68	MDIO preamble sent by STA	22.2.4.5.2	M		32 contiguous logic one bits
MF69	MDIO preamble observed by PHY	22.2.4.5.2	M		32 contiguous logic one bits
MF70	Assignment of PHYAD 0	22.2.4.5.5	M		Address of PHY attached via Mechanical Interface
MF71	Assignment of REGAD 0	22.2.4.5.6	M		MII control register address
MF72	Assignment of REGAD 1	22.2.4.5.6	M		MII status register address
MF73	High impedance during first bit time of turnaround in read transaction	22.2.4.5.7	M		

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22.8.3.5 Management functions *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
MF74	PHY drives zero during second bit time of turnaround in read transaction	22.2.4.5.7	M		
MF75	STA drives MDIO during turnaround in write transaction	22.2.4.5.7	M		
MF76	First data bit transmitted	22.2.4.5.8	M		Bit 15 of the register being addressed
MF77	Incorporate Extended Status register	22.2.4	GM:M		16-bit register Extended Status register (Register 15)
MF78	Reserved bits written as zero	22.2.4.2.8	GM:M		
MF79	Extended Status	22.2.4.2.16	GM:M		Yes (1 if always = 1 for 1000 Mb/s operation)
MF80	Write to Extended Status register	22.2.4.4	GM:M		No effect
MF81	Reserved bits written as zero	22.2.4.4.5	GM:M		
MF82	Reserved bits ignored when read	22.2.4.4.5	GM:M		
MF83	PHY returns 0 in reserved bits	22.2.4.4.5	GM:M		

22.8.3.6 Signal timing characteristics

Item	Feature	Subclause	Status	Support	Value/Comment
ST1	Timing characteristics measured in accordance with Annex 22C	22.3	M		
ST2	Transmit signal clock to output delay	22.3.1	M		Min = 0 ns; Max = 25 ns per Figure 22–16
ST3	Receive signal setup time	22.3.2	M		Min = 10 ns per Figure 22–17
ST4	Receive signal hold time	22.3.2	M		Min = 10 ns per Figure 22–17
ST5	MDIO setup and hold time	22.3.4	M		Setup min = 10 ns; Hold min = 10 ns per Figure 22–18
ST6	MDIO clock to output delay	22.3.4	M		Min = 0 ns; Max = 300 ns per Figure 22–19

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22.8.3.7 Electrical characteristics

Item	Feature	Subclause	Status	Support	Value/Comment
EC1	Signal paths are either point to point, or a sequence of point-to-point transmission paths	22.4.2	M		
EC2	MII uses unbalanced signal transmission paths	22.4.2	M		
EC3	Characteristic impedance of electrically long paths	22.4.2	M		68 Ω ± 15%
EC4	Output impedance of driver used to control reflections	22.4.2	M		On all electrically long point to point signal paths
EC5	V_{oh}	22.4.3.1	M		≥ 2.4 V (I_{oh} = –4 mA)
EC6	V_{ol}	22.4.3.1	M		≤ 0.4 V (I_{ol} = 4 mA)
EC7	Performance requirements to be guaranteed by ac specifications	22.4.3.2	M		Min switching potential change (including its reflection) ≥ 1.8 V
EC8	$V_{ih(min)}$	22.4.4.1	M		2 V
EC9	$V_{il(max)}$	22.4.4.1	M		0.8 V
EC10	Input current measurement point	22.4.4.2	M		At MII connector
EC11	Input current reference potentials	22.4.4.2	M		Reference to MII connector +5 V and COMMON pins
EC12	Input current reference potential range	22.4.4.2	M		0 V to 5.25 V
EC13	Input current limits	22.4.4.2	M		Per Table 22–12
EC14	Input capacitance for signals other than MDIO	22.4.4.3	M		≤ 8 pF
EC15	Input capacitance for MDIO	22.4.4.3	M		≤ 10 pF
EC16	Twisted-pair composition	22.4.5	M		Conductor for each signal with dedicated return path
EC17	Single-ended characteristic impedance	22.4.5.2	M		68 Ω ± 10%
EC18	Characteristic impedance measurement method	22.4.5.2	M		With return conductor connected to cable shield

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22.8.3.7 Electrical characteristics *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
EC19	Twisted-pair propagation delay	22.4.5.3	M		≤ 2.5 ns
EC20	Twisted-pair propagation delay measurement method	22.4.5.3	M		With return conductor connected to cable shield
EC21	Twisted-pair propagation delay measurement frequency	22.4.5.3	M		25 MHz
EC22	Twisted-pair propagation delay variation	22.4.5.4	M		≤ 0.1 ns
EC23	Twisted-pair propagation delay variation measurement method	22.4.5.4	M		With return conductor connected to cable shield
EC24	Cable shield termination	22.4.5.5	M		To the connector shell
EC25	Cable conductor DC resistance	22.4.5.6	M		≤ 150 mΩ
EC26	Effect of hot insertion/removal	22.4.6	M		Causes no damage
EC27	State of PHY output buffers during hot insertion	22.4.6	M		High impedance
EC28	State of PHY output buffers after hot insertion	22.4.6	M		High impedance until enabled via Isolate bit

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22.8.3.8 Power supply

Item	Feature	Subclause	Status	Support	Value/Comment
PS1	Regulated power supply provided	22.5	M		To PHY by Reconciliation sublayer
PS2	Power supply lines	22.5	M		+5 V and COMMON (return of +5 V)
PS3	Regulated supply voltage limits	22.5.1	M		5 Vdc ± 5%
PS4	Over/under voltage limits	22.5.1	M		Over limit = 5.25 Vdc Under limit = 0 V
PS5	Load current limit	22.5.2	M		750 mA
PS6	Surge current limit	22.5.2	M		≤ 5 A peak for 10 ms
PS7	PHY can power up from current limited source	22.5.2	M		From 750 mA current limited source
PS8	Short-circuit protection	22.5.2	M		When +5 V and COMMON are shorted

22.8.3.9 Mechanical characteristics

Item	Feature	Subclause	Status	Support	Value/Comment
*MC1	Use of Mechanical Interface	22.6	O		Optional
MC2	Connector reference standard	22.6.1	MC1:M		IEC 61076-3-101:1997
MC3	Use of female connector	22.6.1	MC1:M		At MAC/RS side
MC4	Use of male connector	22.6.1	MC1:M		At PHY mating cable side
MC5	Connector shell plating	22.6.2	MC1:M		Use conductive material
MC6	Shield transfer impedance	22.6.2	MC1:M		After 500 cycles of mating/unmating, per Table 22–13
MC7	Additions to provide for female shell to male shell conductivity	22.6.2	MC1:M		On shell of conductor with male contacts
MC8	Clearance dimensions	22.6.4	MC1:M		15 mm × 50 mm, per Figure 22–21

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23. Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer and baseband medium, type 100BASE-T4

NOTE—This PHY is not recommended for new installations. Since September 2003, maintenance changes are no longer being considered for this clause.

23.1 Overview

The 100BASE-T4 PCS, PMA, and baseband medium specifications are aimed at users who want 100 Mb/s performance, but would like to retain the benefits of using voice-grade twisted-pair cable. 100BASE-T4 signaling requires four pairs of Category 3 or better cable, installed according to ISO/IEC 11801: 1995, as specified in 23.6. This type of cable, and the connectors used with it, are simple to install and reconfigure. 100BASE-T4 does not transmit a continuous signal between packets, which makes it useful in battery powered applications. The 100BASE-T4 PHY is one of the 100BASE-T family of high-speed CSMA/CD network specifications.

23.1.1 Scope

This clause defines the type 100BASE-T4 Physical Coding Sublayer (PCS), type 100BASE-T4 Physical Medium Attachment (PMA) sublayer, and type 100BASE-T4 Medium Dependent Interface (MDI). Together, the PCS and PMA layers comprise a 100BASE-T4 Physical Layer (PHY). Provided in this document are full functional, electrical, and mechanical specifications for the type 100BASE-T4 PCS, PMA, and MDI. This clause also specifies the baseband medium used with 100BASE-T4.

23.1.2 Objectives

The following are the objectives of 100BASE-T4:

a) To support the CSMA/CD MAC in the half duplex mode of operation.
b) To support the 100BASE-T MII, Repeater, and optional Auto-Negotiation.
c) To provide 100 Mb/s data rate at the MII.
d) To provide for operating over twisted pairs of Category 3, 4, or 5 cable, installed as horizontal runs in accordance with ISO/IEC 11801: 1995, as specified in 23.6, at distances up to 100 m (328 ft).
e) To allow for a nominal network extent of 200 m, including:
   1) Unshielded twisted-pair links of 100 m.
   2) Two-repeater networks of approximately a 200 m span.
f) To provide a communication channel with a mean ternary symbol error ratio, at the PMA service interface, of less than one part in 10^8.

23.1.3 Relation of 100BASE-T4 to other standards

Relations between the 100BASE-T4 PHY and the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model are shown in Figure 23–1. The PHY Layers shown in Figure 23–1 connect one Clause 4 Media Access Control (MAC) layer to a Clause 27 repeater. This clause also discusses other variations of the basic configuration shown in Figure 23–1. This whole clause builds on Clause 1 through Clause 4 of this standard.

23.1.4 Summary

The following paragraphs summarize the PCS and PMA clauses of this standard.

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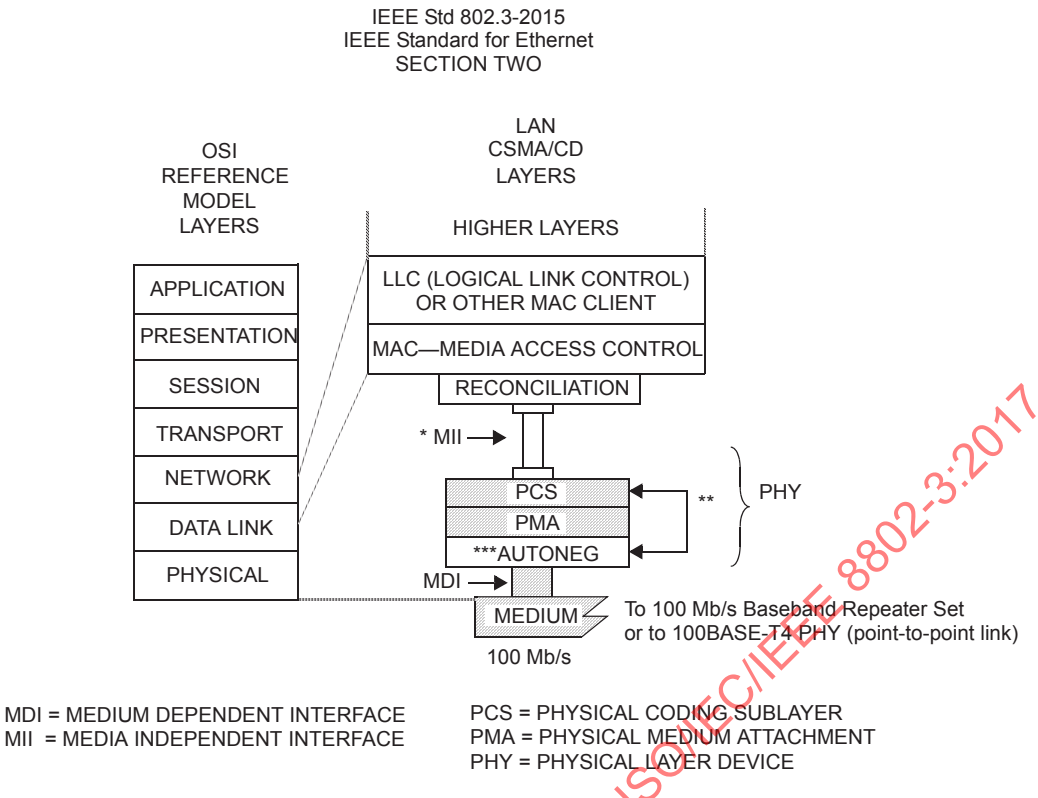

Figure 23–1—Type 100BASE-T4 PHY relationship to the ISO Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

23.1.4.1 Summary of Physical Coding Sublayer (PCS) specification

The 100BASE-T4 PCS couples a Media Independent Interface (MII), as described in Clause 22, to a Physical Medium Attachment sublayer (PMA).

The PCS Transmit function accepts data nibbles from the MII. The PCS Transmit function encodes these nibbles using an 8B6T coding scheme (to be described) and passes the resulting ternary symbols to the PMA. In the reverse direction, the PMA conveys received ternary symbols to the PCS Receive function. The PCS Receive function decodes them into octets, and then passes the octets one nibble at a time up to the MII. The PCS also contains a PCS Carrier Sense function, a PCS Error Sense function, a PCS Collision Presence function, and a management interface.

Figure 23–2 shows the division of responsibilities between the PCS, PMA, and MDI layers.

Physical level communication between PHY entities takes place over four twisted pairs. This specification permits the use of Category 3, 4, or 5 twisted pairs, installed according to ISO/IEC 11801: 1995, as specified in 23.6. Figure 23–3 shows how the PHY manages the four twisted pairs at its disposal.

The 100BASE-T4 transmission algorithm always leaves one pair open for detecting carrier from the far end (see Figure 23–3). Leaving one pair open for carrier detection in each direction greatly simplifies media access control. All collision detection functions are accomplished using only the unidirectional pairs TX_D1 and RX_D2, in a manner similar to 10BASE-T. This collision detection strategy leaves three pairs in each direction free for data transmission, which uses an 8B6T block code, schematically represented in Figure 23–4.

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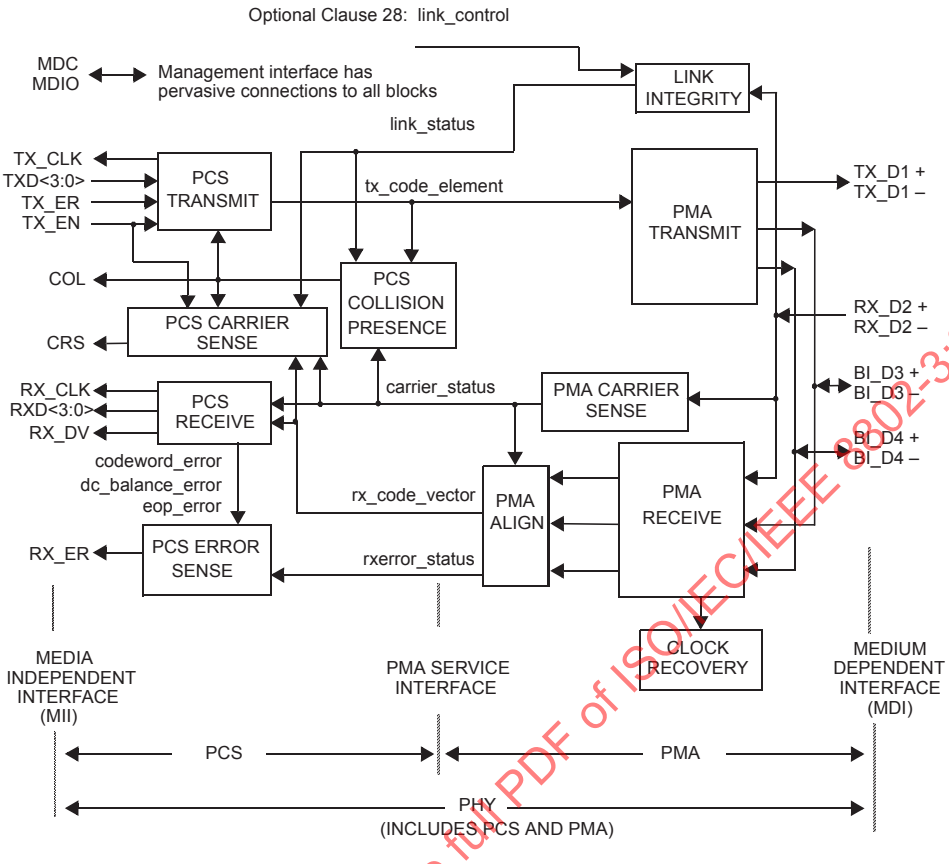

Figure 23–2—Division of responsibilities between 100BASE-T4 PCS and PMA

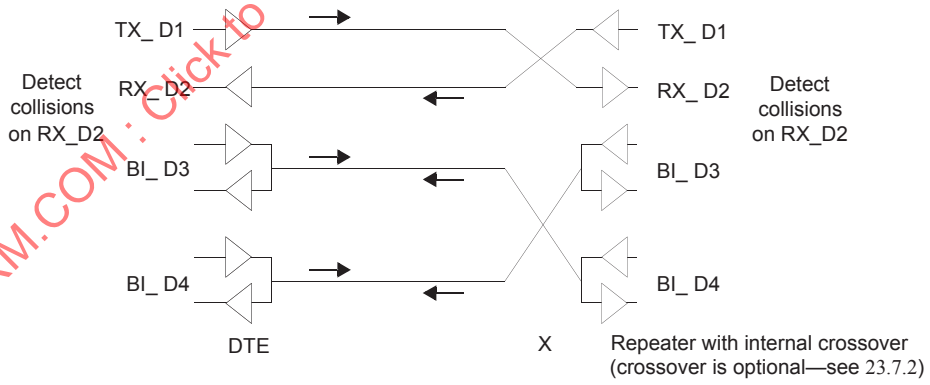

Figure 23–3—Use of wire pairs

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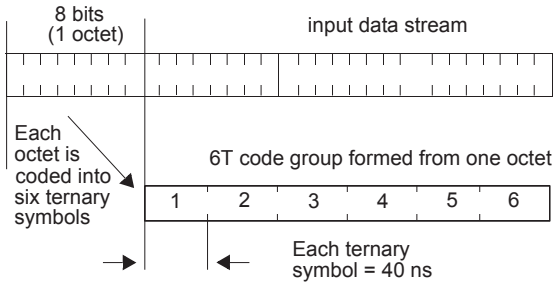

Figure 23–4—8B6T coding

8B6T coding, as used with 100BASE-T4 signaling, maps data octets into ternary symbols. Each octet is mapped to a pattern of 6 ternary symbols, called a 6T code group. The 6T code groups are fanned out to three independent serial channels. The effective data rate carried on each pair is one third of 100 Mb/s, which is 33.333... Mb/s. The ternary symbol transmission rate on each pair is 6/8 times 33.33 Mb/s, or precisely 25.000 MHz.

Refer to Annex 23A for a complete listing of 8B6T codewords.

The PCS functions and state diagrams are specified in 23.2. The PCS electrical interface to the MII conforms to the interface requirements of Clause 21. The PCS interface to the PMA is an abstract message-passing interface specified in 23.3.

23.1.4.2 Summary of physical medium attachment (PMA) specification

The PMA couples messages from the PMA service interface onto the twisted-pair physical medium. The PMA provides communications, at 100 Mb/s, over four pairs of twisted-pair wiring up to 100 m in length.

The PMA Transmit function, shown in Figure 23–2, comprises three independent ternary data transmitters. Upon receipt of a PMA_UNITDATA.request message, the PMA synthesizes one ternary symbol on each of the three output channels (TX_D1, BI_D3, and BI_D4). Each output driver has a *ternary* output, meaning that the output waveform can assume any of three values, corresponding to the transmission of ternary symbols CS0, CS1, or CS-1 (see 23.4.3.1) on each of the twisted pairs.

The PMA Receive function comprises three independent ternary data receivers. The receivers are responsible for acquiring clock, decoding the Start of Stream Delimiter (SSD) on each channel, and providing data to the PCS in the synchronous fashion defined by the PMA_UNITDATA.indication message. The PMA also contains functions for PMA Carrier Sense and Link Integrity.

PMA functions and state diagrams appear in 23.4. PMA electrical specifications appear in 23.5.

23.1.5 Application of 100BASE-T4

23.1.5.1 Compatibility considerations

All implementations of the twisted-pair link shall be compatible at the MDI. The PCS, PMA, and the medium are defined to provide compatibility among devices designed by different manufacturers. Designers are free to implement circuitry within the PCS and PMA (in an application-dependent manner) provided the MDI (and MII, when implemented) specifications are met.

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23.1.5.2 Incorporating the 100BASE-T4 PHY into a DTE

The PCS is required when used with a DTE. The PCS provides functions necessary to the overall system operation (such as 8B6T coding) and cannot be omitted. Refer to Figure 23–1.

When the PHY is incorporated within the physical bounds of a DTE, conformance to the MII interface is optional, provided that the observable behavior of the resulting system is identical to a system with a full MII implementation. For example, an integrated PHY may incorporate an interface between PCS and MAC that is logically equivalent to the MII, but does not have the full output current drive capability called for in the MII specification.

23.1.5.3 Use of 100BASE-T4 PHY for point-to-point communication

The 100BASE-T4 PHY, in conjunction with the MAC specified in Clause 1 through Clause 4 (including parameterized values in 4.2.2 to support 100 Mb/s operation), may be used at both ends of a link for point-to-point applications between two DTEs. Such a configuration does not require a repeater. In this case each PHY may connect through an MII to its respective DTE. Optionally, either PHY (or both PHYs) may be incorporated into the DTEs without an exposed MII.

23.1.5.4 Support for Auto-Negotiation

The PMA service interface contains primitives used by the Auto-Negotiation algorithm (Clause 28) to automatically select operating modes when connected to a like device.

23.2 PCS functional specifications

The 100BASE-T4 PCS couples a Media Independent Interface (MII), as described in Clause 22, to a 100BASE-T4 Physical Medium Attachment sublayer (PMA).

At its interface with the MII, the PCS communicates via the electrical signals defined in Clause 22.

The interface between PCS and the next lower level (PMA) is an abstract message-passing interface described in 23.3. The physical realization of this interface is left to the implementer, provided the requirements of this standard, where applicable, are met.

23.2.1 PCS functions

The PCS comprises one PCS Reset function and five simultaneous and asynchronous operating functions. The PCS operating functions are PCS Transmit, PCS Receive, PCS Error Sense, PCS Carrier Sense, and PCS Collision Presence. All operating functions start immediately after the successful completion of the PCS Reset function.

The PCS reference diagram, Figure 23–5, shows how the five operating functions relate to the messages of the PCS-PMA interface. Connections from the management interface (signals MDC and MDIO) to other layers are pervasive, and are not shown in Figure 23–5. The management functions are specified in Clause 30. See also Figure 23–6, which defines the structure of frames passed from PCS to PMA. See also Figure 23–7, which presents a reference model helpful for understanding the definitions of PCS Transmit function state variables ohr1-4 and tsr.

23.2.1.1 PCS Reset function

The PCS Reset function shall be executed any time either of two conditions occur. These two conditions are “power on” and the receipt of a reset request from the management entity. The PCS Reset function initializes

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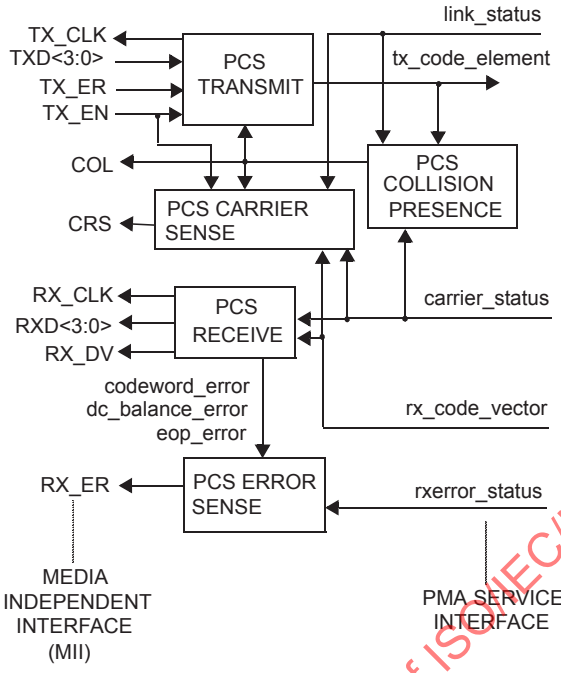

Figure 23–5—PCS reference diagram

all PCS functions. The PCS Reset function sets pcs_reset=ON for the duration of its reset function. All state diagrams take the open-ended pcs_reset branch upon execution of the PCS Reset function. The reference diagrams do not explicitly show the PCS Reset function.

23.2.1.2 PCS Transmit function

The PCS Transmit function shall conform to the PCS Transmit state diagram in Figure 23–8.

The PCS Transmit function receives nibbles from the TXD signals of the MII, assembles pairs of nibbles to form octets, converts the octets into 6T code groups according to the 8B6T code table, and passes the resulting ternary data to the PMA using the PMA_UNITDATA.request message. The state diagram of Figure 23–8 depicts the PCS Transmit function operation. Definitions of state variables tsr, ohr, sosa, sosb, eop1-5, and tx_extend used in that diagram, as well as in the following text, appear in 23.2.4.1. The physical structure represented in Figure 23–7 is not required; it merely serves to explain the meaning of the state diagram variables ohr and tsr in Figure 23–8. Implementers are free to construct any logical devices having functionality identical to that described by this functional description and the PCS Transmit state diagram, Figure 23–8.

PCS Transmit makes use of the tsr and ohr shift registers to manage nibble assembly and ternary symbol transmission. Nibbles from the MII go into tsr, which PCS Transmit reads as octets. PCS Transmit then encodes those octets and writes 6T code groups to the ohr registers. The PMA_UNITDATA.request message passes ternary symbols from the ohr registers to the PMA. In each state diagram block, the ohr loading operations are conducted first, then tx_code_vector is loaded and the state diagram waits 40 ns.

The first 5 octets assembled by the PCS Transmit function are encoded into the sosa codeword and the next 3 octets assembled are encoded into the sosb codeword. This guarantees that every packet begins with a valid preamble pattern. This is accomplished by the definition of tsr. In addition, the PCS Transmit state

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diagram also specifies that at the start of a packet all three output holding registers ohr1, ohr3 and ohr4 will be loaded with the same value (sosa). This produces the ternary symbols labeled P3 and P4 in Figure 23–6.

At the conclusion of the MAC frame, the PCS Transmit function appends eop1-5. This is accomplished by defining a variable tx_extend to stretch the TX_EN signal, and defining tsr during this time to be a sequence of constants that decodes to the proper eop code groups.

The encoding operation shall use the 8B6T code table listed in Annex 23A, and the dc balance encoding rules listed below. Encoding is performed separately for each transmit pair.

23.2.1.2.1 DC balance encoding rules

The encoding operation maintains dc balance on each transmit pair by keeping track of the cumulative weight of all 6T code groups (see *weight of 6T code group*, Annex 23A) transmitted on that pair. For each pair, it initiates the cumulative weight to 0 when the PCS Transmit function is in the AWAITING DATA TO TRANSMIT state. All 6T code groups in the code table have weight 0 or 1. The dc balance algorithm conditionally negates transmitted 6T code groups, so that the code weights transmitted on the line include 0, +1, and –1. This dc balance algorithm ensures that the cumulative weight on each pair at the conclusion of each 6T code group is always either 0 or 1, so only one bit per pair is needed to store the cumulative weight. As used below, the phrase “invert the cumulative weight bit” means “if the cumulative weight bit is zero then set it to one, otherwise set it to zero.”

After encoding any octet, except the constants sosa, sosb, eop1-5 or bad_code, update the cumulative weight bit for the affected pair according to rules a) through c):

a) If the 6T code group weight is 0, do not change the cumulative weight.
b) If the 6T code group weight is 1, and the cumulative weight bit is 0, set the cumulative weight bit to 1.
c) If the 6T code group weight is 1, and the cumulative weight bit is also 1, set the cumulative weight bit to 0, and then algebraically negate all the ternary symbol values in the 6T code group.

After encoding any of the constants sosa, sosb, or bad_code, update the cumulative weight bit for the affected pair according to rule d):

d) Do not change the cumulative weight. Never negate sosa, sosb or bad_code.

After encoding any of the constants eop1-5, update the cumulative weight bit for the affected pair according to rules e) and f):

e) If the cumulative weight is 0, do not change the cumulative weight; algebraically negate all the ternary symbol values in eop1-5.
f) If the cumulative weight is 1, do not change the cumulative weight.

NOTE—The inversion rules for eop1-5 are opposite rule b). That makes eop1-5 look very unlike normal data, increasing the number of errors required to synthesize a false end-of-packet marker.

23.2.1.3 PCS Receive function

The PCS Receive function shall conform to the PCS Receive state diagram in Figure 23–9.

The PCS Receive function accepts ternary symbols from the PMA, communicated via the PMA_UNITDATA.indication message, converts them using 8B6T coding into a nibble-wide format and passes them up to the MII. This function also generates RX_DV. The state diagram of Figure 23–9 depicts the PCS Receive function. Definitions of state variables ih2, ih3, and ih4 used in that diagram, as well as in the following text, appear in 23.2.4.1.

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The last 6 values of the rx_code_vector are available to the decoder. PCS Receive makes use of these stored rx_code_vector values as well as the ih2-4 registers to manage the assembly of ternary symbols into 6T code groups, and the conversion of decoded data octets into nibbles. The last 6 ternary symbols for pair BI_D3 (as extracted from the last 6 values of rx_code_vector) are referred to in the state diagram as BI_D3[0:5]. Other pairs are referenced accordingly.

The PCS Receive state diagram starts the first time the PCS receives a PMA_UNITDATA.indication message with rx_code_vector=DATA (as opposed to IDLE or PREAMBLE). The contents of this first PMA_UNITDATA.indication (DATA) message are specified in 23.4.1.6.

After the sixth PMA_UNITDATA.indication (DATA) message (state DECODE CHANNEL 3), there is enough information to decode the first data octet. The decoded data is transmitted across the MII in two parts, a least significant nibble followed by a most significant nibble (see Clause 22).

During state COLLECT 4TH TERNARY SYMBOL the PCS Receive function raises RX_DV and begins shifting out the nibbles of the 802.3 MAC SFD, least significant nibble first (SFD:LO). The most significant nibble of the 802.3 MAC SFD, called SFD:HI, is sent across the MII during the next state, COLLECT 5TH TERNARY SYMBOL.

Once eop is signaled by the decode operation, the state diagram deasserts RX_DV, preventing the end-of-packet bits from reaching the MII. At any time that RX_DV is deasserted, RXD<3:0> shall be all zeros.

The decode operation shall use the 8B6T code table listed in Annex 23A, and the error-detecting rules listed in 23.2.1.3.1. Decoding and maintenance of the cumulative weight bit is performed separately for each receive pair.

23.2.1.3.1 Error-detecting rules

The decoding operation checks the dc balance on each receive pair by keeping track of the cumulative weight of all 6T code group received on that pair. For each pair, initialize the cumulative weight to 0 when the PCS Receive function is in the AWAITING INPUT state. As in the encoding operation, only one bit per pair is needed to store the cumulative weight.

Before decoding each octet, check the weight of the incoming code group and then apply rules a) through h) in sequence:

a) If the received code group is eop1 (or its negation), set eop=ON. Then check the other pairs for conformance to the end-of-packet rules as follows: Check the last four ternary symbols of the next pair, and the last two ternary symbols from the third pair for exact conformance with the end-of-packet pattern specified by PCS Transmit, including the cumulative weight negation rules. If the received data does not conform, set the internal variable eop_error=ON. Skip the other rules.
b) If the received code group weight is greater than 1 or less than –1, set the internal variable dc_balance_error=ON. Decode to all zeros. Do not change the cumulative weight.
c) If the received code group weight is zero, use the code table to decode. Do not change the cumulative weight.
d) If the received code group weight is +1, and the cumulative weight bit is 0, use the code table to decode. Invert the cumulative weight bit.
e) If the received code group weight is –1, and the cumulative weight bit is 1, algebraically negate each ternary symbol in the code group and then use the code table to decode. Invert the cumulative weight bit.
f) If the received code group weight is +1 and the cumulative weight bit is 1, set the internal variable dc_balance_error=ON. Decode to all zeros. Do not change the cumulative weight.
g) If the received code group weight is –1 and the cumulative weight bit is 0, set the internal variable dc_balance_error=ON. Decode to all zeros. Do not change the cumulative weight.

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h) If the (possibly negated) code group is not found in the code table, set codeword_error =ON. Decode to all zeros. Do not change the cumulative weight.

The variables dc_balance_error, eop_error and codeword_error shall remain OFF at all times other than those specified in the above error-detecting rules.

The codeword_error=ON indication for a (possibly negated) code group not found in the code table shall set RX_ER during the transfer of both affected data nibbles across the MII.

The dc_balance_error=ON indication for a code group shall set RX_ER during the transfer of both affected data nibbles across the MII.

The eop_error=ON indication shall set RX_ER during the transfer of the last decoded data nibble of the previous octet across the MII. That is at least one RX_CLK period earlier than the requirement for codeword_error and dc_balance_error.

These timing requirements imply consideration of implementation delays not specified in the PCS Receive state diagram.

RX_DV is asserted coincident with the transmission across the MII of valid packet data, including the Clause 4 MAC SFD, but not including the 100BASE-T4 end-of-packet delimiters eop1-5. When a packet is truncated due to early deassertion of carrier_status, an RX_ER indication shall be generated and RX_DV shall be deasserted, halting receive processing. The PCS Receive Function may use any of the existing signals codeword_error, dc_balance_error, or eop_error to accomplish this function.

23.2.1.4 PCS Error Sense function

The PCS Error Sense function performs the task of sending RX_ER to the MII whenever rxerror_status=ERROR is received from the PMA sublayer or when any of the PCS decoding error conditions occur. The PCS Error Sense function shall conform to the PCS Error Sense state diagram in Figure 23–10.

Upon detection of any error, the error sense process shall report RX_ER to the MII before the last nibble of the Clause 4 MAC frame has been passed across the MII. Errors attributable to a particular octet are reported to the MII coincident with the octet in which they occurred.

The timing of rxerror_status shall cause RX_ER to appear on the MII no later than the last nibble of the first data octet in the frame.

23.2.1.5 PCS Carrier Sense function

The PCS Carrier Sense function shall perform the function of controlling the MII signal CRS according to the rules presented in this clause.

While link_status = OK, CRS is asserted whenever rx_crs=ON or TX_EN=1, with timing as specified in 23.11.2, and Table 23-6.

23.2.1.6 PCS Collision Presence function

A PCS collision is defined as the simultaneous occurrence of tx_code_vector≠IDLE and the assertion of carrier_status=ON while link_status=OK. While a PCS collision is detected, the MII signal COL shall be asserted, with timing as specified in 23.11.2 and Table 23–7.

At other times COL shall remain deasserted.

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23.2.2 PCS interfaces

23.2.2.1 PCS–MII interface signals

The following signals are formally defined in 22.2.2. Jabber detection as specified in 22.2.4.2.14 is not required by this standard.

Table 23–1—MII interface signals

Signal name	Meaning
TX_CLK	Transmit Clock
TXD<3:0>	Transmit Data
TX_ER	Forces transmission of illegal code
TX_EN	Frames Transmit Data
COL	Collision Indication
CRS	Non-Idle Medium Indication
RX_CLK	Receive Clock
RXD<3:0>	Receive Data
RX_DV	Frames Receive SFD and DATA
RX_ER	Receive Error Indication
MDC	Management Data Clock
MDIO	Management Data

23.2.2.2 PCS–Management entity signals

The management interface has pervasive connections to all functions. Operation of the management control lines MDC and MDIO, and requirements for managed objects inside the PCS and PMA, are specified in Clause 22 and Clause 30, respectively.

The loopback mode of operation shall be implemented in accordance with 22.2.4.1.2. The loopback mode of operation loops back transmit data to receive data, thus providing a way to check for the presence of a PHY.

No spurious signals shall be emitted onto the MDI when the PHY is held in power-down mode as defined in 22.2.4.1.5 (even if TX_EN is ON) or when released from power-down mode, or when external power is first applied to the PHY.

23.2.3 Frame structure

Frames passed from the PCS sublayer to the PMA sublayer shall have the structure shown in Figure 23–6. This figure shows how ternary symbols on the various pairs are synchronized as they are passed by the PMA_UNITDATA.indication and PMA_UNITDATA.request messages. Time proceeds from left to right in the figure.

In the frame structure example, the last 6T code group, DATA N, happens to appear on transmit pair BI_D3. It could have appeared on any of the three transmit pairs, with the five words eop1 through eop5 appended afterward as the next five octets in sequence. The end of packet as recognized by the PCS is defined as the end of the last ternary symbol of eop1. At this point a receiver has gathered enough information to locate the last word in the packet and check the dc balance on each pair.

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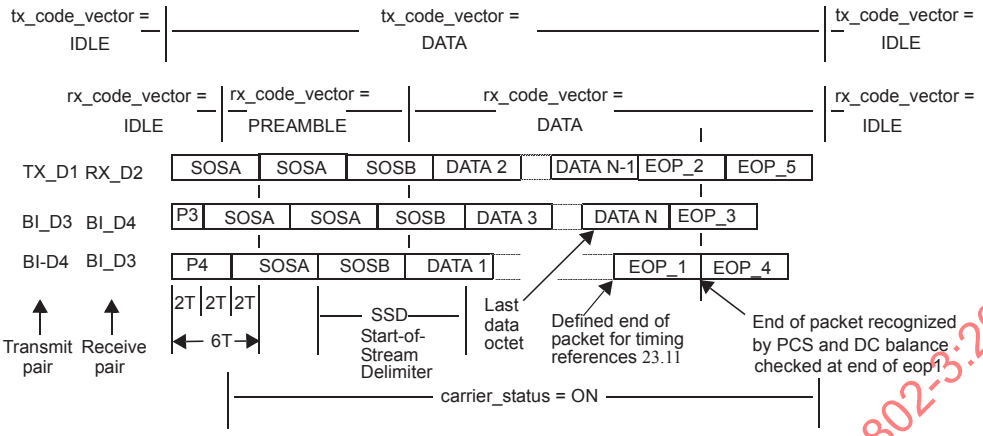

Figure 23–6—PCS sublayer to PMA sublayer frame structure

If the PMA service interface is exposed, data carried between PCS and PMA by the PMA_UNITDATA.indication and PMA_UNITDATA.request messages shall have a clock in each direction. Details of the clock implementation are left to the implementer. The choice of binary encoding for each ternary symbol is left to the implementer.

The following frame elements appear in Figure 23–6 (ternary symbols are transmitted leftmost first):

SOSA	The succession of six ternary symbols: `[ 1 -1 1 -1 1 -1]`, which is the result of encoding the constant sosa.
SOSB	The succession of six ternary symbols: `[ 1 -1 1 -1 -1 1]`, which is the result of encoding the constant sosb.
P3	The succession of two ternary symbols: `[ 1 -1]`.
P4	The succession of four ternary symbols: `[ 1 -1 1 -1]`.
DATA	A 6T code group that is the result of encoding a data octet in a packet that is not part of the Clause 4 MAC preamble or SFD.
EOP1-5	A 6T code group that is the result of encoding one of the end-of-packet patterns eop1-5.

23.2.4 PCS state diagrams

The notation used in the state diagrams follows the conventions of 21.5. Transitions shown without source states are evaluated continuously and take immediate precedence over all other conditions.

23.2.4.1 PCS state diagram constants

Register tsr may take on any of the nine constant values listed below (sosa through eop5, bad_code, and zero_code). These values are used to describe the functional operation of the coding process.

NOTE—Implementers are under no obligation to implement these constants in any particular way. For example, some implementers may choose to implement these codes as special flag bits attached to MII TXD nibble registers. Other implementers may choose to implement insertion of these codes on the downstream side of the coder function, using precoded 6T sequences.

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All 6T codewords are sent leftmost ternary symbol first.

sosa	A constant that encodes to:	[1 -1 1 -1 1 -1].
sosb	A constant that encodes to:	[1 -1 1 -1 -1 1].
eop1	A constant that encodes to:	[1 1 1 1 1 1].
eop2	A constant that encodes to:	[1 1 1 1 -1 -1].
eop3	A constant that encodes to:	[1 1 -1 -1 0 0].
eop4	A constant that encodes to:	[-1 -1 -1 -1 -1 -1].
eop5	A constant that encodes to:	[-1 -1 0 0 0 0].
bad_code	A constant that encodes to:	[-1 -1 -1 1 1 1].
zero_code	A constant that encodes to:	[0 0 0 0 0 0].

23.2.4.2 PCS state diagram variables

codeword_error

Indicates reception of invalid 6T code group.

Values: ON and OFF

Set by: PCS Receive; error-detecting rules

dc_balance_error

Indicates reception of dc coding violation.

Values: ON and OFF

Set by: PCS Receive; error-detecting rules

eop

Indicates reception of eop1.

A state variable set by the decoding operation. Reset to OFF when in PCS Receive state AWAITING INPUT. When the decoder detects eop1 on any pair, it sets this flag ON. The timing of eop shall be adjusted such that the last nibble of the last decoded data octet in a packet is the last nibble sent across the MII by the PMA Receive state diagram with RX_DV set ON.

Values: ON and OFF

Set by: PCS Receive; error-detecting rules

eop_error

Indicates reception of data with improper end-of-packet coding.

Values: ON and OFF

Set by: PCS Receive; error-detecting rules

ih2, ih4, and ih3 (input holding registers)

A set of holding registers used for the purpose of holding decoded data octets in preparation for sending across the MII one nibble at a time. One register is provided for each of the three receive pairs RX_D2, BI_D4, and BI_D3, respectively.

Value: octet

Set by: PCS Receive

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Each time the PCS Receive function decodes a 6T code group, it loads the result (an octet) into one of the ih2-4 registers. These three registers are loaded in round-robin fashion, one register being loaded every two ternary symbol times.

The PCS Receive state diagram reads nibbles as needed from the ih2-4 registers and stuffs them into RXD.

ohr1, ohr3, and ohr4 (output holding registers)

(See Figure 23–7.) A set of shift registers used for the purpose of transferring coded 6T ternary symbol groups one ternary symbol at a time into the PMA. One register is provided for each of the three transmit pairs TX_D1, BI_D3, and BI_D4, respectively.

Value: 6T code group. Each of the six cells holds one ternary symbol (i.e., –1, 0, or 1).

Set by: PCS Transmit

Each time the PCS Transmit function encodes a data octet, it loads the result (a 6T code group) into one of the ohr registers. Three registers are loaded in round-robin fashion, one register being loaded every two ternary symbol times. The PCS shall transmit octets on the three transmit pairs in round-robin fashion, in the order TX_D1, BI_D3, and BI_D4, starting with TX_D1.

The PMA_UNITDATA.request (DATA) message picks the least significant (rightmost) ternary symbol from each ohr register and sends it to the PMA, as shown below. (Note that 6T codewords in Annex 23A are listed with lsb on the left, not the right.)

tx_code_vector[TX_D1] = the LSB of ohr1, also called ohr1[0]

tx_code_vector[BI_D3] = the LSB of ohr3, also called ohr3[0]

tx_code_vector[BI_D4] = the LSB of ohr4, also called ohr4[0]

After each PMA_UNITDATA.request message, all three ohr registers shift right by one ternary symbol, shifting in zero from the left. The PCS Transmit function loads a new 6T code group into each ohr immediately after the last ternary symbol of the previous group is shifted out.

At the beginning of a preamble, the PCS Transmit function loads the same value (sosa) into all three output holding registers, which causes alternating transitions to immediately appear on all three output pairs. The result on pairs BI_D3 and BI_D4 is depicted by codewords P3 and P4 in Figure 23–6.

pcs_reset

Causes reset of all PCS functions when ON.

Values: ON and OFF

Set by: PCS Reset

rx_crs

A latched asynchronous variable. Timing for the MII signal CRS is derived from rx_crs.

Values: ON and OFF

Set ON when: carrier_status changes to ON

Set OFF when either of two events occurs:

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carrier_status changes to OFF, or
detection of eop1, properly framed, on any of the lines RX_D2, BI_D4, or BI_D3

Additionally, if, 20 ternary symbol times after rx_crs falls, carrier_status remains set to ON then set rx_crs=ON.

NOTE—A special circuit for the detection of eop1 and subsequent deassertion of rx_crs, faster than the full 8B6T decoding circuits, is generally required to meet the timing requirements for CRS listed in 23.11.

tsr (transmit shift register)

(See Figure 23–7.) A shift register defined for the purpose of assembling nibbles from the MII TXD into octets.

Values: The variable tsr always contains both the current nibble of TXD and the previous nibble of TXD. Valid values for tsr therefore include all octets. Register tsr may also take on any of the nine constant values listed in 23.2.4.1.

Nibble order: When encoding the tsr octet, the previous TXD nibble is considered the least significant nibble.

Set by: PCS Transmit

During the first 16 TX_CLK cycles after TX_EN is asserted, tsr shall assume the following values in sequence regardless of TXD: sosa, sosa, sosa, sosa, sosa, sosa, sosa, sosa, sosa, sosa, sosb, sosb, sosb, sosb, sosb, sosb. This action substitutes the 100BASE-T4 preamble for the Clause 4 MAC preamble. The PCS Transmit state diagram samples the tsr only every other clock, which reduces the number of sosa and sosb constants actually coded to 5 and 3, respectively.

During the first 10 TX_CLK cycles after TX_EN is deasserted, tsr shall assume the following values in sequence, regardless of TXD: eop1, eop1, eop2, eop2, eop3, eop3, eop4, eop4, eop5, eop5. This action appends the 100BASE-T4 end-of-packet delimiter to each pair. The PCS Transmit state diagram samples the tsr only every other clock, which reduces the number of eop1-5 constants actually coded to 1 each.

Except for the first 16 TX_CLK cycles after TX_EN is asserted, any time TX_ER and TX_EN are asserted, tsr shall assume the value bad_code with such timing as to cause both nibbles of the affected octet to be encoded as bad_code. If TX_ER is asserted at any time during the first 16 TX_CLK cycles after TX_EN is asserted, tsr shall during the 17th and 18th clock cycles assume the value bad_code.

If TX_EN is deasserted on an odd nibble boundary, the PCS shall extend TX_EN by one TX_CLK cycle, and behave as if TX_ER were asserted during that additional cycle.

Except for the first 10 TX_CLK cycles after TX_EN is deasserted, any time TX_EN is not asserted, tsr shall assume the value zero_code.

tx_extend

A latched, asynchronous state variable used to extend the TX_EN signal long enough to ensure complete transmission of all nonzero ternary symbols in eop1-5.

Values: ON and OFF

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Set ON upon: rising edge of TX_EN

Set OFF upon: either of two conditions:
a) In the event of a collision (COL is asserted at any time during transmission) set tx_extend=OFF when TX_EN deasserts.
b) In the event of no collision (COL remains deasserted throughout transmission) set tx_extend=OFF upon completion of transmission of last ternary symbol in eop4.

NOTE 1—The 6T code group eop5 has four zeros at the end. The 6T code group eop4 contains the last non-zero ternary symbol to be transmitted.

NOTE 2—The effect of a collision, if present, is to truncate the frame at the original boundary determined by TX_EN. Noncolliding frames are extended, while colliding frames are not.

23.2.4.3 PCS state diagram timer

tw1_timer

A continuous free-running timer.

Values: The condition tw1_timer_done goes true when the timer expires.

Restart when: Immediately after expiration (restarting the timer resets condition tw1_timer_done).

Duration: 40 ns nominal.

TX_CLK shall be generated synchronous to tw1_timer (see tolerance required for TX_CLK in 23.5.1.2.10).

On every occurrence of tw1_timer_done, the state diagram advances by one block. The message PMA_UNITDATA.request is issued concurrent with tw1_timer_done.

23.2.4.4 PCS state diagram functions

encode()

The encode operation of 23.2.1.2.

Argument: octet

Returns: 6T code group

decode()

The decode operation of 23.2.1.3.

Argument: 6T code group

Returns: octet

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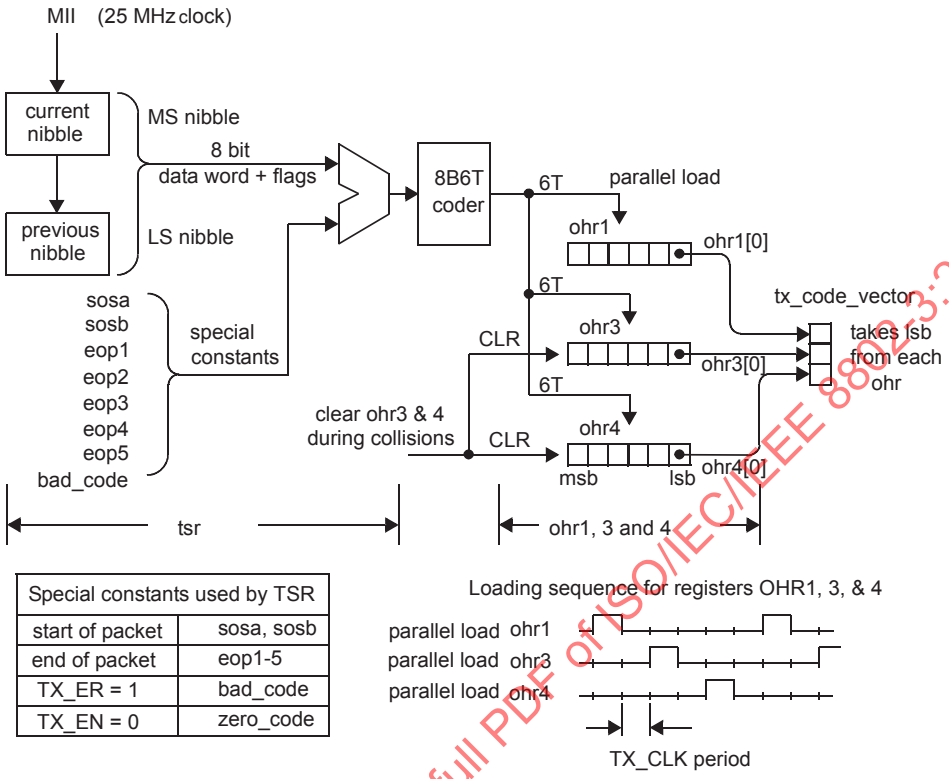

Special constants used by TSR	
start of packet	sosa, sosb
end of packet	eop1-5
TX_ER = 1	bad_code
TX_EN = 0	zero_code

Figure 23–7—PCS Transmit reference diagram

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23.2.4.5 PCS state diagrams

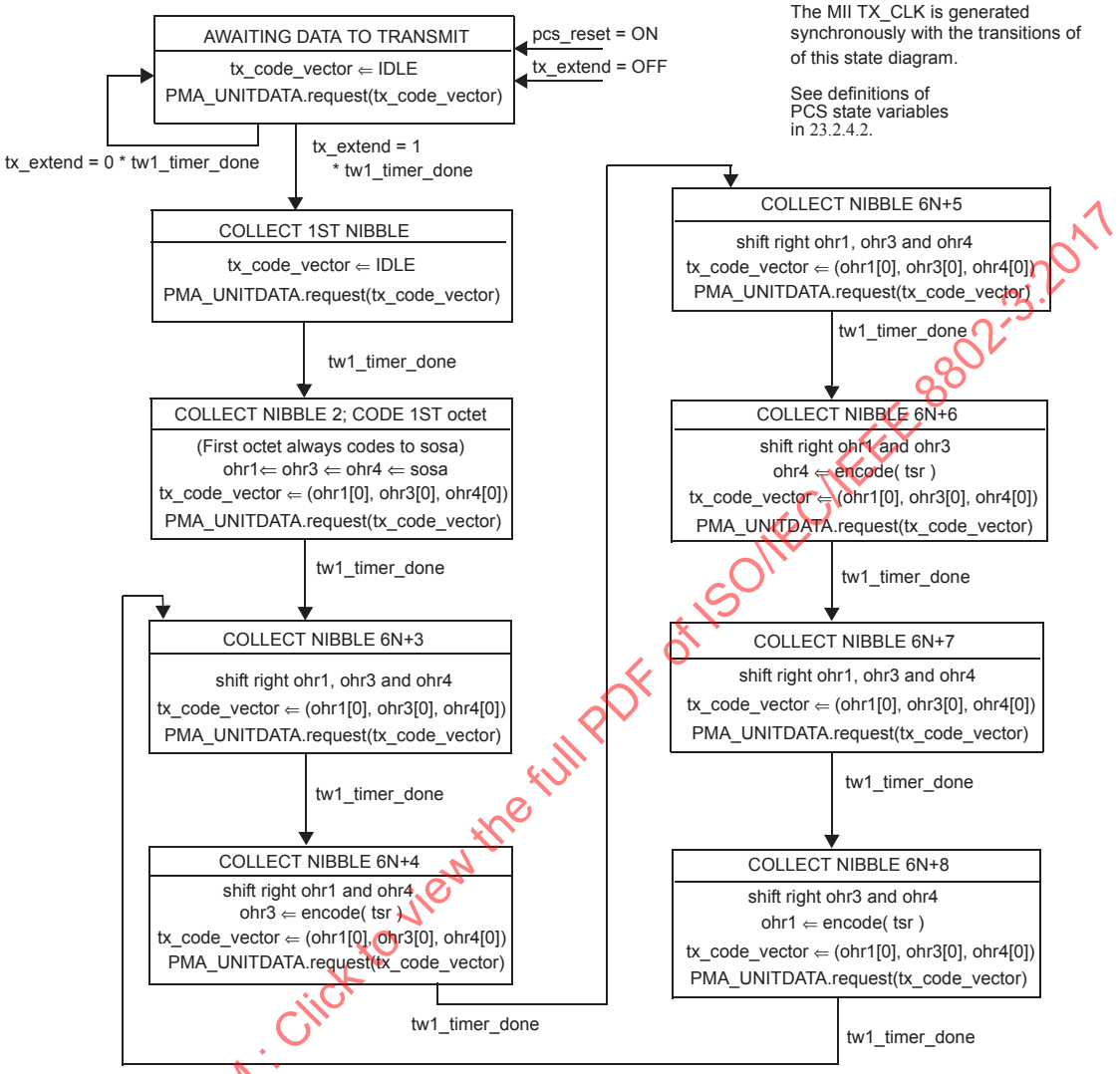

Figure 23–8—PCS Transmit state diagram

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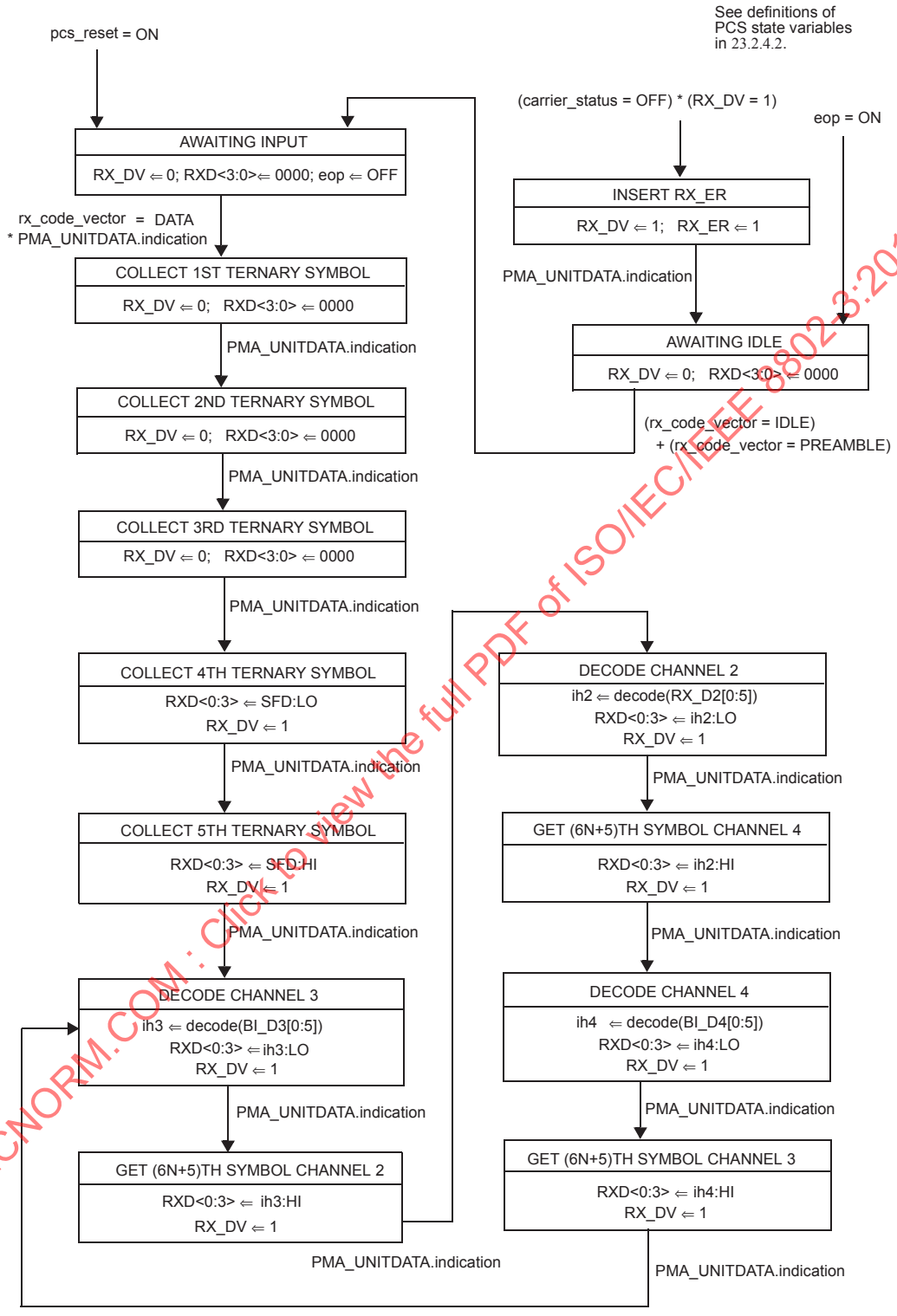

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Figure 23–9—PCS Receive state diagram

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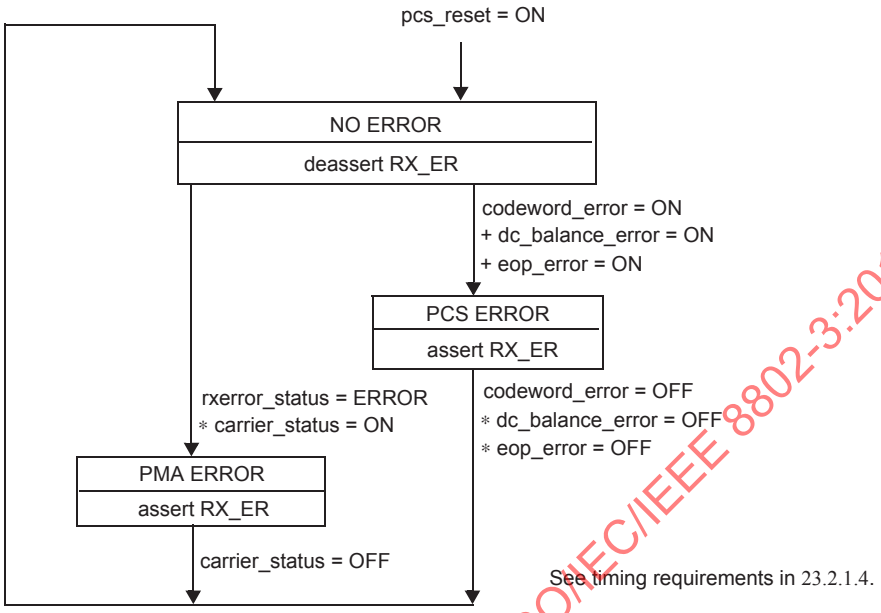

Figure 23–10—PCS Error Sense state diagram

23.2.5 PCS electrical specifications

The interface between PCS and PMA is an abstract message-passing interface, having no specified electrical properties.

Electrical characteristics of the signals passing between the PCS and MII may be found in Clause 22.

23.3 PMA service interface

This clause specifies the services provided by the PMA to either the PCS or a Repeater client. These services are described in an abstract manner and do not imply any particular implementation.

The PMA Service Interface supports the exchange of code vectors between the PMA and its client (either the PCS or a Repeater). The PMA also generates status indications for use by the client.

The following primitives are defined:

PMA_TYPE.indication
PMA_UNITDATA.request
PMA_UNITDATA.indication
PMA_CARRIER.indication
PMA_LINK.indication
PMA_LINK.request
PMA_RXERROR.indication

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23.3.1 PMA_TYPE.indication

This primitive is generated by the PMA to indicate the nature of the PMA instantiation. The purpose of this primitive is to allow clients to support connections to the various types of 100BASE-T PMA entities in a generalized manner.

23.3.1.1 Semantics of the service primitive

PMA_TYPE.indication (pma_type)

The pma_type parameter for use with the 100BASE-T4 PMA is T4.

23.3.1.2 When generated

The PMA shall continuously generate this primitive to indicate the value of pma_type.

23.3.1.3 Effect of receipt

The client uses the value of pma_type to define the semantics of the PMA_UNITDATA.request and PMA_UNITDATA.indication primitives.

23.3.2 PMA_UNITDATA.request

This primitive defines the transfer of data (in the form of tx_code_vector parameters) from the PCS or repeater to the PMA.

23.3.2.1 Semantics of the service primitive

PMA_UNITDATA.request (tx_code_vector)

When transmitting data using 100BASE-T4 signaling, the PMA_UNITDATA.request conveys to the PMA simultaneously the logical output value for each of the three transmit pairs TX_D1, BI_D3, and BI_D4. The value of tx_code_vector during data transmission is therefore a three-element vector, with one element corresponding to each output pair. Each of the three elements of the tx_code_vector may take on one of three logical values: 1, 0, or –1, corresponding to the three ternary possibilities +, 0, and - listed for each ternary symbol in the 8B6T code table (see Annex 23A).

Between packets, the 100BASE-T4 PMA layer sends the 100BASE-T4 idle signal, TP_IDL_100. The PCS informs the PMA layer that it is between packets, thus enabling the PMA idle signal, by setting the tx_code_vector parameter to IDLE.

For pma_type 100BASE-T4, the tx_code_vector parameter can take on either of two forms:

IDLE	A single value indicating to the PMA that there is no data to convey. The PMA generates link integrity pulses during the time that tx_code_vector = IDLE.
DATA	A vector of three ternary symbols, one for each of the three transmit pairs TX_D1, BI_D3, and BI_D4. The ternary symbol for each pair may take on one of three values, 1, 0, or –1.

The ternary symbols comprising tx_code_vector, when they are conveyed using the DATA format, are called, according to the pair on which each will be transmitted, tx_code_vector[BI_D4], tx_code_vector[TX_D1], and tx_code_vector[BI_D3].

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23.3.2.2 When generated

The PCS or Repeater client generates PMA_UNITDATA.request synchronous with every MII TX_CLK.

For the purposes of state diagram descriptions, it may be assumed that at the time PMA_UNITDATA.request is generated, the MII signals TX_EN, and TX_ER, and TXD instantly become valid and that they retain their values until the next PMA_UNITDATA.request.

In the state diagrams, PMA_UNITDATA.request is assumed to occur at the conclusion of each tw1 wait function.

23.3.2.3 Effect of receipt

Upon receipt of this primitive, the PMA transmits the indicated ternary symbols on the MDI.

23.3.3 PMA_UNITDATA.indication

This primitive defines the transfer of data (in the form of rx_code_vector parameters) from the PMA to the PCS or repeater during the time that link_status=OK.

23.3.3.1 Semantics of the service primitive

PMA_UNITDATA.indication (rx_code_vector)

When receiving data using 100BASE-T4 signaling, the PMA_UNITDATA.indication conveys to the PCS simultaneously the logical input value for each of the three receive pairs RX_D2, BI_D4, and BI_D3. The value of rx_code_vector during data reception is therefore a three-element vector, with one element corresponding to each input pair. Each of the three elements of the rx_code_vector may take on one of three logical values: 1, 0, or –1, corresponding to the three ternary possibilities +, 0, and – listed for each ternary symbol in the 8B6T code table (see Annex 23A).

Between packets, the rx_code_vector is set by the PMA to the value IDLE.

From the time the PMA asserts carrier_status=ON until the PMA recognizes the SSD pattern (not all of the pattern need be received in order for the PMA to recognize the pattern), the PMA sets rx_code_vector to the value PREAMBLE.

For pma_type 100BASE-T4, the rx_code_vector parameter can take on any of three forms:

IDLE	A single value indicating that the PMA has no data to convey.
PREAMBLE	A single value indicating that the PMA has detected carrier, but has not received a valid SSD.
DATA	A vector of three ternary symbols, one for each of the three receive pairs RX_D2, BI_D3, and BI_D4. The ternary symbol for each pair may take on one of three values, 1, 0, or –1.

The ternary symbols comprising rx_code_vector, when they are conveyed using the DATA format, are called, according to the pair upon which each symbol was received, rx_code_vector[BI_D3], rx_code_vector[RX_D2], and rx_code_vector[BI_D4].

23.3.3.2 When generated

The PMA shall generate PMA_UNITDATA.indication (DATA) messages synchronous with data received at the MDI.

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23.3.3.3 Effect of receipt

The effect of receipt of this primitive is unspecified.

23.3.4 PMA_CARRIER.indication

This primitive is generated by the PMA to indicate the status of the signal being received from the MDI. The purpose of this primitive is to give the PCS or repeater client the earliest reliable indication of activity on the underlying medium.

23.3.4.1 Semantics of the service primitive

PMA_CARRIER.indication (carrier_status)

The carrier_status parameter can take on one of two values: OFF or ON, indicating whether the incoming signal should be interpreted as being between packets (OFF) or as a packet in progress (ON).

23.3.4.2 When generated

The PMA shall generate this primitive to indicate the value of carrier_status.

23.3.4.3 Effect of receipt

The effect of receipt of this primitive is unspecified.

23.3.5 PMA_LINK.indication

This primitive is generated by the PMA to indicate the status of the underlying medium. The purpose of this primitive is to give the PCS or repeater client or Auto-Negotiation algorithm a means of determining the validity of received code elements.

23.3.5.1 Semantics of the service primitive

PMA_LINK.indication (link_status)

The link_status parameter can take on one of three values: FAIL, READY, or OK:

FAIL	The link integrity function does not detect a valid 100BASE-T4 link.
READY	The link integrity function detects a valid 100BASE-T4 link, but has not been enabled by Auto-Negotiation.
OK	The 100BASE-T4 link integrity function detects a valid 100BASE-T4 link, and has been enabled by Auto-Negotiation.

23.3.5.2 When generated

The PMA shall generate this primitive to indicate the value of link_status.

23.3.5.3 Effect of receipt

The effect of receipt of this primitive is unspecified.

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23.3.6 PMA_LINK.request

This primitive is generated by the Auto-Negotiation algorithm. The purpose of this primitive is to allow the Auto-Negotiation algorithm to enable and disable operation of the PHY.

23.3.6.1 Semantics of the service primitive

PMA_LINK.request (link_control)

The link_control parameter can take on one of three values: SCAN_FOR_CARRIER, DISABLE, or ENABLE.

SCAN_FOR_CARRIER	Used by the Auto-Negotiation algorithm prior to receiving any fast link pulses. During this mode the PHY reports link_status=READY if it recognizes 100BASE-T4 carrier from the far end, but no other actions are enabled.
DISABLE	Used by the Auto-Negotiation algorithm to disable PHY processing in the event fast link pulses are detected. This gives the Auto-Negotiation algorithm a chance to determine how to configure the link.
ENABLE	Used by Auto-Negotiation to turn control over to the PHY for data processing functions. This is the default mode if Auto-Negotiation is not present.

23.3.6.2 Default value of parameter link_control

Upon power-on, reset, or release from power-down, the link_control parameter shall revert to ENABLE. If the optional Auto-Negotiation algorithm is not implemented, no PMA_LINK.request message will arrive and the PHY will operate indefinitely with link_control=ENABLE.

23.3.6.3 When generated

The Auto-Negotiation algorithm generates this primitive to indicate to the PHY how to behave.

Upon power-on, reset, or release from power down, the Auto-Negotiation algorithm, if present, issues the message PMA_LINK.request (SCAN_FOR_CARRIER).

23.3.6.4 Effect of receipt

Whenever link_control=SCAN_FOR_CARRIER, the PHY shall enable the Link Integrity state diagram, but block passage into the state LINK_PASS, while holding rcv=DISABLE, and xmit=DISABLE. While link_control=SCAN_FOR_CARRIER, the PHY shall report link_status=READY if it recognizes 100BASE-T4 link integrity pulses coming from the far end, otherwise it reports link_status=FAIL.

Whenever link_control=DISABLE, the PHY shall report link_status=FAIL and hold the Link Integrity state diagram in the RESET state, while holding rcv=disable and xmit=DISABLE.

While link_control=ENABLE, the PHY shall allow the Link Integrity function to determine if the link is available and, if so, set rcv=ENABLE and xmit=ENABLE.

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23.3.7 PMA_RXERROR.indication

The primitive is generated in the PMA by the PMA Align function to indicate the status of the signal being received from the MDI. The purpose of this primitive is to give the PCS or repeater client an indication of a PMA detectable receive error.

23.3.7.1 Semantics of the service primitive

PMA_RXERROR.indication (rxerror_status)

The rxerror_status parameter can take on one of two values: ERROR or NO_ERROR, indicating whether the incoming signal contains a detectable error (ERROR) or not (NO_ERROR).

23.3.7.2 When generated

The PMA shall generate this primitive to indicate whether or not each incoming packet contains a PMA detectable error (23.2.1.4).

23.3.7.3 Effect of receipt

The effect of receipt of this primitive is unspecified.

23.4 PMA functional specifications

The PMA couples messages from a PMA service interface (23.3) to the 100BASE-T4 baseband medium (23.6).

The interface between PCS and the baseband medium is the Medium Dependent Interface (MDI), specified in 23.7.

23.4.1 PMA functions

The PMA sublayer comprises one PMA Reset function and six simultaneous and asynchronous operating functions. The PMA operating functions are PMA Transmit, PMA Receive, PMA Carrier Sense, Link Integrity, PMA Align, and Clock Recovery. All operating functions are started immediately after the successful completion of the PMA Reset function. When the PMA is used in conjunction with a PCS, the RESET function may be shared between layers.

The PMA reference diagram, Figure 23–11, shows how the operating functions relate to the messages of the PMA Service interface and the signals of the MDI. Connections from the management interface, comprising the signals MDC and MDIO, to other layers are pervasive, and are not shown in Figure 23–11. The Management Interface and its functions are specified in Clause 22.

23.4.1.1 PMA Reset function

The PMA Reset function shall be executed any time either of two conditions occur. These two conditions are power-on and the receipt of a reset request from the management entity. The PMA Reset function initializes all PMA functions. The PMA Reset function sets pma_reset=ON for the duration of its reset function. All state diagrams take the open-ended pma_reset branch upon execution of the PMA Reset function. The reference diagrams do not explicitly show the PMA Reset function.

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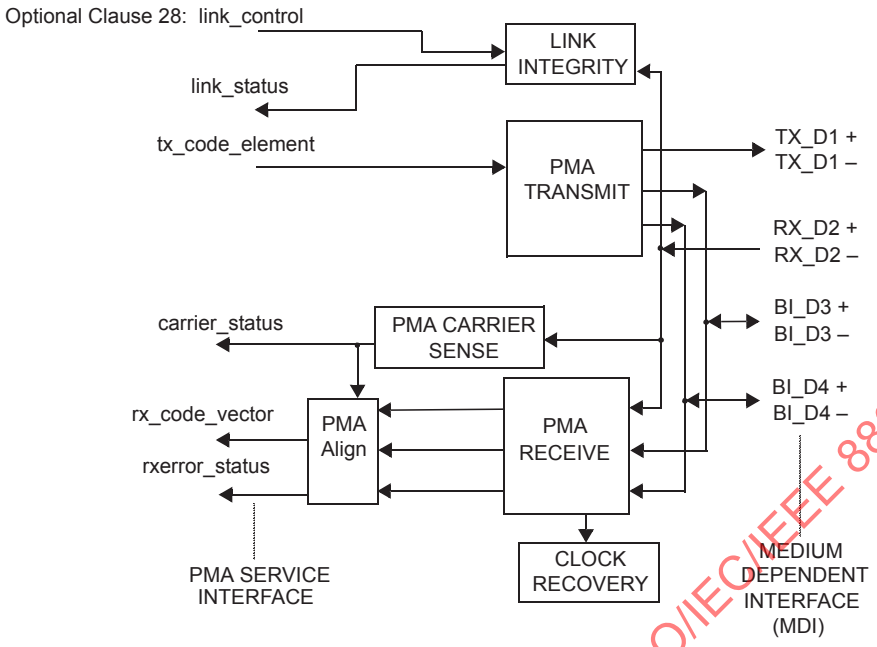

Figure 23–11—PMA reference diagram

23.4.1.2 PMA Transmit function

Except as provided for in the next paragraph, whenever (tx_code_vector=DATA)×(pma_carrier=OFF), the PMA shall transmit onto the MDI ternary symbols on pairs TX_D1, BI_D3, and BI_D4 equal to tx_code_vector[TX_D1], tx_code_vector[BI_D3], and tx_code_vector[BI_D4], respectively.

Whenever (tx_code_vector=DATA)×(pma_carrier=ON), the PMA shall transmit onto the MDI ternary symbols on pairs TX_D1, BI_D3, and BI_D4 equal to tx_code_vector[TX_D1], CS0, and CS0, respectively, and continue doing so until tx_code_vector=IDLE.

NOTE—This shuts off the transmitters on channels BI_D3 and BI_D4, and keeps them off, in the event of a collision. Shutting off the transmitters prevents overload and saturation of the transmitters, and also reduces the amount of near-end crosstalk present while monitoring for the end of carrier.

Whenever tx_code_vector=IDLE, an idle signal shall be transmitted on pair TX_D1 and silence on pairs BI_D3 and BI_D4. The idle signal consists of periods of silence (times where the differential output voltage remains at 0 mV ± 50 mV) broken by the transmission of link integrity test pulses.

The 100BASE-T4 idle signal is similar to the 10BASE-T idle signal, but with 100BASE-T4 ternary signal levels and a faster repetition rate. The 100BASE-T4 idle signal is called TP_IDL_100. The TP_IDL_100 signal shall be a repeating sequence formed from one 1.2 ms ± 0.6 ms period of silence (the time where the differential voltage remains at 0 mV ± 50 mV) and one link test pulse. Each link test pulse shall be a succession of two ternary symbols having logical values of –1 and 1 transmitted on pair TX_D1 using CS-1 and CS1 as defined in 23.4.3.1. Following a packet, the TP_IDL_100 shall start with a period of silence.

Transmission of TP_IDL_100 may be terminated at any time with respect to the link test pulse. It shall be terminated such that ternary symbols of the subsequent packet are not corrupted, and are not delayed any more than is specified in 23.11.

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For any link test pulse occurring within 20 ternary symbol times of the beginning of a preamble, the zero crossing jitter (as defined in 23.5.1.2.5) of the link test pulse when measured along with the zero crossings of the preamble shall be less than 4 ns p-p.

NOTE—The above condition allows clock recovery implementations that optionally begin fast-lock sequences on part of a link integrity pulse to properly acquire lock on a subsequent preamble sequence.

Regardless of other considerations, when the transmitter is disabled (xmit=DISABLE), the PMA Transmit function shall transmit the TP_IDL_100 signal.

23.4.1.3 PMA Receive function

PMA Receive contains the circuits necessary to convert physically encoded ternary symbols from the physical MDI receive pairs (RX_D2, BI_D3 and BI_D4) into a logical format suitable for the PMA_Align function. Each receive pair has its own dedicated PMA Receive circuitry.

The PHY shall receive the signals on the receive pairs (RX_D2, BI_D3, and BI_D4) and translate them into one of the PMA_UNITDATA.indication parameters IDLE, PREAMBLE, or DATA with a ternary symbol error ratio of less than one part in 10^8.

If both pma_carrier=ON and tx_code_vector=DATA, the value of rx_code_vector is unspecified until pma_carrier=OFF.

23.4.1.4 PMA Carrier Sense function

The PMA Carrier Sense function shall set pma_carrier=ON upon reception of the following pattern on pair RX_D2 at the receiving MDI, as measured using a 100BASE-T4 transmit test filter (23.5.1.2.3):

> Any signal greater than 467 mV, followed by any signal less than –225 mV, followed by any signal greater than 467 mV, all three events occurring within 2 ternary symbol times.

The operation of carrier sense is undefined for signal amplitudes greater than 4.5 V.

See 23.5.1.3.2 for a list of signals defined *not* to set pma_carrier=ON.

After asserting pma_carrier=ON, PMA Carrier Sense shall set pma_carrier=OFF upon receiving either of these conditions:

a) Seven consecutive ternary symbols of value CS0 on pair RX_D2.
b) (tx_code_vector=DATA) has not been true at any time since pma_carrier was asserted, *and* the 6T code group eop1 has been received, properly framed, on any of the lines RX_D2, BI_D4, or BI_D3, *and* enough time has passed to assure passage of all ternary symbols of eop4 across the PMA service interface.

NOTE—Designers may wish to take advantage of the fact that the minimum received packet fragment will include at least 24 ternary symbols of data on pair RX_D2. Therefore, once carrier is activated, it is not necessary to begin searching for seven consecutive zeros until after the 24th ternary symbol has been received. During the time that the first 24 ternary symbols are being received, the near-end crosstalk from pairs BI_D3 and BI_D4, which are switched off during collisions, decays substantially.

While rcv=ENABLE, the PMA CARRIER function shall set carrier_status = pma_carrier.

While rcv≠ENABLE, the PMA CARRIER function shall set carrier_status = OFF.

This function operates independently of the Link Integrity function.

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23.4.1.5 Link Integrity function

Link Integrity provides the ability to protect the network from the consequences of failure of the simplex link attached to RX_D2. While such a failure is present, transfer of data by the Transmit and Receive functions is disabled.

Link Integrity observes the incoming wire pair, RX_D2, to determine whether the device connected to the far end is of type 100BASE-T4. Based on its observations, Link Integrity sets two important internal variables:

a) pma_type variable is set to 100BASE-T4.
b) link_status variable is a parameter sent across the PMA Service interface.

The Link Integrity function shall comply with the state diagram of Figure 23–12.

Four conditions gate the progression of states toward LINK_PASS: (1) reception of at least 31 link integrity test pulses; (2) reception of at least 96 more link integrity test pulses, or reception of carrier; (3) cessation of carrier, if it was present; (4) detection of equals link_control ENABLE.

While the PMA is not in the LINK_PASS state, the Link Integrity function sets rcv=DISABLE and xmit=DISABLE, thus disabling the bit transfer of the Transmit and Receive functions.

If a visible indicator is provided on the PHY to indicate the link status, it is recommended that the color be green and that the indicator be labeled appropriately. It is further recommended that the indicator be on when the PHY is in the LINK_PASS state and off otherwise.

23.4.1.6 PMA Align function

The PMA Align function accepts received ternary symbols from the PMA Receive function, along with pma_carrier. PMA Align is responsible for realigning the received ternary symbols to eliminate the effects of unequal pair propagation time, commonly called pair skew. PMA Align also looks for the SSD pattern to determine the proper alignment of 6T code groups, and then forwards PMA_UNITDATA.indication (DATA) messages to the PCS. The SSD pattern includes referencing patterns on each of the three receive lines that may be used to establish the proper relationship of received ternary symbols (see Figure 23–6).

NOTE—The skew between lines is not expected to change measurably from packet to packet.

At the beginning of each received frame, the PMA Carrier Sense function asserts pma_carrier=ON. During the preamble, the Clock Recovery function begins synchronizing its receive clock. Until clock is synchronized, data coming from the low-level PMA Receive function is meaningless. The PMA Align function is responsible for waiting for the receiver clock to stabilize and then properly recognizing the 100BASE-T4 coded SSD pattern. The PMA Align function shall send PMA_UNITDATA.indication (PREAMBLE) messages to the PCS from the time pma_carrier=ON is asserted until the PMA is ready to transfer the first PMA_UNITDATA.indication (DATA) message. Once the PMA Align function locates a SSD pattern, it begins forwarding PMA_UNITDATA.indication (DATA) messages to the PCS, starting with the first ternary symbol of the first data word on pair BI_D3, as defined in Figure 23–6. This first PMA_UNITDATA.indication (DATA) message shall transfer the following ternary symbols, as specified in the frame structure diagram, Figure 23–6:

rx_code_vector[BI_D3]first ternary symbol of first data code group

rx_code_vector[RX_D2]second ternary symbol prior to start of second data code group

rx_code_vector[BI_D4]fourth ternary symbol prior to start of third data code group

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PMA Align shall continue sending PMA_UNITDATA.indication (DATA) messages until pma_carrier=OFF. While pma_carrier=OFF, PMA Align shall emit PMA_UNITDATA.indication (IDLE) messages.

If no valid SSD pattern is recognized within 22 ternary symbol times of the assertion of pma_carrier=ON, the PMA Align function shall set rxerror_status=ERROR. The PMA Align function is permitted to begin sending PMA_UNITDATA.indication (DATA) messages upon receipt of a partially recognized SSD pattern, but it is required to set rxerror_status=ERROR if the complete SSD does not match perfectly the expected ternary symbol sequence. Rxerror_status shall be reset to NO_ERROR when pma_carrier=OFF.

The PMA Align function is permitted to use the first received packet of at least minimum size after RESET or the transition to LINK_PASS to learn the nominal skew between pairs, adjust its equalizer, or perform any other initiation functions. During this first packet, the PMA Align function shall emit PMA_UNITDATA.indication (PREAMBLE) messages, but may optionally choose to never begin sending PMA_UNITDATA.indication (DATA) messages.

The PMA Align function shall tolerate a maximum skew between any two pairs of 60 ns in either direction without error.

To protect the network against the consequences of mistaken packet framing, the PMA Align function shall detect the following error and report it by setting rxerror_status=ERROR (optionally, those error patterns already detected by codeword_error, dc_balance_error, or eop_error do not also have to be detected by rxerror_status): *In a series of good packets, any one packet that has been corrupted with three or fewer ternary symbols in error causing its sosb 6T code groups on one or more pairs to appear in the wrong location.*

Several approaches are available for meeting this requirement, including, but not limited to, a) comparing the relative positions of sosb 6T code groups on successive packets; b) measuring the time between the first preamble pulse and reception of sosb on each pair; c) counting the number of zero crossings from the beginning of the preamble until sosb; and d) monitoring for exception strings like “11” and “–1–1–1” in conjunction with one or more of the above techniques.

Regardless of other considerations, when the receive function is disabled (rcv=DISABLE), the PMA Align function shall emit PMA_UNITDATA.indication (IDLE) messages and no others.

23.4.1.7 Clock Recovery function

The Clock Recovery function couples to all three receive pairs. It provides a synchronous clock for sampling each pair. While it may not drive the MII directly, the Clock Recovery function is the underlying root source of RX_CLK.

The Clock Recovery function shall provide a clock suitable for synchronously decoding ternary symbols on each line within the bit error tolerance provided in 23.4.1.3. During each preamble, in order to properly recognize the frame delimiting pattern formed by codeword sosb on each pair, the received clock signal must be stable and ready for use in time to decode the following ternary symbols: the 16th ternary symbol of pair RX_D2, the 18th ternary symbol of pair BI_D4, and the 14th ternary symbol of pair BI_D3.

23.4.2 PMA interface messages

The messages between the PMA and PCS are defined above in 23.3, PMA Service Interface. Communication between a repeater unit and PMA also uses the PMA Service Interface. Communication through the MDI is summarized in Tables 23–2 and 23–3.

TP_IDL_100 is defined in 23.4.1.2. The waveforms used to convey CS1, CS0, and CS-1 are defined in 23.5.1.2.

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Table 23–2—MDI signals transmitted by the PHY

Signal	Allowed pair	Meaning
CS1	TX_D1, BI_D3 BI_D4	A waveform that conveys the ternary symbol 1. Nominal voltage level +3.5 V.
CS0	TX_D1, BI_D3 BI_D4	A waveform that conveys the ternary symbol 0. Nominal voltage level 0 V.
CS-1	TX_D1, BI_D3 BI_D4	A waveform that conveys the ternary symbol –1. Nominal voltage level –3.5 V.
TP_IDL_100	TX_D1	Idle signal. Indicates transmitter is currently operating at 100 Mb/s.

Table 23–3—Signals received at the MDI

Signal	Allowed pair	Meaning
CS1	RX_D2, BI_D3 BI_D4	A waveform that conveys the ternary symbol 1. Nominal transmitted voltage level +3.5 V.
CS0	RX_D2, BI_D3 BI_D4	A waveform that conveys the ternary symbol 0. Nominal transmitted voltage level 0 V.
CS-1	RX_D2, BI_D3 BI_D4	A waveform that conveys the ternary symbol –1. Nominal transmitted voltage level –3.5 V.
TP_IDL_100	RX_D2	Idle signal. Indicates transmitter is currently operating at 100 Mb/s.

TP_IDL_100 is defined in 23.4.1.2. The encodings for CS1, CS0, and CS-1 are defined in 23.5.1.2.

Re-timing of CS1, CS0, and CS-1 signals within the PMA is required.

23.4.3 PMA state diagrams

The notation used in the state diagrams follows the conventions of 21.5. Transitions shown without source states are evaluated continuously and take immediate precedence over all other conditions.

23.4.3.1 PMA constants

CS0

A waveform that conveys the ternary symbol 0.

Value: CS0 has a nominal voltage of 0 V. See 23.5.1.2.

CS1

A waveform that conveys the ternary symbol 1.

Value: CS1 has a nominal peak voltage of +3.5 V. See 23.5.1.2.

CS-1

A waveform that conveys the ternary symbol –1.

Value: CS-1 has a nominal peak voltage of –3.5 V. See 23.5.1.2.

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link_100_max

A constant.

Value: Greater than 5.0 ms and less than 7.0 ms.

Used by link_max_timer to detect the absence of 100BASE-T4 link test pulses on pair RX_D2.

link_100_min

A constant.

Value: Greater than 0.15 ms and less than 0.45 ms.

Used by cnt_link to detect link test pulses on pair RX_D2 that are too close together to be valid 100BASE-T4 link test pulses.

23.4.3.2 State diagram variables

pma_reset

Causes reset of all PCS functions.

Values: ON and OFF

Set by: PMA Reset

pma_carrier

A version of carrier_status used internally by the PMA sublayer. The variable pma_carrier always functions regardless of the link status. The value of pma_carrier is passed on through the PMA service interface as carrier_status when rcv=ENABLE. At other times, the passage of pma_carrier information to the PMA service interface is blocked.

Values: ON, OFF

Set by: PMA CARRIER

rcv

Controls the flow of data from the PMA to PCS through the PMA_UNITDATA.indication message.

Values: ENABLE (receive is enabled)
DISABLE (the PMA always sends PMA_UNITDATA.indication (IDLE), and carrier_status is set to OFF)

xmit

Controls the flow of data from PCS to PMA through the PMA_UNITDATA.request message.

Values: ENABLE (transmit is enabled)
DISABLE (the PMA interprets all PMA_UNITDATA.request messages as PMA_UNITDATA.request (IDLE). The PMA transmits no data, but continues sending TP_IDL_100).

23.4.3.3 State diagram timers

link_max_timer

A re-triggerable timer.

Values: The condition link_max_timer_done goes true when the timer expires.

Restart when: Timer is restarted for its full duration by every occurrence of either a link test pulse on pair RX_D2 or the assertion of pma_carrier=ON (restarting the timer

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resets the condition link_max_timer_done).

Duration: link_100_max

Used by Link Integrity to detect the absence of 100BASE-T4 link test pulses on pair RX_D2.

23.4.3.4 State diagram counters

cnt_link

Counts number of 100BASE-T4 link test pulses (see 23.5.1.3.1) received on pair RX_D2.

Values: nonnegative integers

Reset to zero: On either of two conditions:

a) While in any state other than LINK_PASS, reset counter to zero if successive link test pulses are received within link_100_min.
b) While in any state, reset to zero if link_max_timer expires.

While in the LINK_PASS state, ignore pulses received within link_100_min (i.e., do not count them).

23.4.3.5 Link Integrity state diagram

The Link Integrity state diagram is shown in Figure 23–12.

23.5 PMA electrical specifications

This clause defines the electrical characteristics of the PHY at the MDI.

The ground reference point for all common-mode tests is the MII ground circuit. Implementations without an MII use the chassis ground. The values of all components in test circuits shall be accurate to within ±1% unless otherwise stated.

23.5.1 PMA-to-MDI interface characteristics

23.5.1.1 Isolation requirement

The PHY shall provide electrical isolation between the DTE, or repeater circuits including frame ground, and all MDI leads. This electrical separation shall withstand at least one of the following electrical strength tests:

a) 1500 V rms at 50 Hz to 60 Hz for 60 s, applied as specified in subclause 5.3.2 of IEC 60950: 1991.
b) 2250 Vdc for 60 s, applied as specified in subclause 5.3.2 of IEC 60950: 1991.
c) A sequence of ten 2400 V impulses of alternating polarity, applied at intervals of not less than 1 s. The shape of the impulses shall be 1.2/50 µs (1.2 µs virtual front time, 50 µs virtual time or half value), as defined in IEC 60060.

There shall be no insulation breakdown, as defined in subclause 5.3.2 of IEC 60950: 1991, during the test. The resistance after the test shall be at least 2 MΩ, measured at 500 Vdc.

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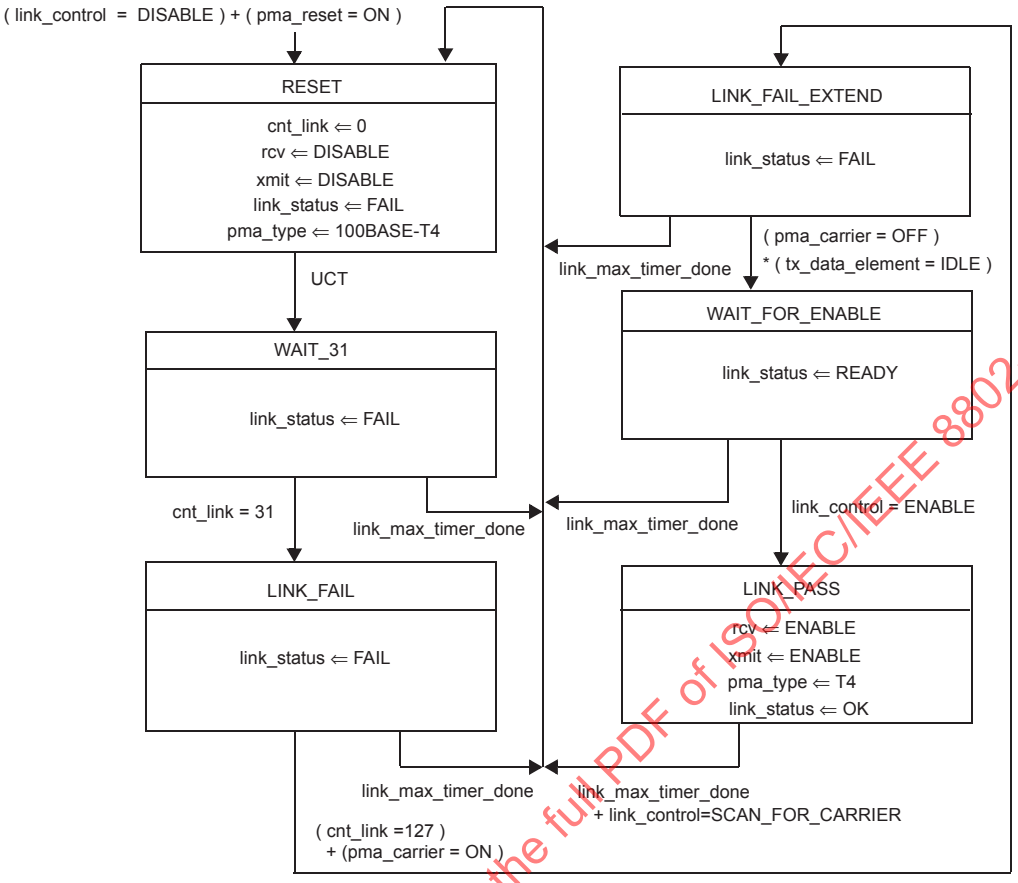

NOTE—The variables link_control and link_status are designated as link_control_[T4] and link_status_[T4], respectively, by the Auto-Negotiation Arbitration state diagram (Figure 28–18).

Figure 23–12—Link Integrity state diagram

23.5.1.2 Transmitter specifications

The PMA shall provide the Transmit function specified in 23.4.1.2 in accordance with the electrical specifications of this clause.

Where a load is not specified, the transmitter shall meet requirements of this clause when each transmit output is connected to a differentially connected 100 Ω resistive load.

23.5.1.2.1 Peak differential output voltage

While repetitively transmitting the ternary sequence [0 0 1 0 0 0 0 0 -1 0 0 0] (leftmost ternary symbol first), and while observing the differential transmitted output at the MDI, for any pair, with no intervening cable, the absolute value of both positive and negative peaks shall fall within the range of 3.15 V to 3.85 V (3.5 V ± 10%).

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23.5.1.2.2 Differential output templates

While repetitively transmitting the ternary sequence [0 0 1 0 0 0 0 0 -1 0 0 0], and while observing the transmitted output at the MDI, the observed waveform shall fall within the normalized transmit template listed in Table 23–4. Portions of this table are represented graphically in Figure 23–13. The entire normalized transmit template shall be scaled by a single factor between 3.15 and 3.85. It is a functional requirement that linear interpolation be used between points. The template time axis may be shifted horizontally to attain the most favorable match. In addition to this simple test pattern, all other pulses, including link integrity pulses and also including the first pulse of each packet preamble, should meet this same normalized transmit template, with appropriate shifting and linear superposition of the CS1 and CS-1 template limits. Transmitters are allowed to insert additional delay in the transmit path in order to meet the first pulse requirement, subject to the overall timing limitations listed in 23.11, Timing summary.

While transmitting the TP_IDL_100 signal, and while observing the transmitted output at the MDI, the observed waveform shall fall within the normalized link pulse template listed in Table 23–4. Portions of this table are represented graphically in Figure 23–14. The entire template shall be scaled by the same factor used for the normalized transmit template test. It is a functional requirement that linear interpolation be used between template points. The template time axis may be shifted horizontally to attain the most favorable match.

After transmitting seven or more consecutive CS0 waveforms during the TP_IDL_100 signal, each pair, as observed using the 100BASE-T4 Transmit Test Filter (23.5.1.2.3) connected to the MDI, shall attain a state within 50 mV of zero.

When the TX_D1, BI_D3, or BI_D4 pair is driven with a repeating pattern (1 -1 1 -1 ...) any harmonic measured at the MDI output shall be at least 27 dB below the fundamental at 12.5 MHz.

NOTE 1—The specification on maximum spectral components is not intended to ensure compliance with regulations concerning RF emissions. The implementer should consider any applicable local, national, or international regulations. Additional filtering of spectral components may therefore be necessary.

NOTE 2—The repetitive pattern [0 0 1 0 0 0 0 0 -1 0 0 0] (leftmost ternary symbol first) may be synthesized using the 8B6T coding rules from a string of repeating data octets with value 73 hex. The repetitive pattern [1 -1 1 -1 1 -1] (leftmost ternary symbol first) may be synthesized using the 8B6T coding rules from a string of repeating data octets with value 92 hex.

The ideal template values may be automatically generated from the following equations:

Laplace transform of
Ideal transmit response $\qquad IdealResponse(s) = \frac{Ideal(s)}{LPF(s)}$

Where $Ideal(s)$ is a 100% raised cosine system response

Where $LPF(s)$ is a 3-pole Butterworth low pass filter response with –3 dB point at 25 MHz

Convert *IdealResponse(s)* from frequency domain to time domain

Use at least 8 samples per ternary symbol for the conversion

Superimpose alternating positive and negative copies of the ideal time response, separated by 6 ternary symbol times, to form the ideal transmit voltage waveform.

The template limits are formed by offsetting the ideal transmit voltage waveform by plus and minus 6% of its peak.

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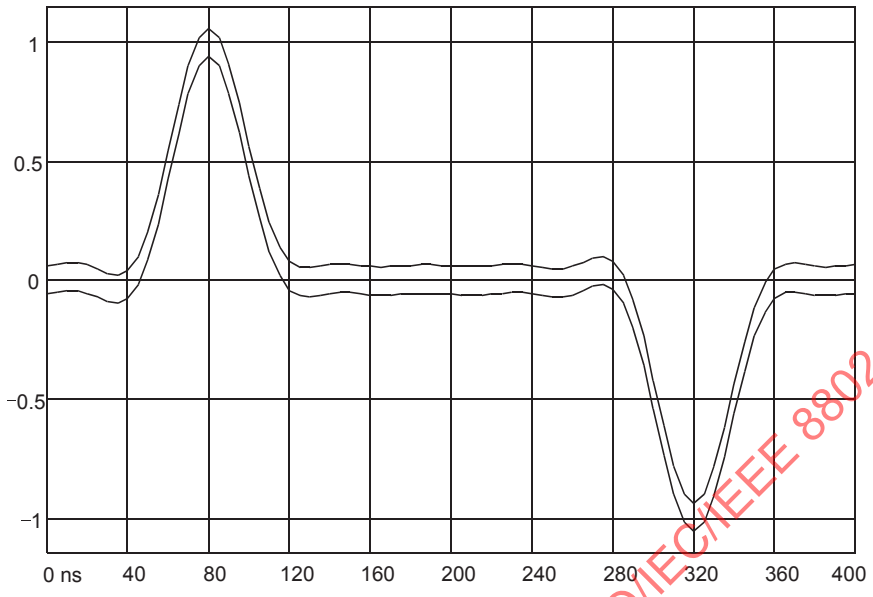

Figure 23–13—Normalized transmit template as measured at MD

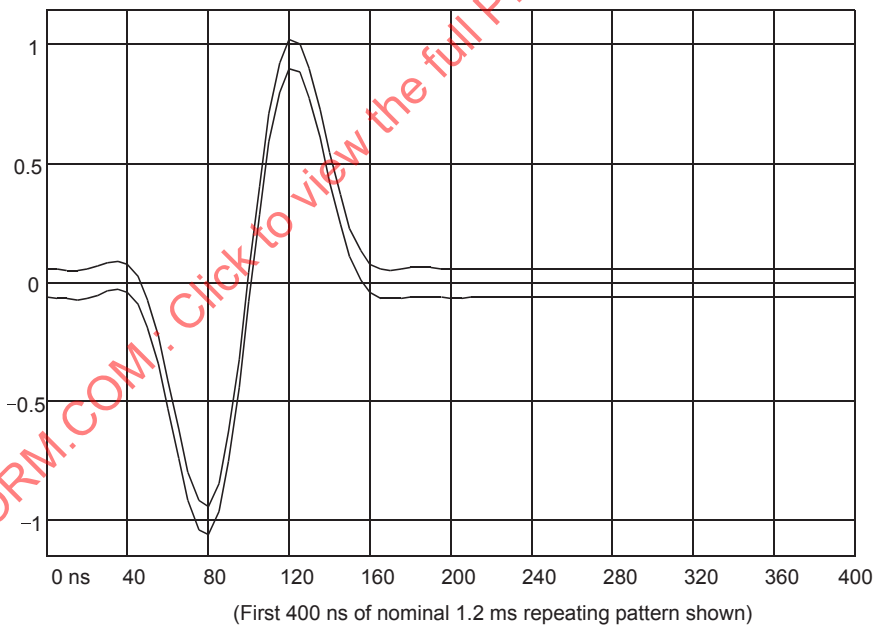

Figure 23–14—Normalized link pulse template as measured at MDI

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Table 23–4—Normalized voltage templates as measured at the MDI

Time, ns	Normalized transmit template, pos. limit	Normalized transmit template, neg. limit	Normalized link template, pos. limit	Normalized link template, neg. limit
0	0.060	–0.061	0.061	–0.060
5	0.067	–0.054	0.056	–0.065
10	0.072	–0.049	0.052	–0.069
15	0.072	–0.049	0.052	–0.069
20	0.063	–0.058	0.058	–0.063
25	0.047	–0.074	0.071	–0.050
30	0.030	–0.091	0.086	–0.035
35	0.023	–0.098	0.094	–0.027
40	0.041	–0.080	0.080	–0.041
45	0.099	–0.022	0.027	–0.094
50	0.206	0.085	–0.076	–0.197
55	0.358	0.237	–0.231	–0.352
60	0.544	0.423	–0.428	–0.549
65	0.736	0.615	–0.640	–0.761
70	0.905	0.784	–0.829	–0.950
75	1.020	0.899	–0.954	–1.075
80	1.060	0.940	–0.977	–1.098
85	1.020	0.899	–0.876	–0.997
90	0.907	0.786	–0.653	–0.774
95	0.744	0.623	–0.332	–0.453
100	0.560	0.439	0.044	–0.077
105	0.384	0.263	0.419	0.298
110	0.239	0.118	0.738	0.617
115	0.137	0.016	0.959	0.838
120	0.077	–0.044	1.060	0.940
125	0.053	–0.068	1.044	0.923
130	0.050	–0.071	0.932	0.811
135	0.057	–0.064	0.759	0.638
140	0.064	–0.057	0.565	0.444
145	0.067	–0.054	0.383	0.262
150	0.065	–0.056	0.238	0.117
155	0.061	–0.060	0.138	0.017
160	0.057	–0.064	0.081	–0.040
165	0.055	–0.066	0.057	–0.064

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Table 23–4—Normalized voltage templates as measured at the MDI *(continued)*

Time, ns	Normalized transmit template, pos. limit	Normalized transmit template, neg. limit	Normalized link template, pos. limit	Normalized link template, neg. limit
170	0.056	–0.065	0.054	–0.067
175	0.059	–0.062	0.058	–0.063
180	0.062	–0.059	0.063	–0.058
185	0.064	–0.057	0.064	–0.057
190	0.064	–0.057	0.063	–0.058
195	0.062	–0.059	0.060	–0.061
200	0.060	–0.061	0.058	–0.063
205	0.057	–0.064	0.058	–0.063
210	0.056	–0.065	0.059	–0.062
215	0.058	–0.063	0.060	–0.061
220	0.061	–0.060	0.062	–0.059
225	0.064	–0.057	0.062	–0.059
230	0.066	–0.055	0.062	–0.059
235	0.065	–0.056	0.061	–0.060
240	0.061	–0.060	0.060	–0.061
245	0.054	–0.067	0.060	–0.061
250	0.049	–0.072	0.060	–0.061
255	0.049	–0.072	0.060	–0.061
260	0.058	–0.063	0.061	–0.060
265	0.074	–0.047	0.061	–0.060
270	0.091	–0.030	0.061	–0.060
275	0.099	–0.022	0.061	–0.060
280	0.080	–0.041	0.060	–0.061
285	0.022	–0.099	0.060	–0.061
290	–0.085	–0.206	0.060	–0.061
295	–0.238	–0.359	0.060	–0.061
300	–0.423	–0.544	0.061	–0.060
305	–0.615	–0.736	0.061	–0.060
310	–0.783	–0.904	0.061	–0.060
315	–0.899	-1.020	0.061	–0.060
320	–0.940	-1.061	0.060	–0.061
325	–0.899	-1.020	0.060	–0.061
330	–0.786	–0.907	0.060	–0.061
335	–0.623	–0.744	0.060	–0.061

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Table 23–4—Normalized voltage templates as measured at the MDI *(continued)*

Time, ns	Normalized transmit template, pos. limit	Normalized transmit template, neg. limit	Normalized link template, pos. limit	Normalized link template, neg. limit
340	–0.439	–0.560	0.061	–0.060
345	–0.263	–0.384	0.061	–0.060
350	–0.118	–0.239	0.061	–0.060
355	–0.016	–0.137	0.061	–0.060
360	0.044	–0.077	0.060	–0.061
365	0.068	–0.053	0.060	–0.061
370	0.070	–0.051	0.060	–0.061
375	0.064	–0.057	0.060	–0.061
380	0.057	–0.064	0.061	–0.060
385	0.054	–0.067	0.061	–0.060
390	0.056	–0.065	0.061	–0.060
395	0.060	–0.061	0.061	–0.060
400	0.064	–0.057	0.060	–0.061
405	0.065	–0.056	0.060	–0.061
410	0.064	–0.057	0.060	–0.061
415	0.061	–0.060	0.060	–0.061
420	0.059	–0.062	0.061	–0.060
425	0.058	–0.063	0.061	–0.060
430	0.059	–0.062	0.061	–0.060
435	0.060	–0.061	0.061	–0.060
440	0.061	–0.060	0.060	–0.061
445	0.062	–0.059	0.060	–0.061
450	0.062	–0.059	0.060	–0.061
455	0.061	–0.060	0.060	–0.061
460	0.060	–0.061	0.061	–0.060
465	0.059	–0.062	0.061	–0.060
470	0.060	–0.061	0.061	–0.060
475	0.060	–0.061	0.061	–0.060
480	0.061	–0.060	0.060	–0.061

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23.5.1.2.3 Differential output ISI (intersymbol interference)

While observing a pseudo-random 8B6T coded data sequence (with every 6T code group represented at least once) preceded by at least 128 octets and followed by at least 128 octets of data, and while observing the transmitted output through a 100BASE-T4 Transmit Test Filter (one implementation of which is

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depicted in Figure 23–16), the ISI shall be less than 9%. The ISI for this test is defined by first finding the largest of the three peak-to-peak ISI error voltages marked in Figure 23–15 as TOP ISI, MIDDLE ISI, and BOTTOM ISI.

The largest of these peak-to-peak ISI error voltages is then divided by the overall peak-to-peak signal voltage. (The technique of limiting the ratio of worst ISI to overall peak-to-peak voltage at 9% accomplishes the same end as limiting the ratio of worst ISI to nominal peak-to-peak at 10%.)

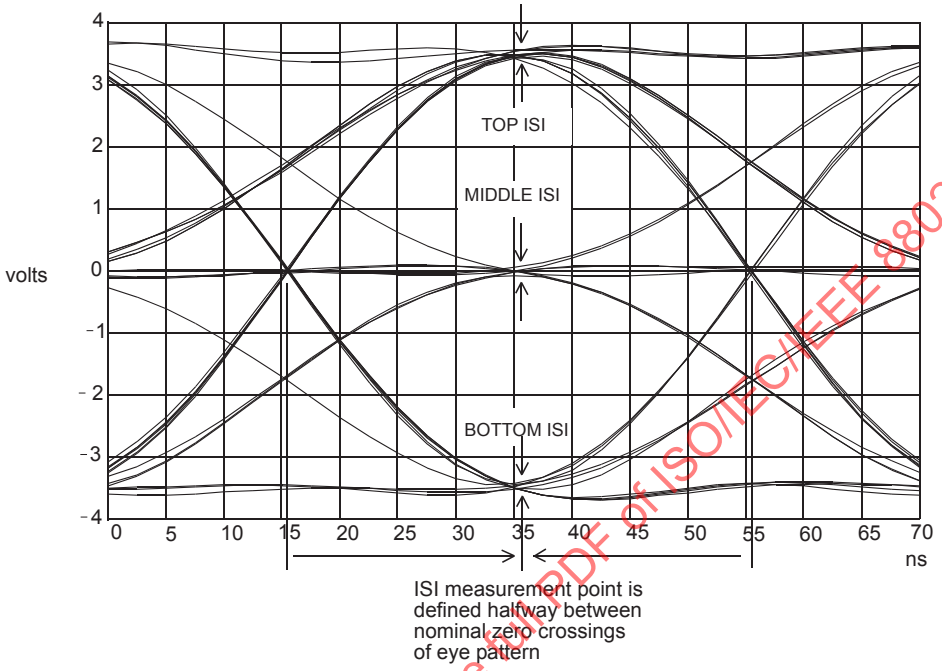

Figure 23–15—Definition of sampling points for ISI measurement

It is a mandatory requirement that the peak-to-peak ISI, and the overall peak-to-peak signal voltage, be measured at a point in time halfway between the nominal zero crossings of the observed eye pattern.

It is a mandatory requirement that the 100BASE-T4 Transmit Test Filter perform the function of a third-order Butterworth filter with its –3 dB point at 25.0 MHz.

One acceptable implementation of a 100BASE-T4 Transmit Test Filter appears in Figure 23–16. That implementation uses the 100BASE-T4 Transmit Test Filter as a line termination. The output of the filter is terminated in 100 Ω. It is a mandatory requirement that such implementations of the 100BASE-T4 Transmit Test Filter be designed such that the reflection loss of the filter, when driven by a 100 Ω source, exceeds 17 dB across the frequency range 2 to 12.5 MHz.

Equivalent circuits that implement the same overall transfer function are also acceptable. For example, the 100BASE-T4 Transmit Test Filter may be tapped onto a line in parallel with an existing termination. It is a mandatory requirement that such implementations of the 100BASE-T4 Transmit Test Filter be designed with an input impedance sufficiently high that the reflection loss of the parallel combination of filter and 100 Ω termination, when driven by 100 Ω, exceeds 17 dB across the frequency range 2 to 12.5 MHz.

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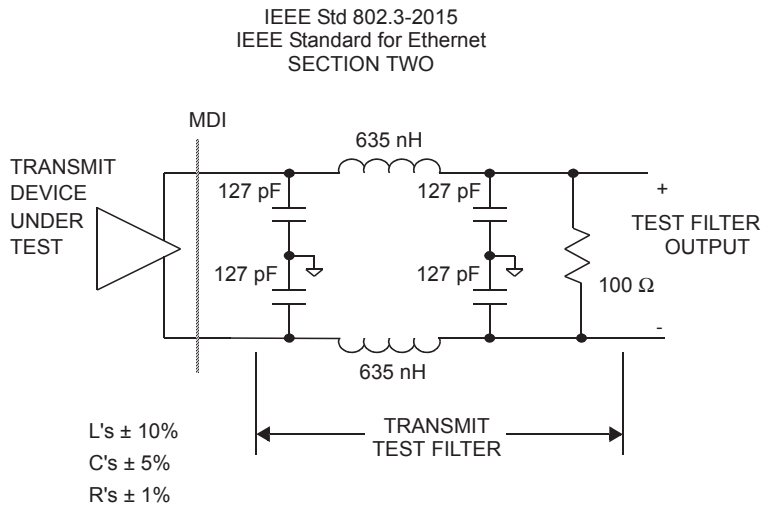

Figure 23–16—Acceptable implementation of transmit test filter

23.5.1.2.4 Transmitter differential output impedance

The differential output impedance as measured at the MDI for each transmit pair shall be such that any reflection due to differential signals incident upon the MDI from a balanced cable having an impedance of 100 Ω is at least 17 dB below the incident signal, over the frequency range of 2.0 MHz to 12.5 MHz. This return loss shall be maintained at all times when the PHY is fully powered.

With every transmitter connected as in Figure 23–17, and while transmitting a repeating sequence of packets as specified in Table 23–5, the amount of droop on any transmit pair as defined in Figure 23–18 during the transmission of eop1 and eop4 shall not exceed 6.0%.

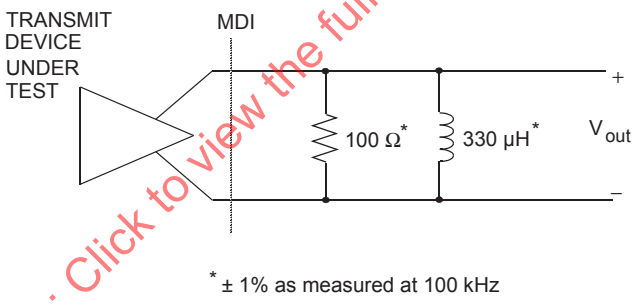

Figure 23–17—Output impedance test setup

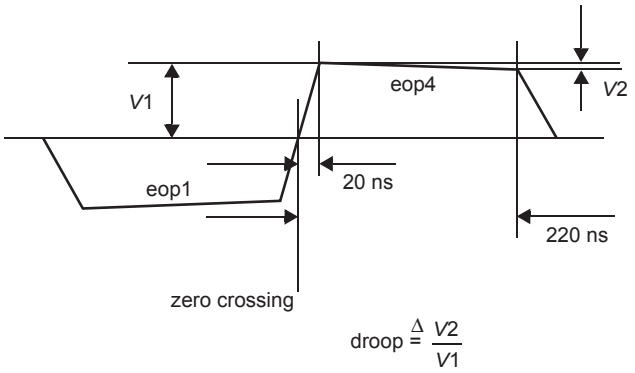

Figure 23–18—Measurement of output droop

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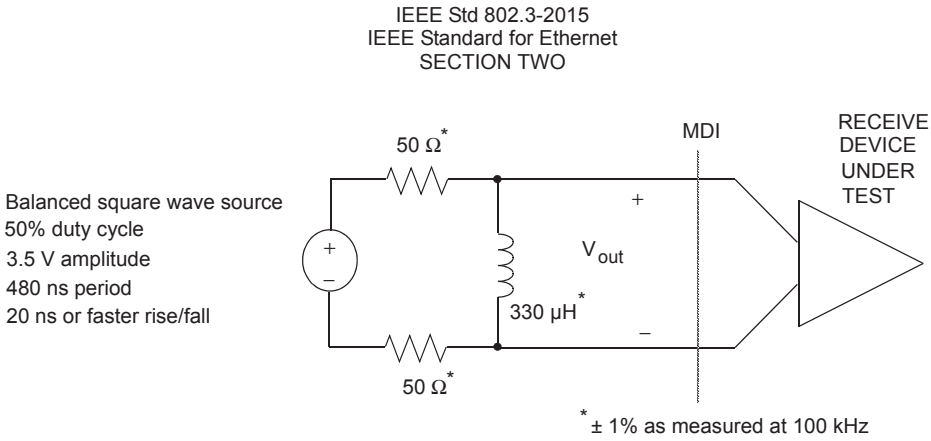

Figure 23–19—Input impedance test setup

Table 23–5—Sequence of packets for droop test

Packet sequence (Transmit this sequence of packets in a repetitive loop)	**Packet length** (Number of data octets)	**Data, hex** (All octets in each packet are the same)
First packet	64	AA
Second packet	65	AA
Third packet	66	AA

23.5.1.2.5 Output timing jitter

While repetitively transmitting a random sequence of valid 8B6T codewords, and while observing the output of a 100BASE-T4 Transmit Test Filter connected at the MDI to any of the transmit pairs as specified in 23.5.1.2.3, the measured jitter shall be no more than 4 ns p-p. For the duration of the test, each of the other transmit pairs shall be connected to either a 100BASE-T4 Transmit Test Filter or a 100 Ω resistive load.

NOTE 1—Jitter is the difference between the actual zero crossing point in time and the ideal time. For various ternary transitions, the zero crossing time is defined differently. For transitions between +1 and –1 or vice versa, the zero crossing point is defined as that point in time when the voltage waveform crosses zero. For transitions between zero and the other values, or from some other value to zero, the zero crossing time is defined as that point in time when the voltage waveform crosses the boundary between logical voltage levels, halfway between zero volts and the logical +1 or logical –1 ideal level.

NOTE 2—The ideal zero crossing times are contained in a set of points $\{t_n\}$ where $t_n = t_0 + n/f$, where n is an integer, and f is in the range 25.000 MHz ± 0.01%. A collection of zero crossing times satisfies the jitter requirement if there exists a pair (t_0, f) such that each zero crossing time is separated from some member of $\{t_n\}$ by no more than 4 ns.

23.5.1.2.6 Transmitter impedance balance

The common-mode to differential-mode impedance balance of each transmit output shall exceed

$$29 - 17\log\left(\frac{f}{10}\right)\text{dB}$$

where f is the frequency (in MHz) over the frequency range 2.0 MHz to 12.5 MHz. The balance is defined as

$$20\log\left(\frac{E_{cm}}{E_{dif}}\right)$$

where E_{cm} is an externally applied sine-wave voltage as shown in Figure 23–20.

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NOTE—The balance of the test equipment (such as the matching of the test resistors) must be insignificant relative to the balance requirements.

23.5.1.2.7 Common-mode output voltage

The implementer should consider any applicable local, national, or international regulations. Driving unshielded twisted pairs with high-frequency, common-mode voltages may result in interference to other equipment. FCC conducted and radiated emissions tests may require that, while transmitting data, the magnitude of the total common-mode output voltage, $E_{cm(out)}$, on any transmit circuit, be less than a few millivolts when measured as shown in Figure 23–21.

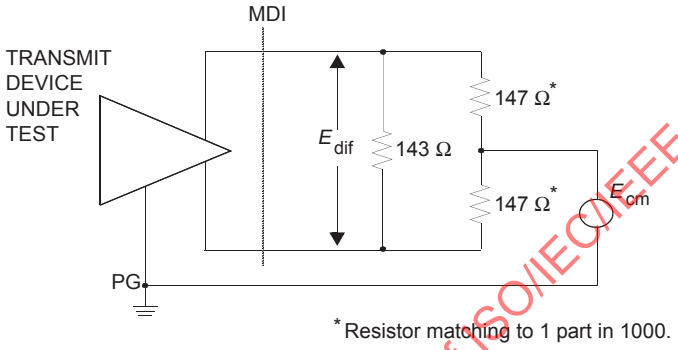

Figure 23–20—Transmitter impedance balance and common-mode rejection test circuit

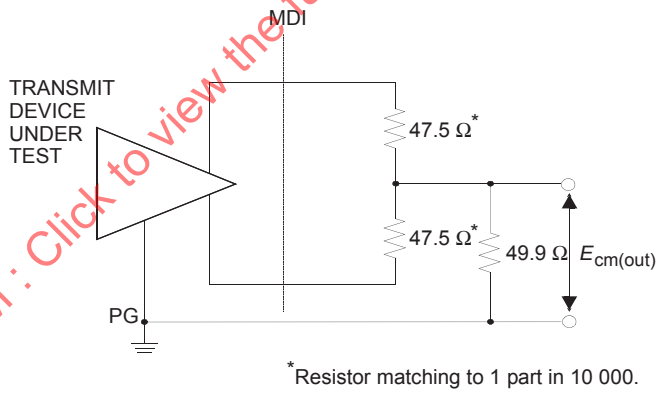

Figure 23–21—Common-mode output voltage test circuit

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23.5.1.2.8 Transmitter common-mode rejection

The application of E_{cm} as shown in Figure 23–20 shall not change the differential voltage at any transmit output, E_{dif}, by more than 100 mV for all data sequences while the transmitter is sending data. Additionally, the edge jitter added by the application of E_{cm} shall be no more than 1.0 ns. E_{cm} shall be a 15 V peak 10.1 MHz sine wave.

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23.5.1.2.9 Transmitter fault tolerance

Transmitters, when either idle or nonidle, shall withstand without damage the application of short circuits across any transmit output for an indefinite period of time and shall resume normal operation after such faults are removed. The magnitude of the current through such a short circuit shall not exceed 420 mA.

Transmitters, when either idle or nonidle, shall withstand without damage a 1000 V common-mode impulse applied at E_{cm} of either polarity (as indicated in Figure 23–22). The shape of the impulse shall be 0.3/50 µs (300 ns virtual front time, 50 µs virtual time of half value), as defined in IEC 60060.

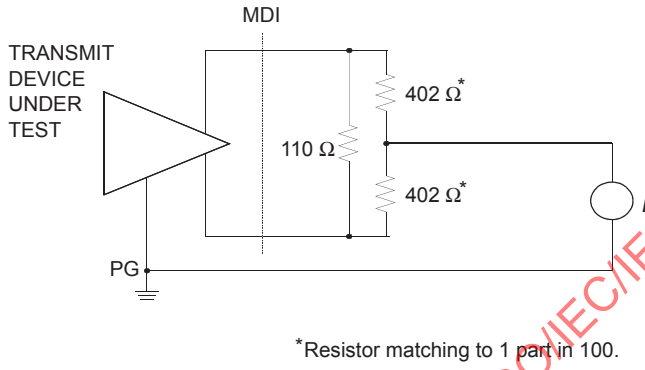

Figure 23–22—Transmitter fault tolerance test circuit

23.5.1.2.10 Transmit clock frequency

The ternary symbol transmission rate on each pair shall be 25.000 MHz ± 0.01%.

23.5.1.3 Receiver specifications

The PMA shall provide the Receive function specified in 23.4.1.3 in accordance with the electrical specifications of this clause. The patch cables and interconnecting hardware used in test configurations shall meet Category 5 specifications as in ISO/IEC 11801: 1995.

The term *worst-case UTP model*, as used in this clause, refers to lumped-element cable model shown in Figure 23–23 that has been developed to simulate the attenuation and group delay characteristics of 100 m of worst-case Category 3 PVC UTP cable.

This constant resistance filter structure has been optimized to best match the following amplitude and group delay characteristics, where the argument f is in hertz, and the argument x is the cable length in meters. For the worst-case UTP model, argument x was set to 100 m, and the component values determined for a best least mean squared fit of both real and imaginary parts of $H(f, x)$ over the frequency range 2 to 15 MHz.

NOTE—This group delay model is relative and does not includes the fixed delay associated with 100 m of Category 3 cable. An additional 570 ns of fixed delay should be added in order to obtain the absolute group delay.

$$PropagationImag(f, x) = j(-10)\sqrt{\frac{f}{10^7}}\left(\frac{x}{100}\right)$$

$$PropagationReal(f, x) = -\left(7.1\sqrt{\frac{f}{10^6}} + 0.70\frac{f}{10^6}\right)\left(\frac{x}{305}\right)$$

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$$H(f,x) = 10^{\frac{PropagationImag(f,x) + PropagationReal(f,x)}{20}}$$

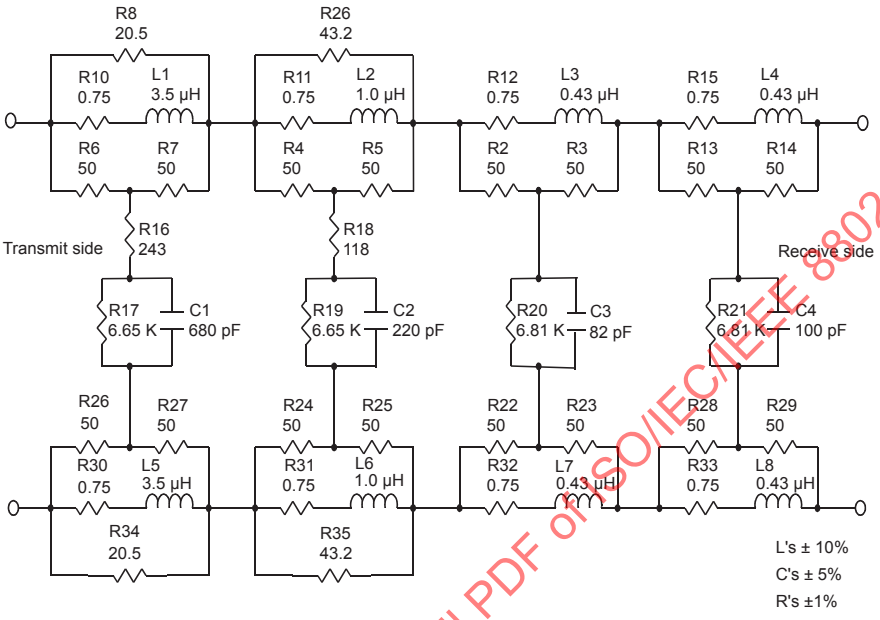

Figure 23–23—Worst-case UTP model

23.5.1.3.1 Receiver differential input signals

Differential signals received on the receive inputs that were transmitted within the constraints of 23.5.1.2, and have then passed through a worst-case UTP model, shall be correctly translated into one of the PMA_UNITDATA.indication messages and sent to the PCS. In addition, the receiver, when presented with a link test pulse generated according to the requirements of 23.4.1.2 and followed by at least 3T of silence on pair RX_D2, shall accept it as a link test pulse.

Both data and link test pulse receive features shall be tested in at least two configurations: using the worst-case UTP model, and with a connection less than one meter in length between transmitter and receiver.

A receiver is allowed to discard the first received packet after the transition into state LINK_PASS, using that packet for the purpose of fine-tuning its receiver equalization and clock recovery circuits.

NOTE—Implementers may find it practically impossible to meet the requirements of this subclause without using some form of adaptive equalization.

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23.5.1.3.2 Receiver differential noise immunity

The PMA, when presented with 8B6T encoded data meeting the requirements of 23.5.1.3.1, shall translate this data into PMA_UNITDATA.indication (DATA) messages with a bit loss of no more than that specified in 23.4.1.3.

The PMA Carrier Sense function shall *not* set pma_carrier=ON upon receiving any of the following signals on pair RX_D2 at the receiving MDI, as measured using a 100BASE-T4 transmit test filter (23.5.1.2.3):

a) All signals having a peak magnitude less than 325 mV.
b) All continuous sinusoidal signals of amplitude less than 8.7 V peak-to-peak and frequency less than 1.7 MHz.
c) All sine waves of single cycle or less duration, starting with phase 0° or 180°, and of amplitude less than 8.7 V peak-to-peak, where the frequency is between 1.7 MHz and 15 MHz. For a period of 7 BT before and after this single cycle, the signal shall be less than 325 mV.
d) Fast link pulse burst (FLP burst), as defined in Clause 28.
e) The link integrity test pulse signal TP_IDL_100.

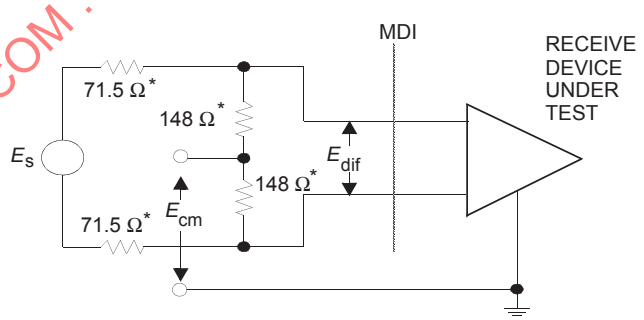
23.5.1.3.3 Receiver differential input impedance

The differential input impedance as measured at the MDI for each receive input shall be such that any reflection due to differential signals incident upon each receive input from a balanced cable having an impedance of 100 Ω is at least 17 dB below the incident signal, over the frequency range of 2.0 MHz to 12.5 MHz. This return loss shall be maintained at all times when the PHY is fully powered.

With each receiver connected as in Figure 23–19, and with the source adjusted to simulate eop1 and eop4 (50% duty cycle square wave with 3.5 V amplitude, period of 480 ns, and risetime of 20 ns or faster), the amount of droop on each receive pair as defined in Figure 23–18 shall not exceed 6.0%.

23.5.1.3.4 Common-mode rejection

While receiving packets from a compliant 100BASE-T4 transmitter connected to all MDI pins, a receiver shall send the proper PMA_UNITDATA.indication messages to the PCS for any differential input signal E_s that results in a signal E_{dif} that meets 23.5.1.3.1 even in the presence of common-mode voltages E_{cm} (applied as shown in Figure 23–24). E_{cm} shall be a 25 V peak-to-peak square wave, 500 kHz or lower in frequency, with edges no slower than 4 ns (20%–80%), connected to each of the receive pairs RX_D2, BI_D3, and BI_D4.



* Resistor matching to 1 part in 1000.

Figure 23–24—Receiver common-mode rejection test circuit

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23.5.1.3.5 Receiver fault tolerance

The receiver shall tolerate the application of short circuits between the leads of any receive input for an indefinite period of time without damage and shall resume normal operation after such faults are removed. Receivers shall withstand without damage a 1000 V common-mode impulse of either polarity (E_{cm} as indicated in Figure 23–25). The shape of the impulse shall be 0.3/50 µs (300 ns virtual front time, 50 µs virtual time of half value), as defined in IEC 60060.

23.5.1.3.6 Receiver frequency tolerance

The receive feature shall properly receive incoming data with a ternary symbol rate within the range 25.000 MHz ± 0.01%.

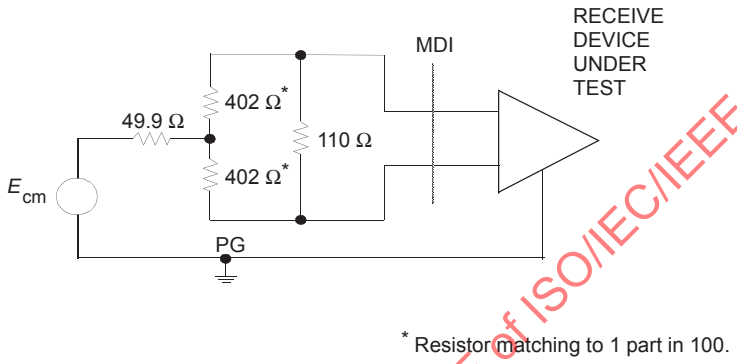

Figure 23–25—Common-mode impulse test circuit

23.5.2 Power consumption

After 100 ms following PowerOn, the current drawn by the PHY shall not exceed 0.75 A when powered through the MII.

The PHY shall be capable of operating from all voltage sources allowed by Clause 22, including those current limited to 0.75 A, as supplied by the DTE or repeater through the resistance of all permissible MII cables.

The PHY shall not introduce extraneous signals on the MII control circuits during normal power-up and power-down.

While in power-down mode the PHY is not required to meet any of the 100BASE-T4 performance requirements.

23.6 Link segment characteristics

23.6.1 Cabling

Cabling and installation practices generally suitable for use with this standard appear in ISO/IEC 11801: 1995. Exceptions, notes, and additional requirements are as follows:

a) 100BASE-T4 uses a star topology. Horizontal cabling is used to connect PHY entities.

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b) 100BASE-T4 is an ISO/IEC 11801: 1995 class C application, with additional installation requirements and transmission parameters specified in 23.6.2 through 23.6.4. The highest fundamental frequency transmitted by 8B6T coding is 12.5 MHz. The aggregate data rate for three pairs using 8B6T coding is 100 Mb/s.
c) 100BASE-T4 shall use four pairs of balanced cabling, Category 3 or better, with a nominal characteristic impedance of 100 Ω.
d) When using Category 3 cable for the link segment, Clause 23 recommends, but does not require, the use of Category 4 or better connecting hardware, patch cords and jumpers. The use of Category 4 or better connecting hardware increases the link segment composite NEXT loss, composite ELFEXT loss and reduces the link segment insertion loss. This lowers the link segment crosstalk noise, which in turn decreases the probability of errors.
e) The use of shielded cable is outside the scope of this standard.

23.6.2 Link transmission parameters

Unless otherwise specified, link segment testing shall be conducted using source and load impedances of 100 Ω.

23.6.2.1 Insertion loss

The insertion loss of a simplex link segment shall be no more than 12 dB at all frequencies between 2 MHz and 12.5 MHz. This consists of the attenuation of the twisted pairs, connector losses, and reflection losses due to impedance mismatches between the various components of the simplex link segment. The insertion loss specification shall be met when the simplex link segment is terminated in source and load impedances that satisfy 23.5.1.2.4 and 23.5.1.3.3.

NOTE—The loss of PVC-insulated cable exhibits significant temperature dependence. At temperatures greater than 40 °C, it may be necessary to use a less temperature-dependent cable, such as many Fluorinated Ethylene Propylene (FEP), Polytetrafluoroethylene (PTFE), or Perfluoroalkoxy (PFA) plenum-rated cables.

23.6.2.2 Differential characteristic impedance

The magnitude of the differential characteristic impedance of a 3 m length of twisted pair used in a simplex link shall be between 85 Ω and 115 Ω for all frequencies between 2 MHz and 12.5 MHz.

23.6.2.3 Coupling parameters

In order to limit the noise coupled into a simplex link segment from adjacent simplex link segments, Near-End Crosstalk (NEXT) loss and Equal Level Far-End Crosstalk (ELFEXT) loss are specified for each simplex link segment. In addition, since three simplex links (TX_D1, Bl_D3, and Bl_D4) are used to send data between PHYs and one simplex link (RX_D2) is used to carry collision information as specified in 23.1.4, Multiple-Disturber NEXT loss and Multiple-Disturber ELFEXT loss are also specified.

23.6.2.3.1 Differential Near-End Crosstalk (NEXT) loss

The differential Near-End Crosstalk (NEXT) loss between two simplex link segments is specified in order to ensure that collision information can be reliably received by the PHY receiver. The NEXT loss between each of the three data carrying simplex link segments and the collision sensing simplex link segment shall be at least $24.5 - 15\times\log_{10}(f/12.5)$ (where f is the frequency in MHz) over the frequency range 2.0 MHz to 12.5 MHz.

23.6.2.3.2 Multiple-disturber NEXT (MDNEXT) loss

Since three simplex links are used to send data between PHYs and one simplex link is used to carry collision information, the NEXT noise that is coupled into the collision, sensing simplex link segment is from multiple (three) signal sources, or disturbers. The MDNEXT loss between the three data carrying simplex link

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segments and the collision sensing simplex link segment shall be at least $21.4 - 15\times\log_{10}(f/12.5)$ dB (where f is the frequency in MHz) over the frequency range 2.0 to 12.5 MHz. Refer to 12.7.3.2 and Annex B.3 Example Crosstalk Computation for Multiple Disturbers, for a tutorial and method for estimating the MDNEXT loss for an n-pair cable.

23.6.2.3.3 Equal Level Far-End Crosstalk (ELFEXT) loss

Equal Level Far-End Crosstalk (ELFEXT) loss is specified in order to limit the crosstalk noise at the far end of a simplex link segment to meet the BER objective specified in 23.1.2 and the noise specifications of 23.6.3. Far-End Crosstalk (FEXT) noise is the crosstalk noise that appears at the far end of a simplex link segment which is coupled from an adjacent simplex link segment with the noise source (transmitters) at the near end. ELFEXT loss is the ratio of the data signal to FEXT noise at the output of a simplex link segment (receiver input). To limit the FEXT noise from adjacent simplex link segments, the ELFEXT loss between two data carrying simplex link segments shall be greater than $23.1 - 20\times\log_{10}(f/12.5)$ dB (where f is the frequency in MHz) over the frequency range 2.0 MHz to 12.5 MHz. ELFEXT loss at frequency f and distance l is defined as

$$\text{ELFEXT_Loss}\ (f,l) = 20 \times \log_{10}\left(\frac{V_{pds}}{V_{pcn}}\right) - \text{SLS_Loss (dB)}$$

where

V_{pds} is the peak voltage of disturbing signal (near-end transmitter)
V_{pcn} is the peak crosstalk noise at the far end of disturbed simplex link segment
SLS_Loss is the insertion loss of the disturbing simplex link segment

23.6.2.3.4 Multiple-disturber ELFEXT (MDELFEXT) loss

Since three simplex links are used to transfer data between PHYs, the FEXT noise that is coupled into an data carrying simplex link segment is from multiple (two) signal sources, or disturbers. The MDELFEXT loss between a data carrying simplex link segment and the other two data carrying simplex link segments shall be greater than $20.9 - 20\times\log_{10}(f/12.5)$ (where f is the frequency in MHz) over the frequency range 2.0 MHz to 12.5 MHz. Refer to 12.7.3.2 and Annex B.3, Example Crosstalk Computation for Multiple Disturbers, for a tutorial and method for estimating the MDELFEXT loss for an n-pair cable.

23.6.2.4 Delay

Since T4 sends information over three simplex link segments in parallel, the absolute delay of each and the differential delay are specified to comply with network round-trip delay limits and ensure the proper decoding by receivers, respectively.

23.6.2.4.1 Maximum link delay

The propagation delay of a simplex link segment shall not exceed 570 ns at all frequencies between 2.0 MHz and 12.5 MHz.

23.6.2.4.2 Maximum link delay per meter

The propagation delay per meter of a simplex link segment shall not exceed 5.7 ns/m at all frequencies between 2.0 MHz and 12.5 MHz.

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23.6.2.4.3 Difference in link delays

The difference in propagation delay, or skew, under all conditions, between the fastest and the slowest simplex link segment in a link segment shall not exceed 50 ns at all frequencies between 2.0 MHz and 12.5 MHz. It is a further functional requirement that, once installed, the skew between all pair combinations due to environmental conditions shall not vary more than ± 10 ns, within the above requirement.

23.6.3 Noise

The noise level on the link segments shall be such that the objective error ratio is met. The noise environment consists generally of two primary contributors: self-induced near-end crosstalk, which affects the ability to detect collisions, and far-end crosstalk, which affects the signal-to-noise ratio during packet reception.

23.6.3.1 Near-End Crosstalk

The MDNEXT (Multiple-Disturber Near-End Crosstalk) noise on a link segment depends on the level of the disturbing signals on pairs TX_D1, BI_D3, and BI_D4, and the crosstalk loss between those pairs and the disturbed pair, RX_D2.

The MDNEXT noise on a link segment shall not exceed 325 mVp.

This standard is compatible with the following assumptions:

a) Three disturbing pairs with 99th percentile pair-to-pair NEXT loss greater than 24.5 dB at 12.5 MHz (i.e., Category 3 cable).
b) Six additional disturbers (2 per simplex link) representing connectors at the near end of the link segment with 99th percentile NEXT loss greater than 40 dB at 12.5 MHz (i.e., Category 3 connectors installed in accordance with 23.6.4.1).
c) All disturbers combined according to the MDNEXT Monte Carlo procedure outlined in Appendix A3, Example Crosstalk Computation for Multiple Disturbers.

The MDNEXT noise is defined using three maximum level 100BASE-T4 transmitters sending uncorrelated continuous data sequences while attached to the simplex link segments TX_D1, BI_D3, and BI_D4 (disturbing links), and the noise measured at the output of a filter connected to the simplex link segment RX_D2. (disturbed link). Each continuous data sequence is a pseudo-random bit pattern having a length of at least 2047 bits that has been coded according to the 8B6T coding rules in 23.2.1.2. The filter is the 100BASE-T4 Transmit Test Filter specified in 23.5.1.2.3.

23.6.3.2 Far-End Crosstalk

The MDFEXT (Multiple-Disturber Far-End Crosstalk) noise on a link segment depends on the level of the disturbing signals on pairs TX_D1, BI_D3, and BI_D4, and the various crosstalk losses between those pairs.

The MDFEXT noise on a link segment shall not exceed 87 mVp.

This standard is compatible with the following assumptions:

a) Two disturbing pairs with 99th percentile ELFEXT (Equal Level Far-End Crosstalk) loss greater than 23 dB at 12.5 MHz.
b) Nine additional disturbers (three per simplex link) representing connectors in the link segment with 99th percentile NEXT loss greater than 40 dB at 12.5 MHz.
c) All disturbers combined according to the MDNEXT Monte Carlo procedure outlined in Appendix A3, Example Crosstalk Computation for Multiple Disturbers.

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The MDFEXT noise is defined using two maximum level 100BASE-T4 transmitters sending uncorrelated continuous data sequences while attached to two simplex link segments (disturbing links) and the noise measured at the output of a filter connected to the far end of a third simplex link segment (disturbed link). Each continuous data sequence is a pseudo-random bit pattern having a length of at least 2047 bits that has been coded according to the 8B6T coding rules in 23.2.1.2. The filter is the 100BASE-T4 Transmit Test Filter specified in 23.5.1.2.3.

23.6.4 Installation practice

23.6.4.1 Connector installation practices

The amount of untwisting in a pair as a result of termination to connecting hardware should be no greater than 25 mm (1.0 in) for Category 3 cables. This is the same value recommended in ISO/IEC 11801:1995 for Category 4 connectors.

23.6.4.2 Disallow use of Category 3 cable with more than four pairs

Jumper cables, or horizontal runs, made from more than four pairs of Category 3 cable are not allowed.

23.6.4.3 Allow use of Category 5 jumpers with up to 25 pairs

Jumper cables made from up to 25 pairs of Category 5 cable, for the purpose of mass-terminating port connections at a hub, are allowed. Such jumper cables, if used, shall be limited in length to no more than 10 m total.

23.7 MDI specification

This clause defines the MDI. The link topology requires a crossover function between PMAs. Implementation and location of this crossover are also defined in this clause.

23.7.1 MDI connectors

Eight-pin connectors meeting the requirements of section 3 and figures 1 through 5 of IEC 60603-7: 1990 shall be used as the mechanical interface to the balanced cabling. The plug connector shall be used on the balanced cabling and the jack on the PHY. These connectors are depicted (for informational use only) in Figure 23–26 and Figure 23–27. Table 23-6 shows the assignment of PMA signals to connector contacts for PHYs with and without an internal crossover.

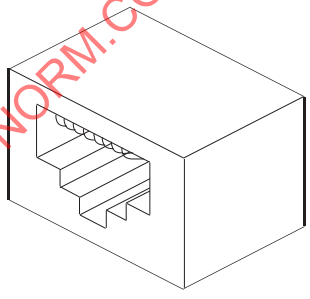

Figure 23–26—MDI connector

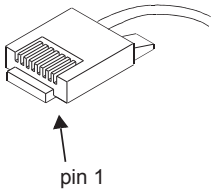

Figure 23–27—Balanced cabling connector

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Table 23-6—MDI connection and labeling requirements

Contact	PHY without internal crossover (recommended for DTE) internal PMA signals	PHY with internal crossover (recommended for repeater) internal PMA signals	MDI labeling requirement
1	TX_D1+	RX_D2+	TX_D1+
2	TX_D1–	RX_D2–	TX_D1–
3	RX_D2+	TX_D1+	RX_D2+
4	BI_D3+	BI_D4+	BI_D3+
5	BI_D3–	BI_D4–	BI_D3–
6	RX_D2–	TX_D1–	RX_D2–
7	BI_D4+	BI_D3+	BI_D4+
8	BI_D4–	BI_D3–	BI_D4–

23.7.2 Crossover function

It is a functional requirement that a crossover function be implemented in every link segment. The crossover function connects the transmitters of one PHY to the receivers of the PHY at the other end of the link segment. Crossover functions may be implemented internally to a PHY or elsewhere in the link segment. For a PHY that does not implement the crossover function, the MDI labels in the last column of Table 23–4 refer to its own internal circuits (second column). For PHYs that do implement the internal crossover, the MDI labels in the last column of Table 23–4 refer to the internal circuits of the remote PHY of the link segment. Additionally, the MDI connector for a PHY that implements the crossover function shall be marked with the graphical symbol “X”. Internal and external crossover functions are shown in Figure 23–28. The crossover function specified here for pairs TX_D1 and RX_D2 is compatible with the crossover function specified in 14.5.2 for pairs TD and RD.

When a link segment connects a DTE to a repeater, it is recommended the crossover be implemented in the PHY local to the repeater. If both PHYs of a link segment contain internal crossover functions, an additional external crossover is necessary. It is recommended that the crossover be visible to an installer from one of the PHYs. When both PHYs contain internal crossovers, it is further recommended in networks in which the topology identifies either a central backbone segment or a central repeater that the PHY furthest from the central element be assigned the external crossover to maintain consistency.

Implicit implementation of the crossover function within a twisted-pair cable, or at a wiring panel, while not expressly forbidden, is beyond the scope of this standard.

23.8 System considerations

The repeater unit specified in Clause 27 forms the central unit for interconnecting 100BASE-T4 twisted-pair links in networks of more than two nodes. It also provides the means for connecting 100BASE-T4 twisted-pair links to other 100 Mb/s baseband segments. The proper operation of a CSMA/CD network requires that network size be limited to control round-trip propagation delay as specified in Clause 29.

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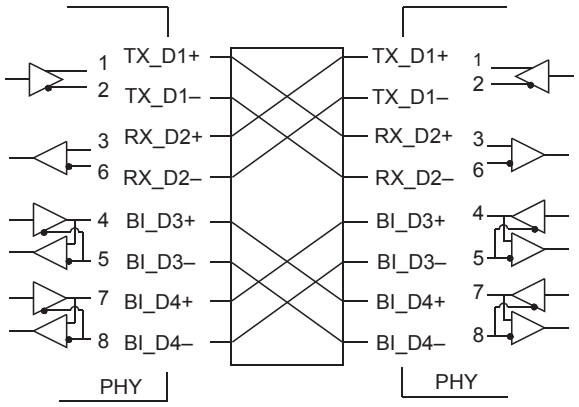
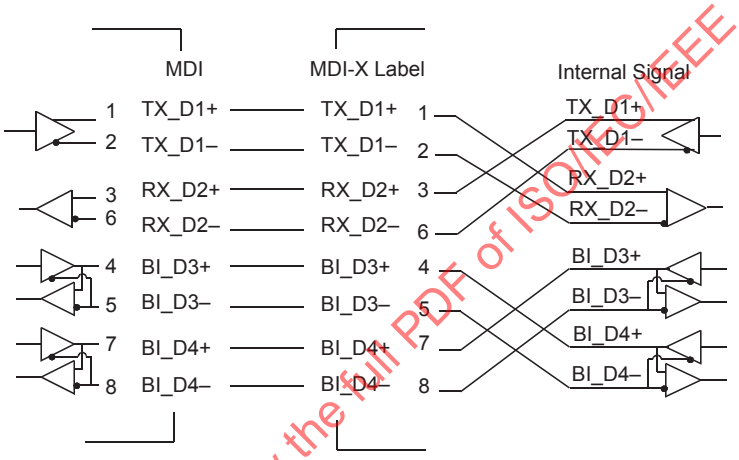


a) Two PHYs with external crossover function



b) PHY with internal crossover function

Figure 23–28—Crossover function

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23.9 Environmental specifications

23.9.1 General safety

All equipment meeting this standard shall conform to IEC 60950: 1991.

23.9.2 Network safety

This clause sets forth a number of recommendations and guidelines related to safety concerns; the list is neither complete nor does it address all possible safety issues. The designer is urged to consult the relevant local, national, and international safety regulations to ensure compliance with the appropriate requirements.

LAN cable systems described in this clause are subject to at least four direct electrical safety hazards during their installation and use. These hazards are as follows:

a) Direct contact between LAN components and power, lighting, or communications circuits
b) Static charge buildup on LAN cables and components
c) High-energy transients coupled onto the LAN cable system

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d) Voltage potential differences between safety grounds to which various LAN components are connected

Such electrical safety hazards must be avoided or appropriately protected against for proper network installation and performance. In addition to provisions for proper handling of these conditions in an operational system, special measures must be taken to ensure that the intended safety features are not negated during installation of a new network or during modification or maintenance of an existing network.

23.9.2.1 Installation

It is a mandatory functional requirement that sound installation practice, as defined by applicable local codes and regulations, be followed in every instance in which such practice is applicable.

23.9.2.2 Grounding

Any safety grounding path for an externally connected PHY shall be provided through the circuit ground of the MII connection.

WARNING

It is assumed that the equipment to which the PHY is attached is properly grounded, and not left floating nor serviced by a "doubly insulated, ac power distribution system." The use of floating or insulated equipment, and the consequent implications for safety, are beyond the scope of this standard.

23.9.2.3 Installation and maintenance guidelines

It is a mandatory functional requirement that, during installation and maintenance of the cable plant, care be taken to ensure that noninsulated network cable conductors do not make electrical contact with unintended conductors or ground.

23.9.2.4 Telephony voltages

The use of building wiring brings with it the possibility of wiring errors that may connect telephony voltages to 100BASE-T4 equipment. Other than voice signals (which are low voltage), the primary voltages that may be encountered are the "battery" and ringing voltages. Although there is no universal standard, the following maximums generally apply.

Battery voltage to a telephone line is generally 56 Vdc applied to the line through a balanced 400 Ω source impedance.

Ringing voltage is a composite signal consisting of an ac component and a dc component. The ac component is up to 175 V peak at 20 Hz to 60 Hz with a 100 Ω source resistance. The dc component is 56 Vdc with a 300 Ω to 600 Ω source resistance. Large reactive transients can occur at the start and end of each ring interval.

Although 100BASE-T4 equipment is not required to survive such wiring hazards without damage, application of any of the above voltages shall not result in any safety hazard.

NOTE—Wiring errors may impose telephony voltages differentially across 100BASE-T4 transmitters or receivers. Because the termination resistance likely to be present across a receiver's input is of substantially lower impedance than an off-hook telephone instrument, receivers will generally appear to the telephone system as off-hook telephones. Therefore, full-ring voltages will be applied for only short periods. Transmitters that are coupled using transformers will similarly appear like off-hook telephones (though perhaps a bit more slowly) due to the low resistance of the transformer coil.

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23.9.3 Environment

23.9.3.1 Electromagnetic emission

The twisted-pair link shall comply with applicable local and national codes for the limitation of electromagnetic interference.

23.9.3.2 Temperature and humidity

The twisted-pair link is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

It is recommended that manufacturers indicate in the literature associated with the PHY the operating environmental conditions to facilitate selection, installation, and maintenance.

23.10 PHY labeling

It is recommended that each PHY (and supporting documentation) be labeled in a manner visible to the user with at least these parameters:

a) Data rate capability in Mb/s
b) Power level in terms of maximum current drain (for external PHYs)
c) Any applicable safety warnings

See also 23.7.2.

23.11 Timing summary

23.11.1 Timing references

All MII signals are defined (or corrected to) the DTE end of a zero length MII cable.

NOTE—With a finite length MII cable, TX_CLK appears in the PHY one cable propagation delay *earlier* than at the MII. This advances the transmit timing. Receive timing is retarded by the same amount.

The phrase *adjusted for pair skew*, when applied to a timing reference on a particular pair, means that the designated timing reference has been adjusted by adding to it the difference between the time of arrival of preamble on the latest of the three receive pairs and the time of arrival of preamble on that particular pair.

PMA_UNITDATA.request

Figures 23–29, 23–30, 23–31, and 23–32. The implementation of this abstract message is not specified. Conceptually, this is the time at which the PMA has been given full knowledge and use of the ternary symbols to be transmitted.

PMA_UNITDATA.indication

Figure 23–33. The implementation of this abstract message is not specified. Conceptually, this is the time at which the PCS has been given full knowledge and use of the ternary symbols received.

WAVEFORM

Figure 23–29. Point in time at which output waveform has moved 1/2 way from previous nominal output level to present nominal output level.

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TX_EN

Figure 23–30. First rising edge of TX_CLK following the rising edge of TX_EN.

NOT_TX_EN

Figure 23–31 and Figure 23–32. First rising edge of TX_CLK following the falling edge of TX_EN.

CRS

Figure 23–33. Rising edge of CRS.

CARRIER_STATUS

Figure 23–33. Rising edge of carrier_status.

NOT_CARRIER_STATUS

Figure 23–34. Falling edge of carrier_status.

RX_DV

No figure. First rising edge of RX_CLK following rising edge of RX_DV.

COL

No figure. Rising edge of COL signal at MII.

NOT_COL

No figure. Falling edge of COL signal at MII.

PMA_ERROR

No figure. Time at which rxerror_status changes to ERROR.

23.11.2 Definitions of controlled parameters

PMA_OUT

Figure 23–29. Time between PMA_UNITDATA.request (tx_code_vector) and the WAVEFORM timing reference for each of the three transmit channels TX_D1, BI_D3, or BI_D4.

TEN_PMA

Figure 23–30, Figure 23–31, and Figure 23–32. Time between TX_EN timing reference and MA_UNITDATA.request (tx_code_vector).

TEN_CRS

Figure 23–30. Time between TX_EN timing reference and the loopback of TX_EN to CRS as measured at the CRS timing reference point.

NOT_TEN_CRS

Figure 23–31 and Figure 23–32. Time between NOT_TX_EN timing reference and the loopback of TX_EN to CRS as measured at the NOT_CRS timing reference point. In the event of a collision (COL is raised at any point during a packet) the minimum time for NOT_TEN_CRS may optionally be as short as 0.

RX_PMA_CARRIER

Figure 23–33. Time between the WAVEFORM timing reference, adjusted for pair skew, of first pulse of a normal preamble (or first pulse of a preamble preceded by a link test pulse or a partial link test pulse) and the CARRIER_STATUS timing reference.

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RX_CRS

Figure 23–33. Time between the WAVEFORM timing reference, adjusted for pair skew, of first pulse of a normal preamble (or first pulse of a preamble preceded by a link test pulse or a partial link test pulse) and the CRS timing reference.

NOTE—The input waveform used for this test is an ordinary T4 preamble, generated by a compliant T4 transmitter. As such, the delay between the first and third pulses of the preamble (which are used by the carrier sense logic) is very nearly 80 ns.

RX_NOT_CRS

For a data packet, the time between the WAVEFORM timing reference, adjusted for pair skew, of the first pulse of eop1, and the deassertion of CRS. For a collision fragment, the time between the WAVEFORM timing reference, adjusted for pair skew, of the ternary symbol on pair TX_D2, which follows the last ternary data symbol received on pair RX_D2, and the deassertion of CRS.

Both are limited to the same value. For a data packet, detection of the six ternary symbols of eopo1 is accomplished in the PCS layer. For a collision fragment, detection of the concluding seven ternary zeros is accomplished in the PMA layer, and passed to the PCS in the form of the carrier_status indication.

FAIRNESS

The difference between RX_NOT_CRS at the conclusion of one packet and RX_CRS on a subsequent packet. The packets used in this test may arrive with an IPG anywhere in the range of 80 to 160.

RX_PMA_DATA

Figure 23–33. Time between the WAVEFORM timing reference, adjusted for pair skew, of first pulse of a normal preamble (or first pulse of a preamble preceded by a link test pulse or a partial link test pulse) and the particular PMA_UNITDATA.indication that transfers to the PCS the first ternary symbol of the first 6T code group from receive pair BI_D3.

EOP_CARRIER_STATUS

Figure 23–34. For a data packet, the time between the WAVEFORM timing reference, adjusted for pair skew, of first pulse of eop1 and the NOT_CARRIER_STATUS timing reference.

EOC_CARRIER_STATUS

Figure 23–35. In the case of a colliding packet, the time between the WAVEFORM timing reference, adjusted for pair skew, of the ternary symbol on pair RX_D2, which follows the last ternary data symbol received on pair RX_D2 and the NOT_CARRIER_STATUS timing reference.

RX_RXDV

No figure. Time between WAVEFORM timing reference, adjusted for pair skew, of first pulse of a normal preamble (or first pulse of a preamble preceded by a link test pulse or a partial link test pulse) and the RX_DV timing reference.

RX_PMA_ERROR

No figure. In the event of a preamble in error, the time between the WAVEFORM timing reference adjusted for pair skew, of first pulse of that preamble (or first pulse of the preamble preceded by a link test pulse or a partial link test pulse), and the PMA_ERROR timing reference.

RX_COL

No figure. In the event of a collision, the time between the WAVEFORM timing reference adjusted for pair skew, of first pulse of a normal preamble (or first pulse of a preamble preceded by a link test pulse or a partial link test pulse), and the COL timing reference.

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RX_NOT_COL

No figure. In the event of a collision in which the receive signal stops before the locally transmitted signal, the time between the WAVEFORM timing reference adjusted for pair skew, of the ternary symbol on pair RX_D2, which follows the last ternary data symbol received on pair RX_D2 and the NOT_COL timing reference point.

TX_NOT_COL

No figure. In the event of a collision in which the locally transmitted signal stops before the received signal, the time between the NOT_TX_EN timing reference and the loopback of TX_EN to COL as measured at the NOT_COL timing reference point.

TX_SKEW

Greatest absolute difference between a) the waveform timing reference of the first pulse of a preamble as measured on output pair TX_D1; b) the waveform timing reference of the first pulse of a preamble as measured on output pair BI_D3; and c) the waveform timing reference of the first pulse of a preamble as measured on output pair BI_D4. Link test pulses, if present during the measurement, must be separated from the preamble by at least 100 ternary symbols.

CRS_PMA_DATA

Time between the timing reference for CARRIER STATUS and the transfer, via PMA_UNITDATA.indication, of the first ternary symbol of the 6T code group marked DATA1 in Figure 23–6.

COL_to_BI_D3/D4_OFF

No figure. In the case of a colliding packet, the time between the WAVE FORM timing reference, adjusted for pair skew, of the first pulse of preamble (or the first pulse of the preamble preceded by a link test pulse or a partial link test pulse) on RX_D2, and the first ternary zero transmitted on BI_D3 and on BI_D4.

NOTE—Subclause 23.4.1.2 mandates that transmission on pairs BI_D3 and BI_D4 be halted in the event of a collision.

23.11.3 Table of required timing values

While in the LINK_PASS state, each PHY timing parameter shall fall within the Low and High limits listed in Table 23–7. All units are in bit times. A bit time equals 10 ns.

Table 23–7—Required timing values

Controlled parameter	Low limit (bits)	High limit (bits)	Comment
PMA_OUT	1	9.5	
TEN_PMA + PMA_OUT	7	17.5	
TEN_CRS	0	+4	
NOT_TEN_CRS	0	36	
RX_PMA_CARRIER	0	15.5	
RX_CRS	0	27.5	
RX_NOT_CRS	0	51.5	

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Table 23–7—Required timing values *(continued)*

Controlled parameter	Low limit (bits)	High limit (bits)	Comment
FAIRNESS	0	28	
RX_PMA_DATA	67	90.5	
EOP_CARRIER_STATUS	51	74.5	
EOC_CARRIER_STATUS	3	50.5	
RX_RXDV	81	114.5	
RX_PMA_ERROR	RX_PMA_DATA	RX_PMA_DATA + 20	Allowed limits equal the actual RX_PMA_DATA time for the device under test plus from 0 to 20 BT
RX_COL	0	27.5	SAME AS RX_CRS
RX_NOT_COL	0	51.5	SAME AS RX_NOT_CRS
TX_NOT_COL	0	36	
TX_SKEW	0	0.5	
CRS_PMA_DATA	0	78.5	
COL_to_BI_D3/D4_OFF	0	40	

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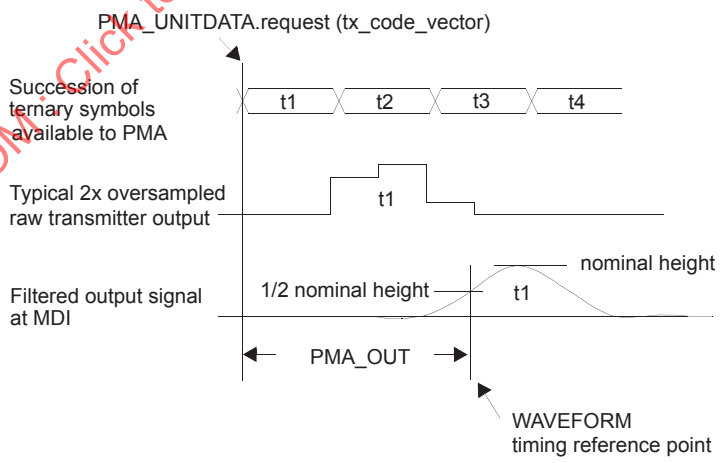

Figure 23–29—PMA TRANSMIT timing while tx_code_vector = DATA

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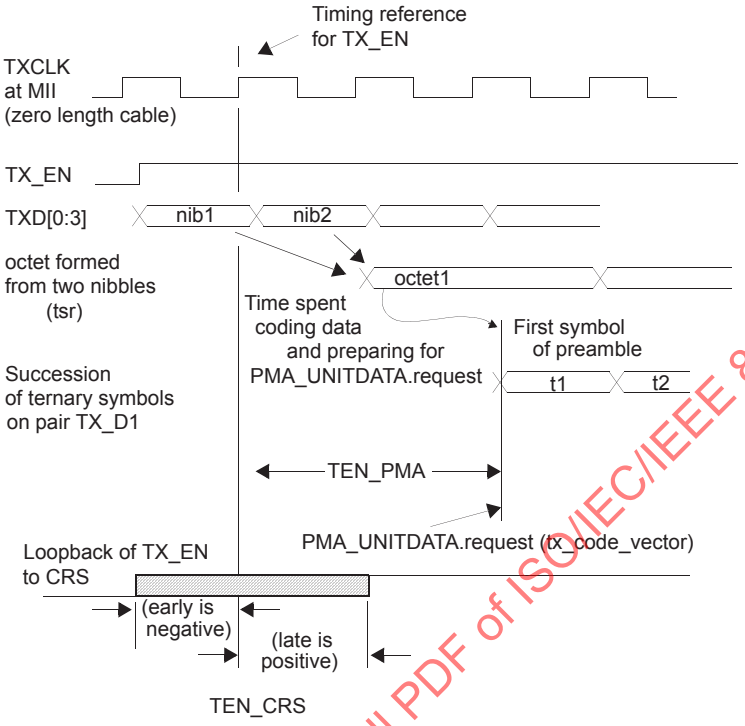

Figure 23–30—PCS TRANSMIT timing at start of packet

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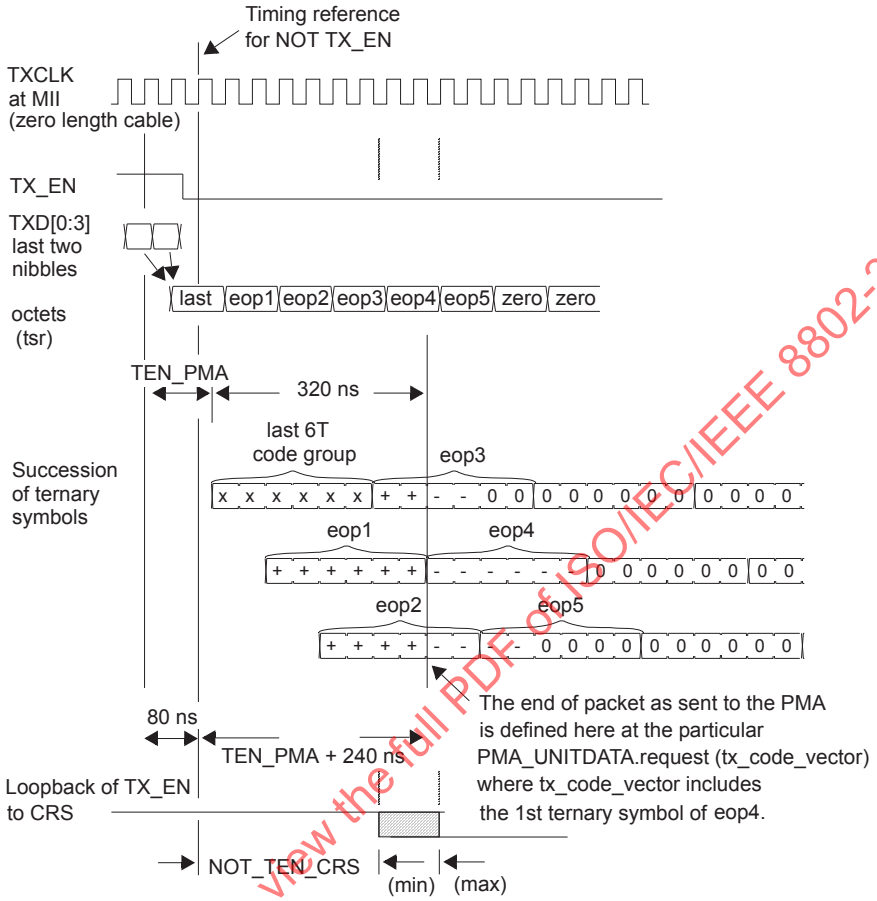

Figure 23–31—PCS TRANSMIT timing end of normal packet

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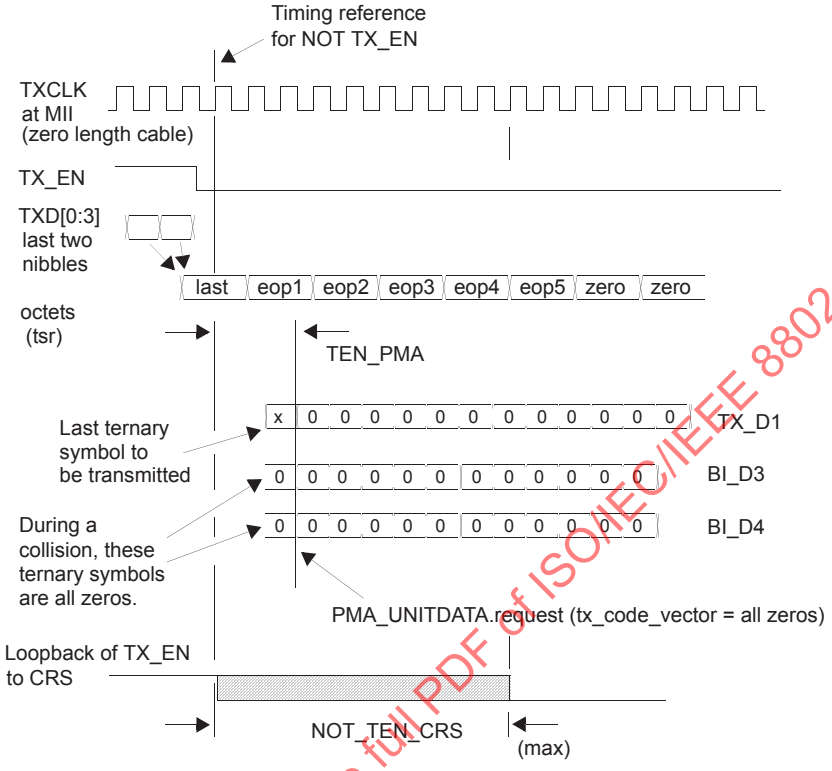

Figure 23–32—PCS TRANSMIT timing end of colliding packet

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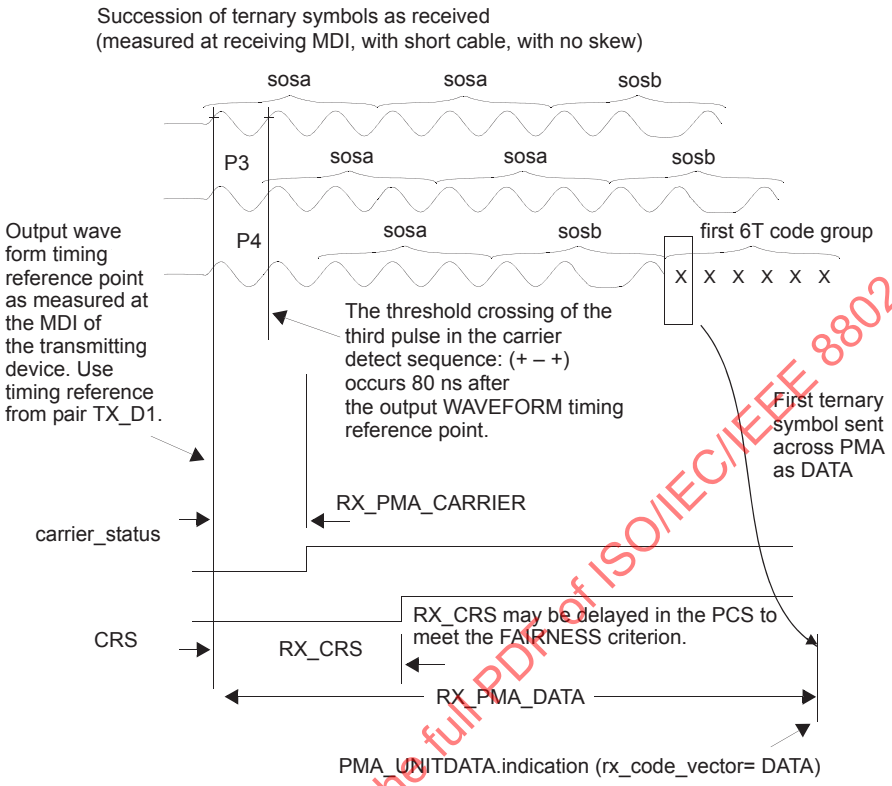

Figure 23–33—PMA RECEIVE timing start of packet

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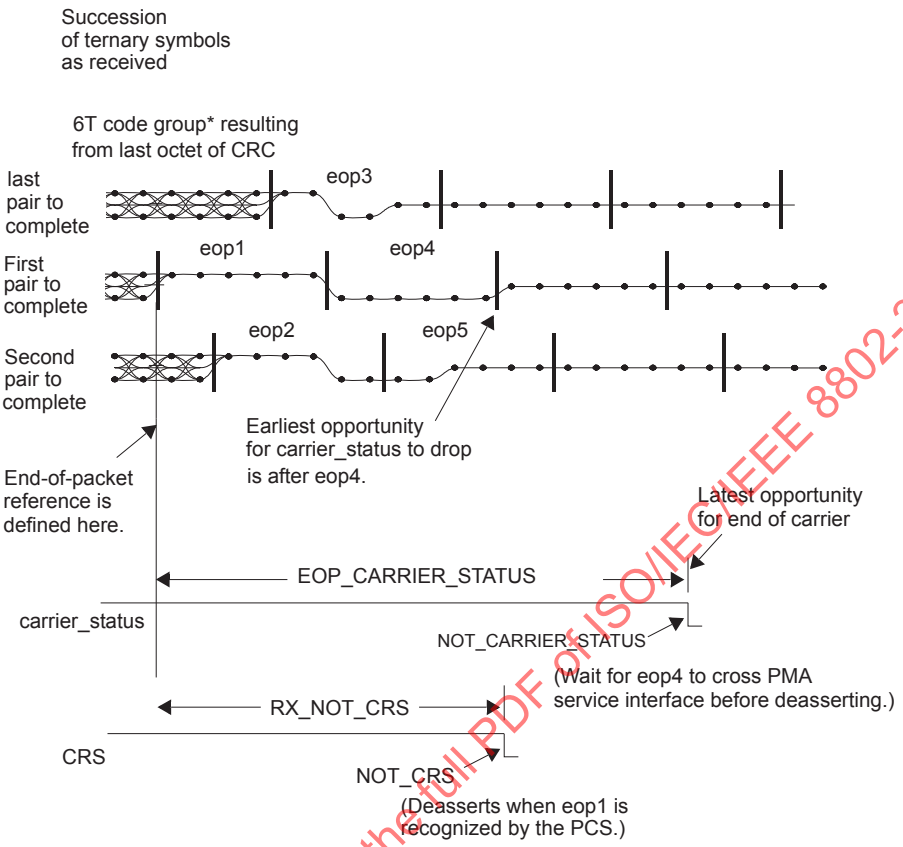

*RX_DV deasserts after sending the last nibble of this decoded octet across the MII. CRS may deassert prior to that time.

Figure 23–34—PMA RECEIVE timing end of normal packet

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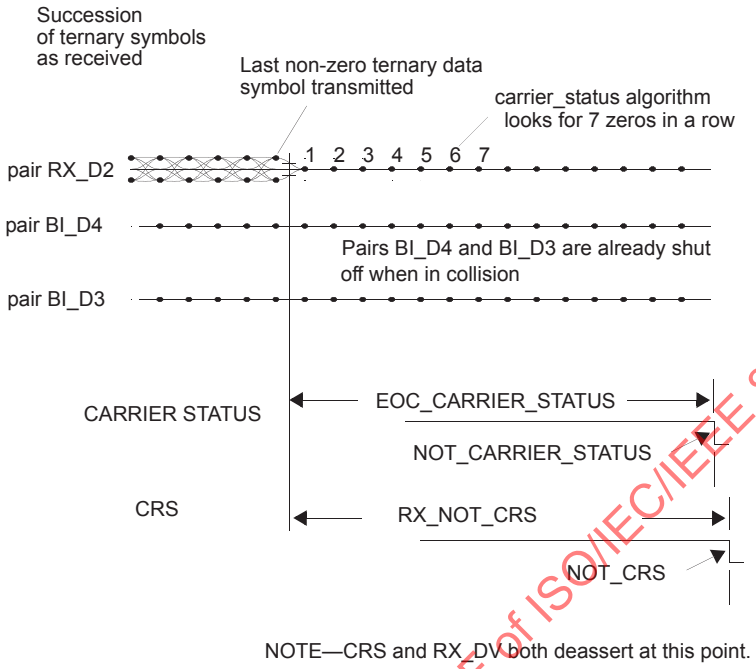

Figure 23–35—PMA RECEIVE timing end of colliding packet

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23.12 Protocol implementation conformance statement (PICS) proforma for Clause 23, Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer, and baseband medium, type 100BASE-T4[4]

23.12.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 23, Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer, and baseband medium, type 100BASE-T4, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

23.12.2 Identification

23.12.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

23.12.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2012, Clause 23, Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer, and baseband medium, type 100BASE-T4
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2012.)	No [ ] Yes [ ]

Date of Statement	

[4]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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23.12.3 Major capabilities/options

Item	Feature	Subclause	Status	Support	Value/Comment
*MII	Exposed MII interface	23.1.5.3	O		Devices supporting this option must also support the PCS option
*PCS	PCS functions	23.1.5.2	O		Required for integration with DTE or MII
*PMA	Exposed PMA service interface	23.1.5.2	O		Required for integration into symbol level repeater core
*XVR	Internal wiring crossover	23.7.2	O		Usually implemented in repeater, usually not in DTE
*NWY	Support for optional Auto-Negotiation (Clause 28)	23.1.5.4	O		Required if Auto-Negotiation is implemented
*INS	Installation / cable		O		Items marked with INS include installation practices and cable specifications not applicable to a PHY manufacturer

23.12.4 PICS proforma tables for the Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer and baseband medium, type 100BASE-T4

23.12.4.1 Compatibility considerations

Item	Feature	Subclause	Status	Support	Value/Comment
CCO-1	Compatibility at the MDI	23.1.5.1	M		

23.12.4.2 PCS Transmit functions

Item	Feature	Subclause	Status	Support	Value/Comment
PCT-1	PCS Transmit function	23.2.1.2	PCS:M		Complies with state diagram Figure 23–8
PCT-2	Data encoding	23.2.1.2	PCS:M		8B6T with DC balance encoding rules
PCT-3	Order of ternary symbol transmission	Annex 23A	PCS:M		Leftmost symbol of each 6T code group first

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23.12.4.3 PCS Receive functions

Item	Feature	Subclause	Status	Support	Value/Comment
PCR1	PCS Receive function	23.2.1.3	PCS:M		Complies with state diagram Figure 23–9
PCR2	Value of RXD<3:0> while RXDV is deasserted	23.2.1.3	PCS:M		All zeros
PCR3	Data decoding	23.2.1.3	PCS:M		8B6T with error detecting rules
PCR4	Value of dc_balance_error, eop_error and codeword_error at times other than those specified in the error detecting rules.	23.2.1.3	PCS:M		OFF
PCR5	Codeword_error indication sets RX_ER when	23.2.1.3	PCS:M		During transfer of both affected data nibbles across the MII
PCR6	Dc_balance_error sets RX_ER when	23.2.1.3	PCS:M		During transfer of both affected nibbles across the MII
PCR7	Eop_error sets RX_ER when	23.2.1.3	PCS:M		During transfer of last decoded data nibble across the MII
PCR8	Action taken if carrier_status is truncated due to early deassertion of carrier_status	23.2.1.3	PCS:M		Assert RX_ER, and then deassert RX_DV

23.12.4.4 Other PCS functions

Item	Feature	Subclause	Status	Support	Value/Comment
PCO1	PCS Reset function executed when	23.2.1.1	PCS:M		Power-on, or the receipt of a reset request from the management entity
PCO2	PCS Error Sense function	23.2.1.4	PCS:M		Complies with state diagram Figure 23–10
PCO3	Signaling of RX_ER to MII	23.2.1.4	PCS:M		Before last nibble of Clause 4 MAC frame has passed across MII
PCO4	Timing of rxerror_status	23.2.1.4	PCS:M		Causes RX_ER to appear on the MII no later than last nibble of first data octet
PCO5	PCS Carrier Sense function	23.2.1.5	PCS:M		Controls MII signal CRS according to rules in 23.2.1.5
PCO6	MII signal COL is asserted when	23.2.1.6	PCS:M		Upon detection of a PCS collision
PCO7	At other times COL remains	23.2.1.6	PCS:M		Deasserted
PCO8	Loopback implemented in accordance with 22.2.4.1.2	23.2.2.2	PCS:M		Redundantly specified in 22.2.4.1.2

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23.12.4.4 Other PCS functions *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
PCO9	No spurious signals emitted on the MDI during or after power down	23.2.2.2	M		
PCO10	PMA frame structure	23.2.3	M		Conformance to Figure 23–6
PCO11	PMA_UNITDATA messages	23.2.3	PMA:M		Must have a clock for both directions

23.12.4.5 PCS state diagram variables

Item	Feature	Subclause	Status	Support	Value/Comment
PCS1	Timing of eop adjusted such that the last nibble sent across the MII with RX_DV asserted is	23.2.4.2	PCS:M		Last nibble of last decoded data octet in a packet
PCS2	Transmission of octets on the three transmit pairs	23.2.4.2	PCS:M		Transmission order is: TX_D1, then BI_D3, and then BI_D4
PCS3	Value of tsr during first 16 TX_CLK cycles after TX_EN is asserted	23.2.4.2	PCS:M		sosa, sosa, sosa, sosa, sosa, sosa, sosa, sosa, sosa, sosa, sosb, sosb, sosb, sosb, sosb, sosb
PCS4	Value of tsr during first 10 TX_CLK cycles after TX_EN is deasserted	23.2.4.2	PCS:M		eop1, eop1, eop2, eop2, eop3, eop3, eop4, eop4, eop5, eop5
PCS5	TX_ER causes transmission of	23.2.4.2	PCS:M		bad_code
PCS6	TX_ER received during the first 16 TX_CLK cycles causes	23.2.4.2	PCS:M		Transmission of **bad_code** during 17th and 18th clock cycles
PCS7	Action taken in event TX_EN falls on an odd nibble boundary	23.2.4.2	PCS:M		Extension of TX_EN by one TX_CLK cycle, and transmission of bad_code
PCS8	Transmission when TX_EN is not asserted	23.2.4.2	PCS:M		zero_code
PCS9	TX_CLK generated synchronous to	23.2.4.2	PCS:M		tw1_timer

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23.12.4.6 PMA service interface

Item	Feature	Subclause	Status	Support	Value/Comment
PMS1	Continuous generation of PMA_TYPE	23.3.1.2	M		
PMS2	Generation of PMA_UNIT-DATA.indication (DATA) messages	23.3.3.2	M		synchronous with data received at the MDI
PMS3	Generation of PMA_CARRIER.indication message	23.3.4.2	M		ON/OFF
PMS4	Generation of PMA_LINK.indication mes-sage	23.3.5.2	M		FAIL/READY/OK
PMS5	Link_control defaults on power-on or reset to	23.3.6.2	M		ENABLE
PMS6	Action taken in SCAN_FOR_CARRIER mode	23.3.6.4	NWY:M		Enables link integrity state dia-gram, but blocks passage into LINK_PASS
PMS7	Reporting of link_status while in SCAN_FOR_CARRRIER mode	23.3.6.4	NWY:M		FAIL / READY
PMS8	Reporting of link_status while in DISABLE mode	23.3.6.4	NWY:M		FAIL
PMS9	Action taken in ENABLE mode	23.3.6.4	NWY:M		enables data processing functions
PMS10	Generation of PMA_RXERROR	23.3.7.2	M		ERROR / NO_ERROR

23.12.4.7 PMA Transmit functions

Item	Feature	Subclause	Status	Support	Value/Comment
PMT1	Transmission while (tx_code_vector=DATA) * (pma_carrier=OFF)	23.4.1.2	M		tx_code_vector[TX_D1] tx_code_vector[BI_D3] tx_code_vector[BI_D4]
PMT2	Transmission from time (tx_code_vector=DATA) * (pma_carrier=ON), until (tx_code_vector=IDLE	23.4.1.2	M		tx_code_vector[TX_D1] CS0 CS0
PMT3	Transmission while tx_code_vector=IDLE	23.4.1.2	M		Idle signal TP_DIL_100
PMT4	Duration of silence between link test pulses	23.4.1.2	M		1.2 ms ± 0.6 ms
PMT5	Link test pulse composed of	23.4.1.2	M		CS-1, CS1 transmitted on TX_D1

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23.12.4.7 PMA Transmit functions *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
PMT6	Following a packet, TP_IDL_100 signal starts with	23.4.1.2	M		Period of silence
PMT7	Effect of termination of TP_IDL_100	23.4.1.2	M		No delay or corruption of subsequent packet
PMT8	Zero crossing jitter of link test pulse	23.4.1.2	M		Less than 4 ns p-p
PMT9	Action taken when xmit=disable	23.4.1.2	M		Transmitter behaves as if tx_code_vector=IDLE

23.12.4.8 PMA Receive functions

Item	Feature	Subclause	Status	Support	Value/Comment
PMR1	Reception and translation of data with ternary symbol error ratio less than	23.4.1.3	M		One part in 10^8
PMR2	Assertion of pma_carrier=ON upon reception of test signal	23.4.1.4	M		Test signal is a succession of three data values, produced synchronously with a 25 MHz clock, both preceded and followed by 100 symbols of silence. The three values are: 467 mV, –225 mV, and then 467 mV again
PMR3	condition required to turn off pma_carrier	23.4.1.4	M		Either of a) Seven consecutive zeros b) Reception of eop1 per 23.4.1.4
PMR4	Value of carrier_status while rcv=ENABLE	23.4.1.4	M		pma_carrier
PMR5	Value of carrier_status while rcv=DISABLE	23.4.1.4	M		OFF

23.12.4.9 Link Integrity functions

Item	Feature	Subclause	Status	Support	Value/Comment
LIF1	Link Integrity function complies with	23.4.1.5	M		State diagram Figure 23–12

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23.12.4.10 PMA Align functions

Item	Feature	Subclause	Status	Support	Value/Comment
ALN1	Generation of PMA_UNITDATA.indication (PREAMBLE) messages	23.4.1.6	M		
ALN2	Ternary symbols transferred by first PMA_UNITADATA.indication (DATA) message	23.4.1.6	M		rx_code_vector[BI_D3]: first ternary symbol of first data code group rx_code_vector[BI_D2]: two ternary symbols prior to start of second data code group rx_code_vector[BI_D4]: four ternary symbols prior to start of third data code group
ALN3	PMA_UNITDATA.indication (DATA) messages continue until carrier_status=OFF	23.4.1.6	M		
ALN4	While carrier_status=OFF, PMA emits message	23.4.1.6	M		PMA_UNITDATA.indication (IDLE)
ALN5	Failure to recognize SSD generates rxerror_status=ERROR	23.4.1.6	M		
ALN6	Action taken when carrier_status=OFF	23.4.1.6	M		Clear rxerror_status
ALN7	Action taken if first packet is used for alignment	23.4.1.6	M		PMA emits PMA_UNITDATA..indication (PREAMBLE)
ALN8	Tolerance of line skew	23.4.1.6	M		60 ns
ALN9	Detection of misplaced **sosb** 6T code group caused by 3 or fewer ternary symbols in error	23.4.1.6	M		
ALN10	Action taken if **rcv**=disable	23.4.1.6	M		PMA emits PMA_UNITDATA..indication (IDLE)

23.12.4.11 Other PMA functions

Item	Feature	Subclause	Status	Support	Value/Comment
PMO1	PMA Reset function	23.4.1.1	M		
PMO2	Suitable clock recovery	23.4.1.7	M		

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23.12.4.12 Isolation requirements

Item	Feature	Subclause	Status	Support	Value/Comment
ISO1	Values of all components used in test circuits	23.5	M		Accurate to within ±1% unless required otherwise
ISO2	Electrical isolation meets	23.5.1.1	M		1500 V at 50–60 Hz for 60 s per IEC 60950: 1991 *or* 2250 Vdc for 60 s per IEC 60950: 1991 *or* Ten 2400 V pulses per IEC 60060
ISO3	Insulation breakdown during isolation test	23.5.1.1	M		None per IEC 60950: 1991
ISO4	Resistance after isolation test	23.5.1.1	M		At least 2 M Ω

23.12.4.13 PMA electrical requirements

Item	Feature	Subclause	Status	Support	Value/Comment
PME1	Conformance to all transmitter specifications in 23.5.1.2	23.5.1.2	M		
PME2	Transmitter load unless otherwise specified	23.5.1.2	M		100 Ω
PME3	Peak differential output voltage	23.5.1.2.1	M		3.15–3.85 V
PME4	Differential transmit template at MDI	23.5.1.2.2	M		Table 23–2
PME5	Differential MDI output template voltage scaling	23.5.1.2.2	M		3.15– 3.85 V
PME6	Interpolation between points on transmit template	23.5.1.2.2	M		Linear
PME7	Differential link pulse template at MDI	23.5.1.2.2	M		Table 23–2
PME8	Differential link pulse template scaling	23.5.1.2.2	M		Same value as used for differential transmit template scaling
PME9	Interpolation between point on link pulse template	23.5.1.2.2	M		Linear
PME10	State when transmitting seven or more consecutive CS0 during TP_IDL-100 signal	23.5.1.2.2	M		–50 mV to 50 mV
PME11	Limit on magnitude of harmonics measured at MDI	23.5.1.2.2	M		27 dB below fundamental
PME12	Differential output ISI	23.5.1.2.3	M		Less than 9%

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23.12.4.13 PMA electrical requirements *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
PME13	Measurement of ISI and peak-to-peak signal voltage	23.5.1.2.3	M		Halfway between nominal zero crossing of the observed eye pattern
PME14	Transfer function of 100BASE-T4 transmit test filter	23.5.1.2.3	M		Third-order Butterworth filter with –3 dB point at 25.0 MHz
PME15	Reflection loss of 100BASE-T4 transmit test filter and 100 W load across the frequency range 2–12.5 MHz	23.5.1.2.3	M		Exceeds 17 dB
PME16	Differential output impedance	23.5.1.2.4	M		Provide return loss into 100 Ω of 17 dB from 2.0 to 12.5 MHz
PME17	Maintenance of return loss	23.5.1.2.4	M		At all times PHY is fully powered
PME18	Droop as defined in Figure 23–18 during transmission of eop1 and eop4	23.5.1.2.4	M		Less than 6%
PME19	Output timing jitter	23.5.1.2.5	M		No more than 4 ns peak-to-peak
PME20	Measurement of output timing jitter	23.5.1.2.5	M		Other transmit outputs connected to 100BASE-T4 ISI test filter or 100 Ω load
PME21	Minimum transmitter impedance balance	23.5.1.2.6	M		$29 - 17\log\left(\frac{f}{10}\right)$ dB
PME22	Transmitter common-mode rejection; effect of E_{cm} as shown in Figure 23–20 upon E_{dif}	23.5.1.2.8	M		Less than 100 mV
PME23	Transmitter common-mode rejection; effect of E_{cm} as shown in Figure 23–20 upon edge jitter	23.5.1.2.8	M		Less than 1.0 ns
PME24	E_{cm} used for common-mode rejection tests	23.5.1.2.8	M		15 V peak, 10.1 MHz sine wave
PME25	Transmitter faults; response to indefinite application of short circuits	23.5.1.2.9	M		Withstand without damage and resume operation after fault is removed
PME26	Transmitter faults; response to 1000 V common-mode impulse per IEC 60060	23.5.1.2.9	M		Withstand without damage
PME27	Shape of impulse used for common-mode impulse test	23.5.1.2.9	M		0.3/50 μs as defined in IEC 60060
PME28	Ternary symbol transmission rate	23.5.1.2.10	M		25.000 MHz ± 0.01%

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23.12.4.13 PMA electrical requirements *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
PME29	Conformance to all receiver specifications in 23.5.1.3	23.5.1.3	M		
PME30	Action taken upon receipt of differential signals that were transmitted within the constraints of 23.5.1.2 and have passed through worst-case UTP model	23.5.1.3.1	M		Correctly translated into PMA_UNITDATA messages
PME31	Action taken upon receipt of link test pulse	23.5.1.3.1	M		Accept as a link test pulse
PME32	Test configuration for data reception and link test pulse tests	23.5.1.3.1	M		Using worst-case UTP model, and with a connection less than one meter in length
PME33	Bit loss	23.5.1.3.2	M		No more than that specified in 23.5.1.3.1
PME34	Reaction of pma_carrier to signal less than 325 mV peak	23.5.1.3.2	M		Must not set pma_carrier=ON
PME35	Reaction of pma_carrier to continuous sinusoid less than 1.7 MHz	23.5.1.3.2	M		Must not set pma_carrier=ON
PME36	Reaction of pma_carrier to single cycle or less	23.5.1.3.2	M		Must not set pma_carrier=ON
PME37	Reaction of pma_carrier to fast link pulse as defined in Clause 28	23.5.1.3.2	M		Must not set pma_carrier=ON
PME38	Reaction of pma_carrier to link integrity test pulse signal TP_IDL_100	23.5.1.3.2	M		Must not set pma_carrier=ON
PME39	Differential input impedance	23.5.1.3.3	M		Provide return loss into 100 Ω of 17 dB from 2.0 to 12.5 MHz
PME40	Maintenance of return loss	23.5.1.3.3	M		At all times PHY is fully powered
PME41	Droop as defined in Figure 23–18 during reception of test signal defined in Figure 23–19	23.5.1.3.3	M		Less than 6%
PME42	Receiver common-mode rejection; effect of E_{cm} as shown in Figure 23–24	23.5.1.3.4	M		Receiver meets 23.5.1.3.1
PME43	E_{cm} used for common-mode rejection tests	23.5.1.3.4	M		25 V peak-to-peak square wave, 500 kHz or lower in frequency, with edges no slower than 4 ns
PME44	Receiver faults; response to indefinite application of short circuits	23.5.1.3.5	M		Withstand without damage and resume operation after fault is removed

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23.12.4.13 PMA electrical requirements *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
PME45	Receiver faults; response to 1000 V common-mode impulse per IEC 60060	23.5.1.3.5	M		Withstand without damage
PME46	Shape of impulse used for common-mode impulse test	23.5.1.3.5	M		0.3/50 µs as defined in IEC 60060
PME47	Receiver properly receives data have a worst-case ternary symbol range	23.5.1.3.6	M		25.00 MHz ± 0.01%
PME48	Steady-state current consumption	23.5.2	MII:M		0.75 A maximum
PME49	PHY operating voltage range	23.5.2	MII:M		Includes worst voltage available from MII
PME50	Extraneous signals induced on the MII control circuits during normal power-up and power-down	23.5.2	M		None

23.12.4.14 Characteristics of the link segment

Item	Feature	Subclause	Status	Support	Value/Comment
LNK1	Cable used	23.6.1	INS:M		Four pairs of balanced cabling, Category 3 or better, with a nominal characteristic impedance of 100 Ω
LNK2	Source and load impedance used for cable testing (unless otherwise specified)	23.6.2	INS:M		100 Ω
LNK3	Insertion loss of simplex link segment	23.6.2.1	INS:M		Less than 12 dB
LNK4	Source and load impedances used to measure cable insertion loss	23.6.2.1	INS:M		Meet 23.5.1.2.4 and 23.5.1.3.3
LNK5	Characteristic impedance over the range 2–12.5 MHz	23.6.2.2	INS:M		85–115 Ω
LNK6	NEXT loss between 2 and 12.5 MHz	23.6.2.3.1	INS:M		Greater than $24.5 - 15\log\left(\frac{f}{12.5}\right)$ dB
LNK7	MDNEXT loss between 2 and 12.5 MHz	23.6.2.3.2	INS:M		Greater than $21.4 - 15\log\left(\frac{f}{12.5}\right)$ dB

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23.12.4.14 Characteristics of the link segment *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
LNK8	ELFEXT loss between 2 and 12.5 MHz	23.6.2.3.3	INS:M		Greater than $23.1 - 15\log\left(\frac{f}{12.5}\right)$ dB
LNK9	MDELFEXT loss between 2 and 12.5 MHz	23.6.2.3.4	INS:M		Greater than $20.9 - 15\log\left(\frac{f}{12.5}\right)$ dB
LNK10	Propagation delay	23.6.2.4.1	INS:M		Less than 570 ns
LNK11	Propagation delay per meter	23.6.2.4.2	INS:M		Less than 5.7 ns/m
LNK12	Skew	23.6.2.4.3	INS:M		Less than 50 ns
LNK13	Variation in skew once installed	23.6.2.4.3	INS:M		Less than ± 10 ns, within constraint of LNK8
LNK14	Noise level	23.6.3	INS:M		Such that objective error ratio is met
LNK15	MDNEXT noise	23.6.3.1	INS:M		Less than 325 mVp
LNK16	MDFEXT noise	23.6.3.2	INS:M		Less than 87 mVp
LNK17	Maximum length of Category 5, 25-pair jumper cables	23.6.3.2	INS:M		10 m

23.12.4.15 MDI requirements

Item	Feature	Subclause	Status	Support	Value/Comment
MDI1	MDI connector	23.7.1	M		IEC 60603-7: 1990
MDI2	Connector used on PHY	23.7.1	M		Jack (as opposed to plug)
MDI3	Crossover in every twisted-pair link	23.7.2	INS:M		
MDI4	MDI connector that implements the crossover function	23.7.2	XVR:M		Marked with “X”

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23.12.4.16 General safety and environmental requirements

Item	Feature	Subclause	Status	Support	Value/Comment
SAF1	Conformance to safety specifications	23.9.1	M		IEC 60950: 1991
SAF2	Installation practice	23.9.2.1	INS:M		Sound practice, as defined by applicable local codes
SAF3	Any safety grounding path for an externally connected PHY shall be provided through the circuit ground of the MII connection	23.9.2.2	M		
SAF4	Care taken during installation to ensure that noninsulated network cable conductors do not make electrical contact with unintended conductors or ground	23.9.2.3	INS:M		
SAF5	Application of voltages specified in 23.9.2.4 does not result in any safety hazard	23.9.2.4	M		
SAF6	Conformance with local and national codes for the limitation of electromagnetic interference	23.9.3.1	INS:M		

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23.12.4.17 Timing requirements

Item	Feature	Subclause	Status	Support	Value/Comment
TIM1	PMA_OUT	23.11.3	PMA:M		1 to 9.5 BT
TIM2	TEN_PMA + PMA_OUT	23.11.3	PCS:M		7 to 17.5 BT
TIM3	TEN_CRS	23.11.3	PCS:M		0 to +4 BT
TIM4	NOT_TEN_CRS	23.11.3	PCS:M		28 to 36 BT
TIM5	RX_PMA_CARRIER	23.11.3	PMA:M		Less than 15.5 BT
TIM6	RX_CRS	23.11.3	PCS:M		Less than 27.5 BT
TIM7	RX_NOT_CRS	23.11.3	PCS:M		0 to 51.5 BT
TIM8	FAIRNESS	23.11.3	PCS:M		0 to 28 BT
TIM9	RX_PMA_DATA	23.11.3	PMA:M		67 to 90.5 BT
TIM10	EOP_CARRIER_STATUS	23.11.3	M		51 to 74.5 BT
TIM11	EOC_CARRIER_STATUS	23.11.3	M		3 to 50.5 BT
TIM12	RX_RXDV	23.11.3	PCS:M		81 to 114.5 BT
TIM13	RX_PMA_ERROR	23.11.3	M		Allowed limits equal the actual RX_PMA_DATA time for the device under test plus from 0 to 20 BT
TIM14	RX_COL	23.11.3	PCS:M		Less than 27.5 BT
TIM15	RX_NOT_COL	23.11.3	PCS:M		Less than 51.5 BT
TIM16	TX_NOT_COL	23.11.3	PCS:M		Less than 36 BT
TIM17	TX_SKEW	23.11.3	M		Less than 0.5 BT
TIM18	CRS_PMA_DATA	23.11.3	PMA:M		Less than 78.5 BT
TIM19	COL_to_BI_D3/4_OFF	23.11.3	PMA:M		Less than 40 BT

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24. Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 100BASE-X

24.1 Overview

24.1.1 Scope

This clause specifies the Physical Coding Sublayer (PCS) and the Physical Medium Attachment (PMA) sublayer that are common to a family of 100 Mb/s Physical Layer implementations, collectively known as 100BASE-X. There are currently two embodiments within this family: 100BASE-TX and 100BASE-FX. 100BASE-TX specifies operation over two pairs of twisted-pair Category 5 cabling. 100BASE-FX specifies operation over two optical fibers. The term 100BASE-X is used when referring to issues common to both 100BASE-TX and 100BASE-FX.

The 100BASE-X may support the capability of Energy-Efficient Ethernet (EEE) as described in Clause 78. When a transmitting station of a link with this capability detects low link utilization, it can request the local PHY transmitter to enter the Low Power Idle (LPI) mode and send appropriate symbols over the link. Upon receiving and decoding those symbols, the link partner's receiver can enter the LPI mode. The transmit and receive paths can enter and exit low power states independently. Energy is conserved by deactivating the corresponding functional blocks of individual path. Only 100BASE-TX supports this optional capability.

100BASE-X leverages the Physical Layer standards of ISO/IEC 9314 and ANSI X3T12 (FDDI) through the use of their Physical Medium Dependent (PMD) sublayers, including their Medium Dependent Interfaces (MDI). For example, ANSI X3.263-1995 (TP-PMD) defines a 125 Mb/s, full duplex signaling system for twisted-pair wiring that forms the basis for 100BASE-TX as defined in Clause 25. Similarly, ISO/IEC 9314-3:1990 defines a system for transmission on optical fiber that forms the basis for 100BASE-FX as defined in Clause 26.

100BASE-X maps the interface characteristics of the FDDI PMD sublayer (including MDI) to the services expected by the CSMA/CD MAC. 100BASE-X can be extended to support any other full duplex medium requiring only that the medium be PMD compliant.

24.1.2 Objectives

The following are the objectives of 100BASE-X:

a) Support the CSMA/CD MAC in the half duplex and the full duplex modes of operation.
b) Support the 100BASE-T MII, repeater, and optional Auto-Negotiation.
c) Provide 100 Mb/s data rate at the MII.
d) Support cable plants using Category 5 twisted-pair, 150 Ω STP or cabled optical fiber, compliant with ISO/IEC 11801.
e) Allow for a nominal network extent of 200–400 m, including
    1) Unshielded twisted-pair links of 100 m
    2) Two repeater networks of approximately 200 m span
    3) One repeater network of approximately 300 m span (using fiber)
    4) DTE/DTE links of approximately 400 m (half duplex mode using fiber) and 2 km (full duplex mode using multimode fiber.
f) Preserve full duplex behavior of underlying PMD channels.
g) Optionally support EEE through the function of LPI (see Clause 78), available only for 100BASE-TX.

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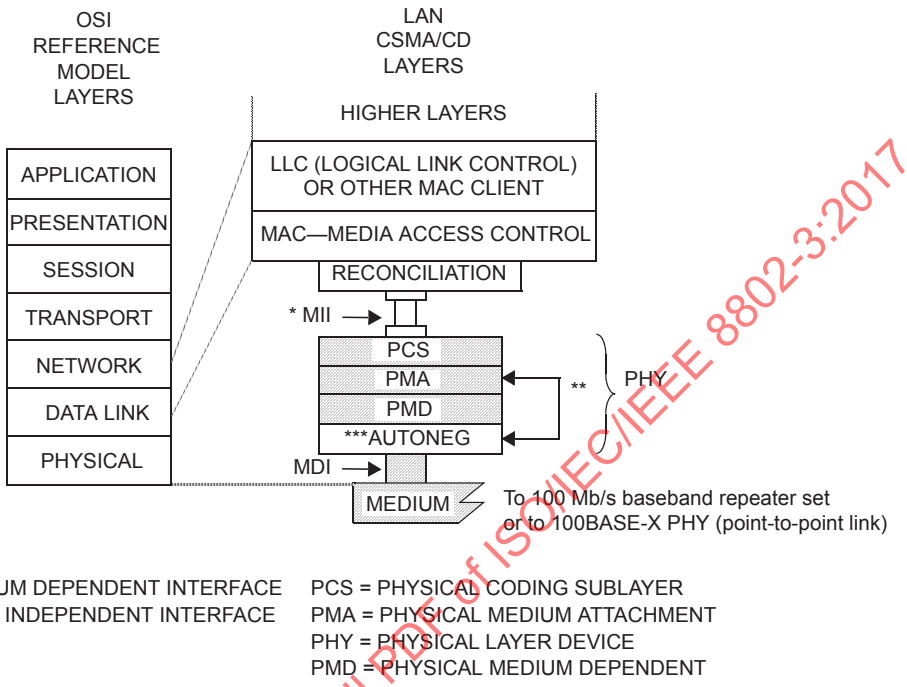
24.1.3 Relationship of 100BASE-X to other standards

Figure 24–1 depicts the relationships among the 100BASE-X sublayers (shown shaded), other 100BASE-T sublayers, the CSMA/CD MAC, and the IEEE 802.2 LLC.



MDI = MEDIUM DEPENDENT INTERFACE
MII = MEDIA INDEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER
PMA = PHYSICAL MEDIUM ATTACHMENT
PHY = PHYSICAL LAYER DEVICE
PMD = PHYSICAL MEDIUM DEPENDENT

* MII is optional.
** AUTONEG communicates with the PMA sublayer through the PMA service interface messages PMA_LINK.request and PMA_LINK.indicate.
*** AUTONEG is mandatory for EEE capability and optional otherwise.

Figure 24–1—Type 100BASE-X PHY relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

24.1.4 Summary of 100BASE-X sublayers

The following provides an overview of the 100BASE-X sublayers that are embodied in the 100BASE-X Physical sublayer (PHY).[5]

24.1.4.1 Physical Coding Sublayer (PCS)

The PCS interface is the Media Independent Interface (MII) that provides a uniform interface to the Reconciliation sublayer for all 100BASE-T PHY implementations (e.g., 100BASE-X and 100BASE-T4). 100BASE-X, as other 100BASE-T PHYs, is modeled as providing services to the MII. This is similar to the use of an AUI interface.

The 100BASE-X PCS realizes all services required by the MII, including the following:

a) Encoding (decoding) of MII data nibbles to (from) five-bit code-groups (4B/5B).
b) Generating Carrier Sense and Collision Detect indications.

[5] The 100BASE-X PHY should not be confused with the FDDI PHY, which is a sublayer functionally aligned to the 100BASE-T PCS.

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c) Serialization (deserialization) of code-groups for transmission (reception) on the underlying serial PMA.
d) Mapping of Transmit, Receive, Carrier Sense and Collision Detection between the MII and the underlying PMA.
e) Optionally, interpreting and generating MII data signals to enable or disable the LPI mode.

24.1.4.2 Physical Medium Attachment (PMA) sublayer

The PMA provides a medium-independent means for the PCS and other bit-oriented clients (e.g., repeaters) to support the use of a range of physical media. The 100BASE-X PMA performs the following functions:

a) Mapping of transmit and receive code-bits between the PMA's client and the underlying PMD.
b) Generating a control signal indicating the availability of the PMD to a PCS or other client, also synchronizing with Auto-Negotiation when implemented.
c) Optionally, generating indications of activity (carrier) and carrier errors from the underlying PMD.
d) Optionally, sensing receive channel failures and transmitting the Far-End Fault Indication; and detecting the Far-End Fault Indication.
e) Optionally, receiving and processing LPI control signals from the PCS.
f) Recovery of clock from the NRZI data supplied by the PMD.

24.1.4.3 Physical Medium Dependent (PMD) sublayer

100BASE-X uses the FDDI signaling standards ISO/IEC 9314-3:1990 and ANSI X3.263-1995 (TP-PMD). These signaling standards, called PMD sublayers, define 125 Mb/s, full duplex signaling systems that accommodate multimode optical fiber and twisted-pair cabling. 100BASE-X uses the PMDs specified in these standards with the PMD Service Interface specified in 24.4.1.

The MDI, logically subsumed within the PMD, provides the actual medium attachment, including connectors, for the various supported media.

100BASE-X does not specify the PMD and MDI other than including the appropriate standard by reference along with the minor adaptations necessary for 100BASE-X. Figure 24–2 depicts the relationship between 100BASE-X and the PMDs of ISO/IEC 9314-3:1990 (for 100BASE-FX) and ANSI X3.263-1995 (for 100BASE-TX). The PMDs (and MDIs) for 100BASE-TX and 100BASE-FX are specified in subsequent clauses of this standard.

24.1.4.4 Auto-Negotiation

Auto-Negotiation shall be implemented for EEE capability. See Clause 28.

24.1.5 Inter-sublayer interfaces

There are a number of interfaces employed by 100BASE-X. Some (such as the PMA and PMD interfaces) use an abstract service model to define the operation of the interface. The PCS Interface is defined as a set of physical signals, in a medium-independent manner (MII). Figure 24–3 depicts the relationship and mapping of the services provided by all of the interfaces relevant to 100BASE-X.

It is important to note that, while this specification defines interfaces in terms of bits, nibbles, and code-groups, implementations may choose other data path widths for implementation convenience. The only exceptions are: a) the MII, which, when implemented, uses a nibble-wide data path as specified in Clause 22, and b) the MDI, which uses a serial, physical interface.

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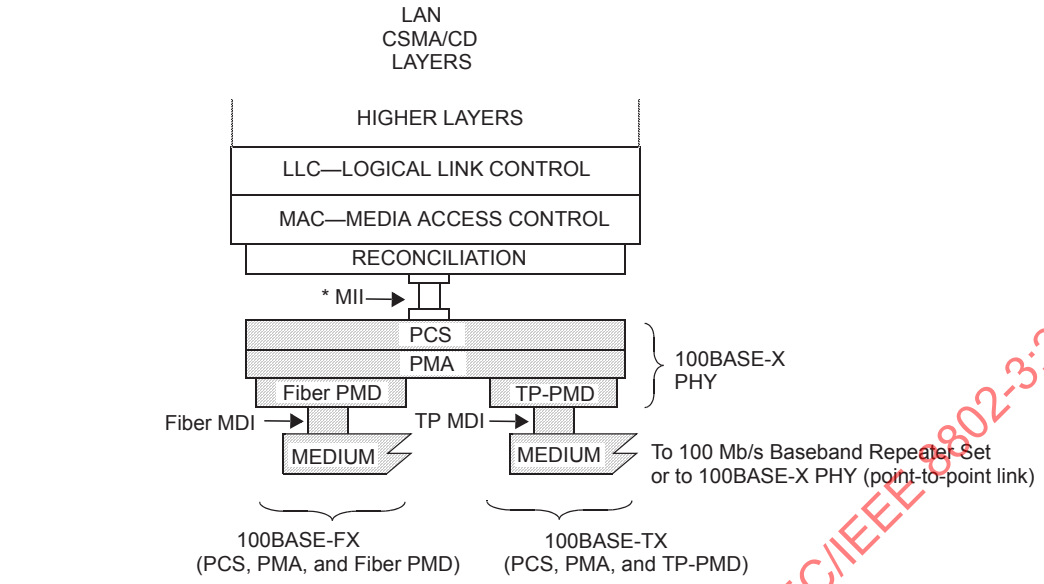

MDI = MEDIUM DEPENDENT INTERFACE
MII = MEDIA INDEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER
PMA = PHYSICAL MEDIUM ATTACHMENT
PHY = PHYSICAL LAYER DEVICE
Fiber PMD = PHYSICAL MEDIUM DEPENDENT SUBLAYER FOR FIBER
TP-PMD = PHYSICAL MEDIUM DEPENDENT SUBLAYER FOR TWISTED PAIRS

NOTE—The PMD sublayers are mutually independent.
* MII is optional.

Figure 24–2—Relationship of 100BASE-X and the PMDs

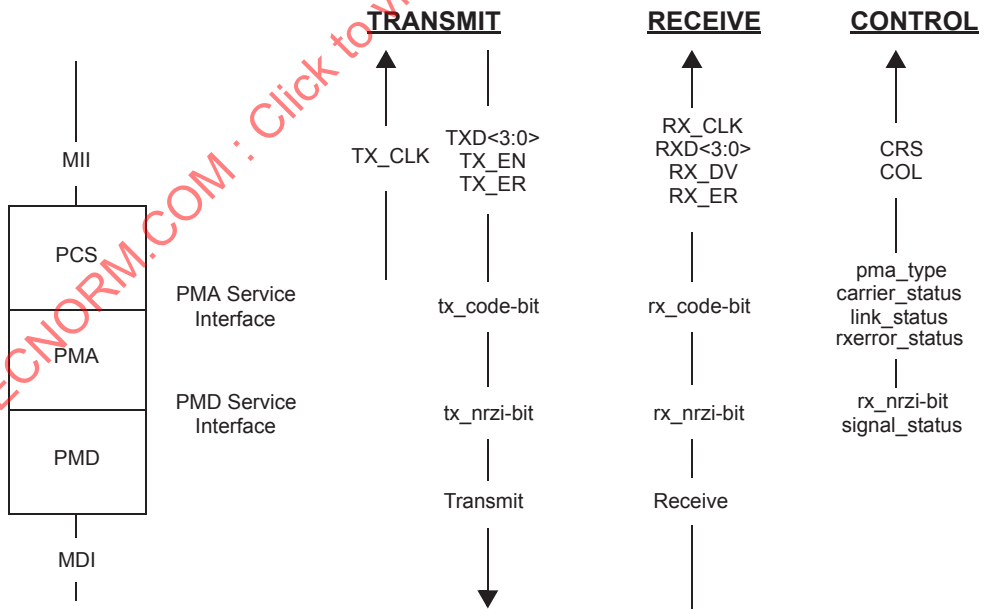

Figure 24–3—Interface mapping

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24.1.6 Functional block diagram

Figure 24–4 provides a functional block diagram of the 100BASE-X PHY. Signals or functions shown with dashed lines are optional.

24.1.7 State diagram conventions

The body of this standard is comprised of state diagrams, including the associated definitions of variables, constants, and functions. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

The notation used in the state diagrams follows the conventions of 21.5; state diagram timers follow the conventions of 14.2.3.2.

24.2 Physical Coding Sublayer (PCS)

24.2.1 Service Interface (MII)

The PCS Service Interface allows the 100BASE-X PCS to transfer information to and from the MAC (via the Reconciliation sublayer) or other PCS client, such as a repeater. The PCS Service Interface is precisely defined as the Media Independent Interface (MII) in Clause 22.

In this clause, the setting of MII variables to TRUE or FALSE is equivalent, respectively, to “asserting” or “deasserting” them as specified in Clause 22.

24.2.2 Functional requirements

The PCS comprises the Transmit, Receive, and Carrier Sense functions for 100BASE-T. In addition, the collisionDetect signal required by the MAC (COL on the MII) is derived from the PMA code-bit stream. The PCS shields the Reconciliation sublayer (and MAC) from the specific nature of the underlying channel. Specifically for receiving, the 100BASE-X PCS passes to the MII a sequence of data nibbles derived from incoming code-groups, each comprised of five code-bits, received from the medium. Code-group alignment and MAC packet delimiting is performed by embedding special non-data code-groups. The MII uses a nibble-wide, synchronous data path, with packet delimiting being provided by separate TX_EN and RX_DV signals. The PCS provides the functions necessary to map these two views of the exchanged data. The process is reversed for transmit.

The following provides a detailed specification of the functions performed by the PCS, which comprise five parallel processes (Transmit, Transmit Bits, Receive, Receive Bits, and Carrier Sense). Figure 24–4 includes a functional block diagram of the PCS.

The Receive Bits process accepts continuous code-bits via the PMA_UNITDATA.indicate primitive. Receive monitors these bits and generates RXD<3:0>, RX_DV, and RX_ER on the MII, and the internal flag, receiving, used by the Carrier Sense and Transmit processes.

Upon receiving proper code-groups via rx_code_bits from the link partner as described in 24.2.2.1.6, the Receive process may support the LPI function by deactivating all or part of receive functional blocks of the PCS, PMA, and PMD to conserve energy during the low link utilization period, and generate commands through the MII as described in 22.2.2.8. By interacting with the Link Monitor of the PMA, a link failure detection mechanism is included to differentiate two conditions of link failure due to signal off: the loss of channel signal during the normal operation and the loss of refresh signal in the LPI mode.

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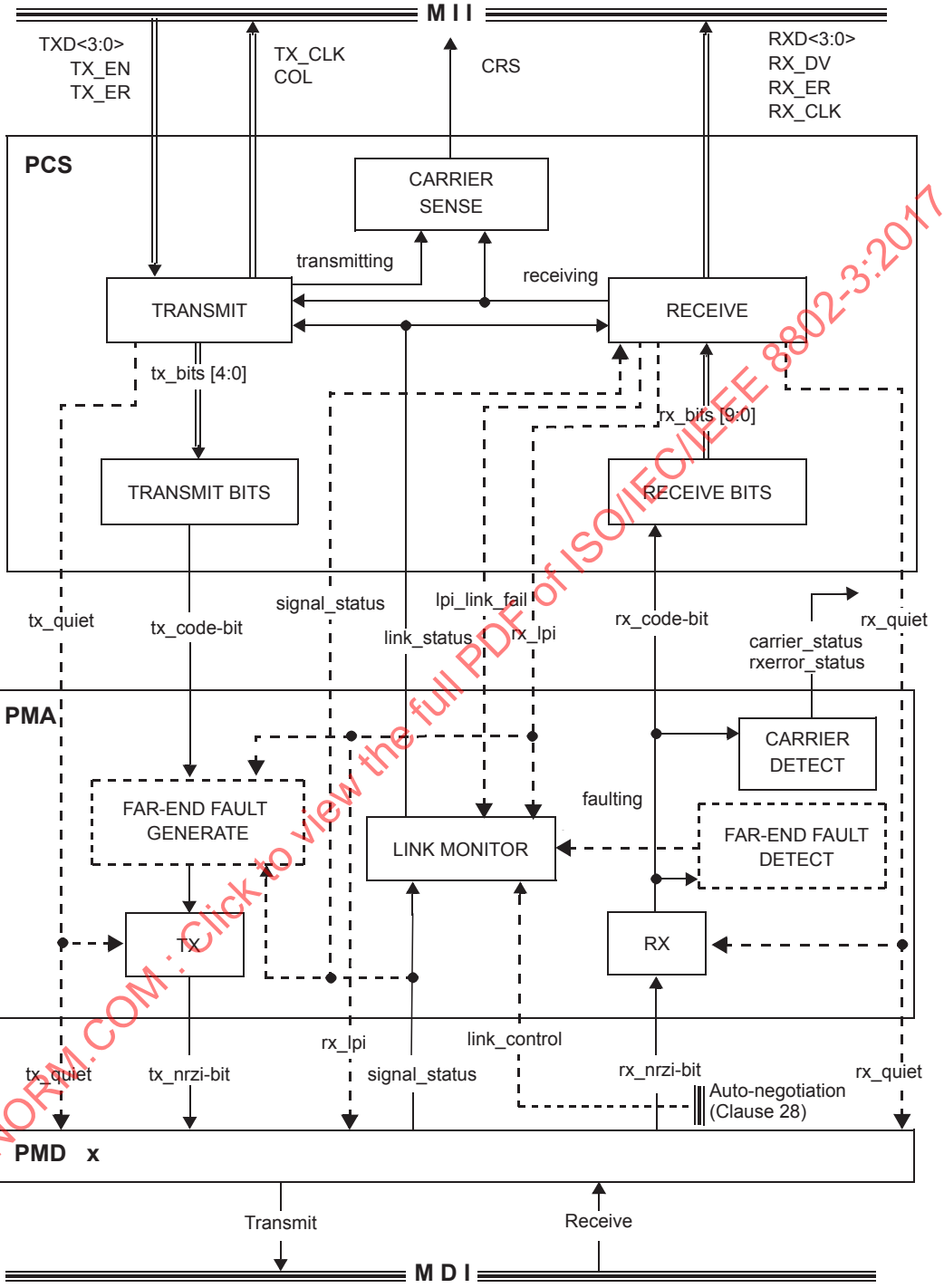

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Figure 24–4—Functional block diagram

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The Transmit process generates continuous code-groups based upon the TXD<3:0>, TX_EN, and TX_ER signals on the MII. These code-groups are transmitted by Transmit Bits via the PMA_UNITDATA.request primitive. The Transmit process generates the MII signal COL based on whether a reception is occurring simultaneously with transmission. Additionally, it generates the internal flag, transmitting, for use by the Carrier Sense process.

The Transmit process may support the LPI function by deactivating all or part of the transmit functional blocks of the PCS, PMA, and PMD to conserve energy during the low link utilization period upon receiving the proper command from MII as described in 22.2.2.4. In this mode, the Transmit process is periodically activated to transmit refresh signal through tx_code_bits in order to allow the remote receiver to keep track of the long-term variation of channel characteristics and the clock drift between link partners.

The Carrier Sense process asserts the MII signal CRS when either transmitting or receiving is TRUE. Both the Transmit and Receive processes monitor link_status via the PMA_LINK.indicate primitive, to account for potential link failure conditions.

24.2.2.1 Code-groups

The PCS maps four-bit nibbles from the MII into five-bit code-groups, and vice versa, using a 4B/5B block coding scheme. A code-group is a consecutive sequence of five code-bits interpreted and mapped by the PCS. Implicit in the definition of a code-group is an establishment of code-group boundaries by an alignment function within the PCS Receive process. It is important to note that, with the sole exception of the SSD, which is used to achieve alignment, code-groups are undetectable and have no meaning outside the 100BASE-X physical protocol data unit, called a “stream.”

The coding method used, derived from ISO/IEC 9314-1, provides

a) Adequate codes (32) to provide for all Data code-groups (16) plus necessary control code-groups.
b) Appropriate coding efficiency (4 data bits per 5 code-bits; 80%) to effect a 100 Mb/s Physical Layer interface on a 125 Mb/s physical channel as provided by FDDI PMDs.
c) Sufficient transition density to facilitate clock recovery (when not scrambled).

Table 24–1 specifies the interpretation assigned to each five bit code-group, including the mapping to the nibble-wide (TXD or RXD) Data signals on the MII. The 32 code-groups are divided into four categories, as shown.

For clarity in the remainder of this clause, code-group names are shown between /slashes/. Code-group sequences are shown in succession, e.g., /1/2/....

The indicated code-group mapping is identical to ISO/IEC 9314-1:1989, with the following five exceptions:

a) The FDDI term *symbol* is avoided in order to prevent confusion with other 100BASE-T terminology. In general, the term *code-group* is used in its place.
b) The /S/ and /Q/ code-groups are not used by 100BASE-X and are interpreted as INVALID.
c) The /R/ code-group is used in 100BASE-X as the second code-group of the End-of-Stream delimiter rather than to indicate a Reset condition.
d) The /H/ code-group is used to propagate receive errors rather than to indicate the Halt Line State.
e) The /P/ code-group is used to indicate LPI.

24.2.2.1.1 Data code-groups

A Data code-group conveys one nibble of arbitrary data between the MII and the PCS. The sequence of Data code-groups is arbitrary, where any Data code-group can be followed by any other Data code-group. Data code-groups are coded and decoded but not interpreted by the PCS. Successful decoding of Data code-groups depends on proper receipt of the Start-of-Stream delimiter sequence, as defined in Table 24–1.

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Table 24–1—4B/5B code-groups

	PCS code-group [4:0] 4 3 2 1 0	Name	MII (TXD/RXD) <3:0> 3 2 1 0	Interpretation
DATA	1 1 1 1 0	0	0 0 0 0	Data 0
	0 1 0 0 1	1	0 0 0 1	Data 1
	1 0 1 0 0	2	0 0 1 0	Data 2
	1 0 1 0 1	3	0 0 1 1	Data 3
	0 1 0 1 0	4	0 1 0 0	Data 4
	0 1 0 1 1	5	0 1 0 1	Data 5
	0 1 1 1 0	6	0 1 1 0	Data 6
	0 1 1 1 1	7	0 1 1 1	Data 7
	1 0 0 1 0	8	1 0 0 0	Data 8
	1 0 0 1 1	9	1 0 0 1	Data 9
	1 0 1 1 0	A	1 0 1 0	Data A
	1 0 1 1 1	B	1 0 1 1	Data B
	1 1 0 1 0	C	1 1 0 0	Data C
	1 1 0 1 1	D	1 1 0 1	Data D
	1 1 1 0 0	E	1 1 1 0	Data E
	1 1 1 0 1	F	1 1 1 1	Data F
	1 1 1 1 1	I	undefined	IDLE; used as inter-stream fill code
	0 0 0 0 0	P	0 0 0 1	SLEEP; LPI code only for the EEE capability. Otherwise, Invalid code; refer to Table 22–1 and Table 22–2
CONTROL	1 1 0 0 0	J	0 1 0 1	Start-of-Stream Delimiter, Part 1 of 2; always used in pairs with K
	1 0 0 0 1	K	0 1 0 1	Start-of-Stream Delimiter, Part 2 of 2; always used in pairs with J
	0 1 1 0 1	T	undefined	End-of-Stream Delimiter, Part 1 of 2; always used in pairs with R
	0 0 1 1 1	R	undefined	End-of-Stream Delimiter, Part 2 of 2; always used in pairs with T
INVALID	0 0 1 0 0	H	Undefined	Transmit Error; used to force signaling errors
	0 0 0 0 0	V	Undefined	Invalid code
	0 0 0 0 1	V	Undefined	Invalid code
	0 0 0 1 0	V	Undefined	Invalid code
	0 0 0 1 1	V	Undefined	Invalid code
	0 0 1 0 1	V	Undefined	Invalid code
	0 0 1 1 0	V	Undefined	Invalid code
	0 1 0 0 0	V	Undefined	Invalid code
	0 1 1 0 0	V	Undefined	Invalid code
	1 0 0 0 0	V	Undefined	Invalid code
	1 1 0 0 1	V	Undefined	Invalid code

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24.2.2.1.2 Idle code-groups

The Idle code-group (/I/) is transferred between streams. It provides a continuous fill pattern to establish and maintain clock synchronization. Idle code-groups are emitted from, and interpreted by, the PCS.

24.2.2.1.3 Control code-groups

The Control code-groups are used in pairs (/J/K/, /T/R/) to delimit MAC packets. Control code-groups are emitted from, and interpreted by, the PCS.

24.2.2.1.4 Start-of-Stream delimiter (/J/K/)

A Start-of-Stream delimiter (SSD) is used to delineate the boundary of a data transmission sequence and to authenticate carrier events. The SSD is unique in that it may be recognized independently of previously established code-group boundaries. The Receive function within the PCS uses the SSD to establish code-group boundaries. A SSD consists of the sequence /J/K/.

On transmission, the first 8 bits of the MAC preamble are replaced by the SSD, a replacement that is reversed on reception.

24.2.2.1.5 End-of-Stream delimiter (/T/R/)

An End-of-Stream delimiter (ESD) terminates all normal data transmissions. Unlike the SSD, an ESD cannot be recognized independent of previously established code-group boundaries. An ESD consists of the sequence /T/R/.

24.2.2.1.6 SLEEP code-groups (/P/)

The SLEEP code-group (/P/) is used to delineate the boundary of an LPI sequence and to deliver a refresh signal to maintain clock synchronization and verify the link status. The SLEEP code-groups are emitted from, and interpreted by, the PCS.

24.2.2.1.7 Invalid code-groups

The /H/ code-group indicates that the PCS's client wishes to indicate a Transmit Error to its peer entity. The normal use of this indicator is for repeaters to propagate received errors. Transmit Error code-groups are emitted from the PCS, at the request of the PCS's client through the use of the TX_ER signal, as described in 24.2.4.2.

The presence of any invalid code-group on the medium, including /H/, denotes a collision artifact or an error condition. Invalid code-groups are not intentionally transmitted onto the medium by DTE's. The PCS indicates the reception of an Invalid code-group on the MII through the use of the RX_ER signal, as described in 24.2.4.4.

24.2.2.2 Encapsulation

The 100BASE-X PCS accepts frames from the MAC through the Reconciliation sublayer and MII. Due to the continuously signaled nature of the underlying PMA, and the encoding performed by the PCS, the 100BASE-X PCS encapsulates the MAC frame (100BASE-X Service Data Unit, SDU) into a Physical Layer stream (100BASE-X Protocol Data Unit, PDU).

Except for the two code-group SSD, data nibbles within the SDU (including the non-SSD portions of the MAC preamble and SFD) are not interpreted by the 100BASE-X PHY. The conversion from a MAC frame to a Physical Layer stream and back to a MAC frame is transparent to the MAC.

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Figure 24–5 depicts the mapping between MAC frames and Physical Layer streams.

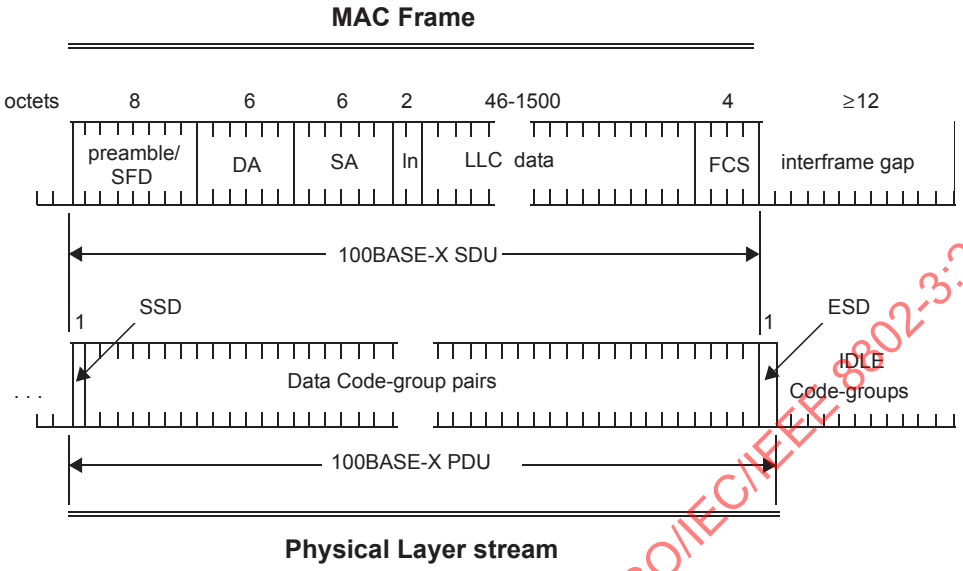

Figure 24–5—PCS encapsulation

A properly formed stream can be viewed as comprising the following three elements:

a) *Start-of-Stream Delimiter.* The start of a Physical Layer stream is indicated by a SSD, as defined in 24.2.2.1. The SSD replaces the first octet of the preamble from the MAC frame and vice versa.
b) *Data Code-groups.* Between delimiters (SSD and ESD), the PCS conveys Data code-groups corresponding to the data nibbles of the MII. These Data code-groups comprise the 100BASE-X Service Data Unit (SDU). Data nibbles within the SDU (including those corresponding to the MAC preamble and SFD) are not interpreted by the 100BASE-X PCS.
c) *End-of-Stream Delimiter.* The end of a properly formed stream is indicated by an ESD, as defined in 24.2.2.1. The ESD is transmitted by the PCS following the deassertion of TX_EN on the MII, which corresponds to the last data nibble composing the FCS from the MAC. It is transmitted during the period considered by the MAC to be the interframe gap (IFG). On reception, ESD is interpreted by the PCS as terminating the SDU.

Between streams, IDLE code-groups are conveyed between the PCS and PMA.

24.2.2.3 Data delay

The PCS maps a non-aligned code-bit data path from the PMA to an aligned, nibble-wide data path on the MII, both for Transmit and Receive. Logically, received bits must be buffered to facilitate SSD detection and alignment, coding translation, and ESD detection. These functions necessitate an internal PCS delay of at least two code-groups. In practice, alignment may necessitate even longer delays of the incoming code-bit stream.

When the MII is present as an exposed interface, the MII signals TX_CLK and RX_CLK, not depicted in the following state diagrams, shall be generated by the PCS in accordance with Clause 22.

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24.2.2.4 Mapping between MII and PMA

Figure 24–6 depicts the mapping of the nibble-wide data path of the MII to the five-bit-wide code-groups (internal to the PCS) and the code-bit path of the PMA interface.

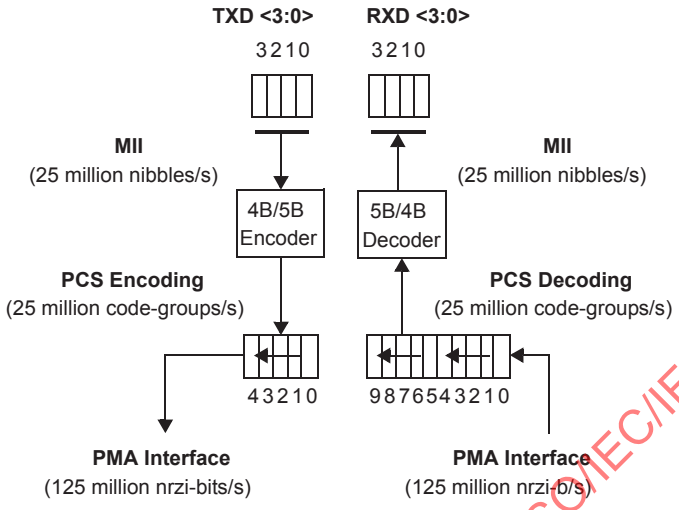

Figure 24–6—PCS reference diagram

Upon receipt of a nibble from the MII, the PCS encodes it into a five-bit code-group, according to 24.2.2.1. Code-groups are serialized into code-bits and passed to the PMA for transmission on the underlying medium, according to Figure 24–6. The first transmitted code-bit of a code-group is bit 4, and the last code-bit transmitted is bit 0. There is no numerical significance ascribed to the bits within a code-group; that is, the code-group is simply a five-bit pattern that has some predefined interpretation.

Similarly, the PCS deserializes code-bits received from the PMA, according to Figure 24–6. After alignment is achieved, based on SSD detection, the PCS converts code-groups into MII data nibbles, according to 24.2.2.1.

24.2.3 State variables

24.2.3.1 Constants

DATA
: The set of 16 code-groups corresponding to valid DATA, as specified in 24.2.2.1. (In the Receive state diagram, the set operators $\in$ and $\notin$ are used to represent set membership and non-membership, respectively.)

ESD
: The code-group pair corresponding to the End-of-Stream delimiter, as specified in 24.2.2.1.

ESD1
: The code-group pair corresponding to the End-of-Stream delimiter, Part 1 (/T/), as specified in 24.2.2.1.

ESD2
: The code-group pair corresponding to the End-of-Stream delimiter, Part 2 (/R/), as specified in

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24.2.2.1.

HALT

The Transmit Error code-group (/H/), as specified in 24.2.2.1.

IDLE

The IDLE code-group, as specified in 24.2.2.1.

IDLES

A code-group pair comprised of /I/I/; /I/ as specified in 24.2.2.1.

SSD

The code-group pair corresponding to the Start-of-Stream delimiter, as specified in 24.2.2.1.

SSD1

The code-group corresponding to the Start-of-Stream delimiter, Part 1 (/J/), as specified in 24.2.2.1.

SSD2

The code-group corresponding to the Start-of-Stream delimiter, Part 2 (/K/), as specified in 24.2.2.1.

The following constants are required only for the optional EEE capability:

SLEEP

The SLEEP code-group (/P/) used by the LPI state delineator, as specified in 24.2.2.1.

TX_LP_IDLE

A binary value 0001 of transmit nibble-wide Data signals (TXD), together with the deassertion of TX_EN and the assertion of TX_ER on the MII, used to indicate “Assert LPI”, as specified in 22.2.2.

RX_LP_IDLE

A binary value 0001 of receive nibble-wide Data signals (RXD), together with the deassertion of RX_DV and the assertion of RX_ER on the MII, used to indicate “Assert LPI”, as specified in 22.2.2.

24.2.3.2 Variables

In the following, values for the MII parameters are definitively specified in Clause 22.

COL

The COL signal of the MII as specified in Clause 22.

CRS

The CRS signal of the MII as specified in Clause 22.

link_status

The link_status parameter as communicated by the PMA_LINK.indicate primitive.

Values: FAIL; the receive channel is not intact
READY; the receive channel is intact and ready to be enabled by Auto-Negotiation
OK; the receive channel is intact and enabled for reception

receiving

A Boolean set by the Receive process to indicate non-IDLE activity (after squelch). Used by the Carrier Sense process, and also interpreted by the Transmit process for indicating a collision.

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Values: TRUE; unsquelched carrier being received
FALSE; carrier not being received

rx_bits [9:0]

A vector of the 10 most recently received code-bits from the PMA as assembled by Receive Bits and processed by Receive. rx_bits [0] is the most recently received (newest) code-bit; rx_bits [9] is the least recently received code-bit (oldest). When alignment has been achieved, it contains the last two code-groups.

rx_code-bit

The rx_code-bit parameter as communicated by the most recent PMA_UNITDATA.indicate primitive (that is, the value of the most recently received code-bit from the PMA).

RX_DV

The RX_DV signal of the MII as specified in Clause 22. Set by the Receive process, RX_DV is also interpreted by the Receive Bits process as an indication that rx_bits is code-group aligned.

RX_ER

The RX_ER signal of the MII as specified in Clause 22.

RXD <3:0>

The RXD <3:0> signal of the MII as specified in Clause 22.

transmitting

A Boolean set by the Transmit Process to indicate a transmission in progress. Used by the Carrier Sense process.

Values: TRUE; the PCS's client is transmitting
FALSE; the PCS's client is not transmitting

tx_bits [4:0]

A vector of code-bits representing a code-group prepared for transmission by the Transmit Process and transmitted to the PMA by the Transmit Bits process.

TX_EN

The TX_EN signal of the MII as specified in Clause 22.

TX_ER

The TX_ER signal of the MII as specified in Clause 22.

TXD <3:0>

The TXD <3:0> signal of the MII as specified in Clause 22.

The following variables are required only for the optional EEE capability:

lpi_link_fail

A Boolean set by the Receive process to control the transition to a Link Down state when in the LPI mode. Used by the Link Monitor process of the PMA as communicated through the PMA_LPILINKFAIL.request primitive.

Values: TRUE; local receiver has detected a link failure status when in the LPI mode
FALSE; local receiver is functioning normally when in the LPI mode

rx_lpi

A Boolean set by the Receive process to indicate the LPI mode. Used by the Link Monitor process of the PMA as communicated through the PMA_RXLPI.request primitive. This parameter is used to alter the signal detection time as shown in Table 25–3. It can also be used to halt the clock RXC of MII as described in Clause 22.

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Values: TRUE; local receiver is in the LPI mode
FALSE; local receiver is in the normal mode

rx_quiet

A Boolean set by the Receive process to indicate a Quiet state of the receiver in the LPI mode as communicated through the PMD_RXQUIET.request primitive. Also may be used to control the power-saving function of various receive blocks (PCS, PMA, and PMD).

Values: TRUE; the local receiver is in the Quiet state
FALSE; the local receiver is not in the Quiet state

tx_quiet

A Boolean set by the Transmit process to indicate a Quiet state of the transmitter in the LPI mode as communicated through the PMD_TXQUIET.request primitive. Also may be used to control the power-saving function of various transmit blocks (PCS, PMA, and PMD).

Values: TRUE; the local transmitter is in the Quiet state
FALSE; the local transmitter is not in the Quiet state

signal_status

The signal_status parameter as communicated by the PMD_SIGNAL.indicate primitive.

Values: ON; the quality and level of the received signal is satisfactory
OFF; the quality and level of the received signal is not satisfactory

24.2.3.3 Functions

nibble DECODE (code-group)

In Receive, this function takes as its argument a five-bit code-group and returns the corresponding MII RXD <3:0> nibble, per Table 24–1.

code-group ENCODE (nibble)

In the Transmit process, this function takes as its argument an MII TXD <3:0> nibble, and returns the corresponding five-bit code-group per Table 24–1.

SHIFTLEFT (rx_bits)

In Receive Bits, this function shifts rx_bits left one bit placing rx_bits [8] in rx_bits [9], rx_bits [7] in rx_bits [8] and so on until rx_bits [1] gets rx_bits [0].

24.2.3.4 Timers

code-bit_timer

In the Transmit Bits process, the timer governing the output of code-bits from the PCS to the PMA and thereby to the medium with a nominal 8 ns period. This timer shall be derived from a fixed frequency oscillator with a base frequency of 125 MHz ± 0.005% and phase jitter above 20 kHz less than ± 8°.

The following timers are required only for the optional EEE capability:

lpi_link_fail_timer

In the LPI mode, the receiver in Wake state is checking if valid symbols are properly received. This timer defines the maximum time allowed for the PHY between entry into the Wake state and subsequent entry into the Quiet, Sleep, or Idle states before assuming a link failure. The timer shall have a period between 90 µs and 110 µs.

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lpi_rx_ti_timer

In the LPI mode, the receiver can move to the Idle state when it receives consecutive IDLE symbols. In order to distinguish the intended IDLE symbols sent by the link partner from ones falsely decoded during the transition from the Sleep state to the Quiet state before the signal status is deasserted, this receiver timer counts the minimum duration of received IDLE symbols. During this period of time, the receiver stays in an intermediate state. The timer shall have a period between 0.8 µs and 0.9 µs.

lpi_rx_tq_timer

In the LPI mode, this receiver timer counts the maximum duration the PHY stays in the Quiet state before it expects a Refresh signal. If the PHY fails to receive a valid Refresh signal or Wake signal before this timer expires, the receiver shall assume a link failure. The timer shall have a period between 24 ms and 26 ms.

lpi_rx_ts_timer

In the LPI mode, this receiver timer counts the maximum duration the PHY is allowed to stay in the Sleep state before assuming a link failure. The timer shall have a period between 240 µs and 260 µs.

lpi_rx_tw_timer

In the LPI mode, the receiver in the Quiet state is woken up by the receiving signal. This receiver timer counts the expected duration for the PHY to identify if valid SLEEP symbols for the Refresh state or valid IDLES for the Wake state have been properly received. If none of the SLEEP or IDLE symbols are received when the timer expires, the wake error counter as defined in MDIO manageable device (MMD) register 3.22 (see 45.2.3.10) shall be incremented. The timer shall have a period that does not exceed 20.5 µs.

lpi_tx_tq_timer

In the LPI mode, this transmitter timer counts the duration the PHY remains in the Quiet state before it must wake to send a refresh signal. The timer shall have a period between 20 ms and 22 ms.

lpi_tx_ts_timer

In the LPI mode, this transmitter timer counts the duration the PHY is sending continuous SLEEP symbols in the Sleep state before going into the Quiet state. The timer shall have a period between 200 µs and 220 µs.

24.2.3.5 Messages

gotCodeGroup.indicate

A signal sent to the Receive process by the Receive Bits process after alignment has been achieved signifying completion of reception of the next code-group in rx_bits(4:0), with the preceding code-group moved to rx_bits [9:5]. rx_bits [9:5] may be considered as the “current” code-group.

PMA_UNITDATA.indicate (rx_code-bit)

A signal sent by the PMA signifying that the next code-bit from the medium is available in rx_code-bit.

sentCodeGroup.indicate

A signal sent to the Transmit process from the Transmit Bits process signifying the completion of

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transmission of the code-group in tx_bits [4:0].

24.2.4 State diagrams

24.2.4.1 Transmit Bits

Transmit Bits is responsible for taking code-groups prepared by the Transmit process and transmitting them to the PMA using PMA_UNITDATA.request, the frequency of which determines the transmit clock. Transmit deposits these code-groups in tx_bits with Transmit Bits signaling completion of a code-group transmission with sentCodeGroup.indicate.

The PCS shall implement the Transmit Bits process as depicted in Figure 24–7 including compliance with the associated state variables as specified in 24.2.3.

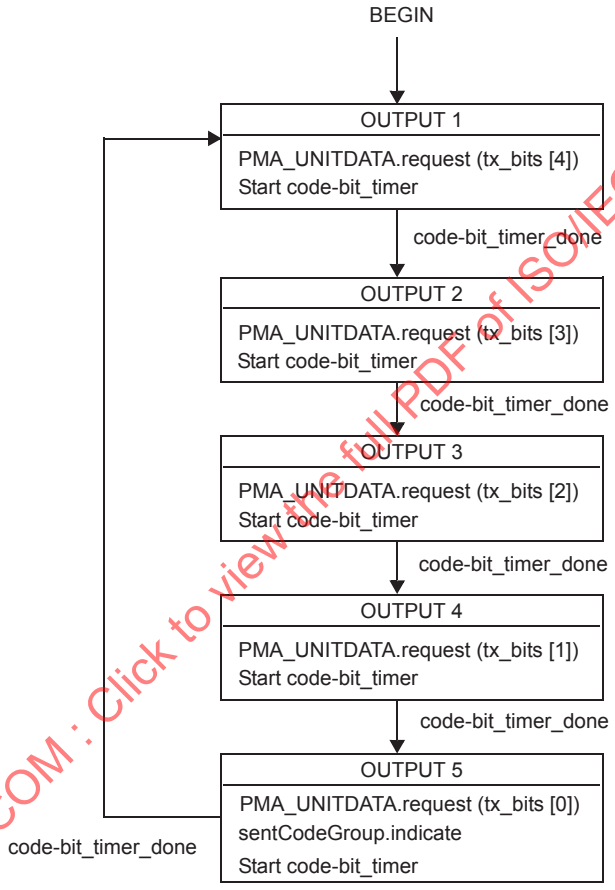

Figure 24–7—Transmit Bits state diagram

24.2.4.2 Transmit

The Transmit process sends code-groups to the PMA via tx_bits and the Transmit Bits process. When initially invoked, and between streams (delimited by TX_EN on the MII), except in the LPI mode for the optional EEE capability, the Transmit process sources continuous Idle code-groups (/I/) to the PMA. Upon the assertion of TX_EN by the MII, the Transmit process passes an SSD (/J/K/) to the PMA, ignoring the TXD<3:0> nibbles during these two code-group times. Following the SSD, each TXD<3:0> nibble is encoded into a five-bit code-group until TX_EN is deasserted. If, while TX_EN is asserted, the TX_ER signal is asserted, the Transmit process passes Transmit Error code-groups (/H/) to the PMA. Following the

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deassertion of TX_EN, an ESD (/T/R/) is generated, after which the transmission of Idle code-groups is resumed by the IDLE state.

If EEE Capability is supported, upon the assertion of LPI on the MII (a binary value 0001 of TXD, together with the deassertion of TX_EN and the assertion of TX_ER, see 22.2.2), the Transmit process enters the LPI mode and starts to source SLEEP (/P/) code-groups to the PMA. In the LPI mode, the Transmit process is controlled by timers to switch between the TX_SLEEP and TX_QUIET states. The Transmit process returns to the IDLE state whenever the MII deasserts LPI.

Collision detection is implemented by noting the occurrence of carrier receptions during transmissions, following the model of 10BASE-T.

The indication of link_status ≠ OK by the PMA at any time causes an immediate transition to the IDLE state and supersedes any other Transmit process operations.

The PCS shall implement the Transmit process as depicted in Figure 24–8 including compliance with the associated state variables as specified in 24.2.3.

24.2.4.3 Receive Bits

The Receive Bits process collects code-bits from the PMA interface passing them to the Receive process via rx_bits. rx_bits [9:0] represents a sliding, 10-bit window on the PMA code-bits, with newly received code-bits from the PMA (rx_code-bit) being shifted into rx_bits [0]. This is depicted in Figure 24–9. Bits are collected serially until Receive indicates alignment by asserting RX_DV, after which Receive Bits signals Receive for every five code-bits accumulated. Serial processing resumes with the deassertion of RX_DV.

The PCS shall implement the Receive Bits process as depicted in Figure 24–10 including compliance with the associated state variables as specified in 24.2.3.

24.2.4.4 Receive

The Receive process state diagram can be viewed as comprising two sections: prealigned and aligned. In the prealigned states, IDLE, CARRIER DETECT, and IDENTIFY JK, except for the detection of SLEEP code-groups when supporting the optional EEE capability, the Receive process is waiting for an indication of channel activity followed by an SSD. After successful alignment, the incoming code-groups are decoded while waiting for stream termination.

If EEE Capability is supported, when the Receive process successfully aligns and decodes two consecutive SLEEP (/P/) code-groups, it enters the LPI mode and stays in LPI states until either the IDLE code-groups are received, where it leads the Receive process to the IDLE state, or a link failure condition in the LPI mode occurs, where it causes the Receive process to enter the RX_LPI_LINK_FAIL state and eventually move to the IDLE state.

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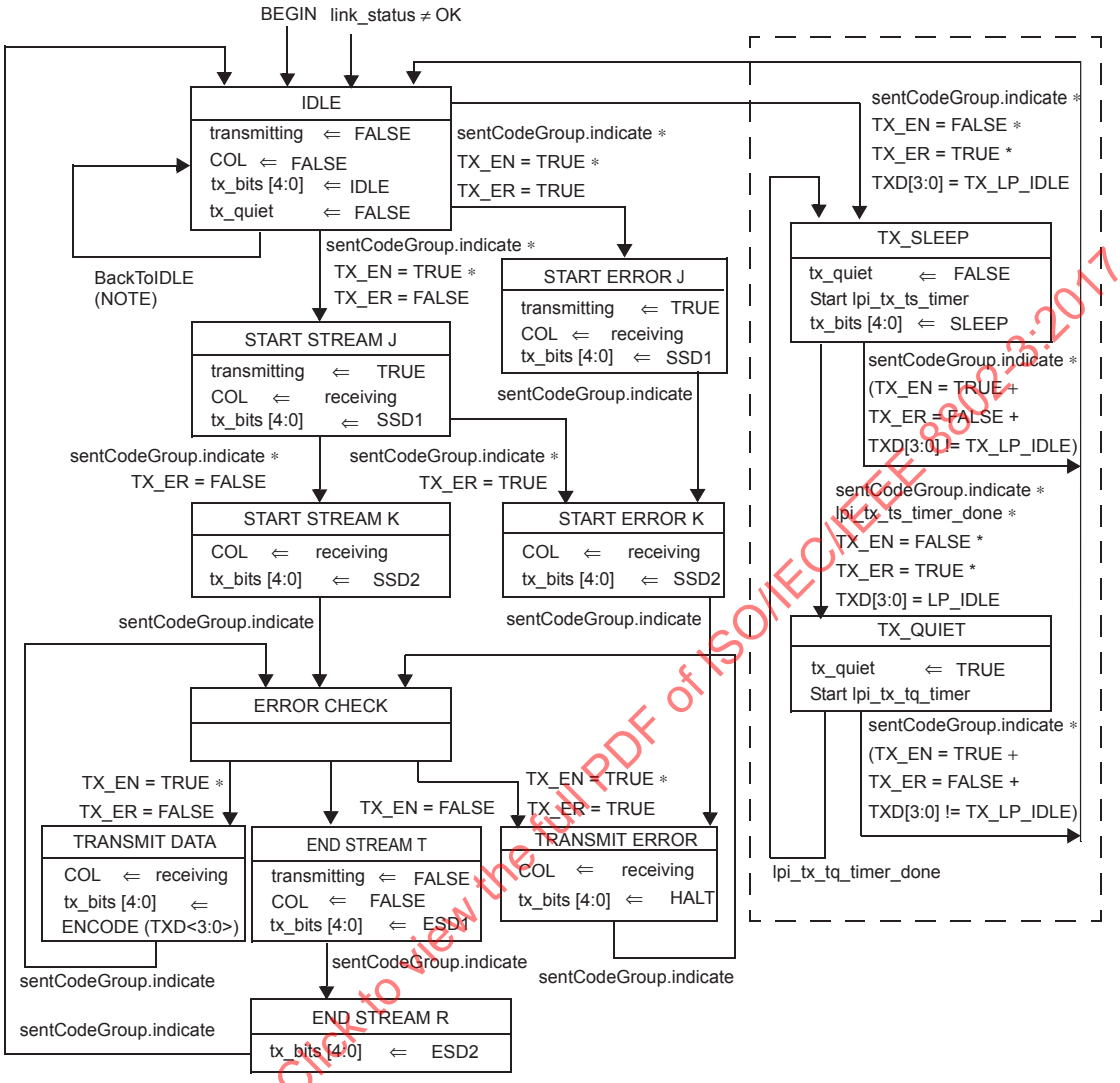

NOTE 1—BackToIDLE represents the following branch condition:
If the EEE capability is supported,
sentCodeGroup.indicate * TX_EN = FALSE * (TX_E R= FALSE + (TX_ER = TRUE * TXD[3:0] ≠ TX_LP_IDLE))
Otherwise,
sentCodeGroup.indicate * TX_EN = FALSE

NOTE 2—States and state transitions shown within the dashed box are only required for the EEE capability

Figure 24–8—Transmit state diagram

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24.2.4.4.1 Detecting channel activity

In a DTE operating in half duplex mode, the detection of activity on the underlying channel is used both by the MAC (via the MII CRS signal and the Reconciliation sublayer) for deferral purposes, and by the Transmit process for collision detection. Activity, signaled by the assertion of receiving, is indicated by the receipt of two non-contiguous ZEROS within any 10 code-bits of the incoming code-bit stream.

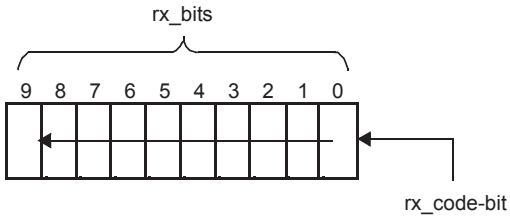

Figure 24–9—Receive Bits reference diagram

24.2.4.4.2 Code-group alignment

After channel activity is detected, the Receive process first aligns the incoming code-bits on code-group boundaries for subsequent data decoding. This is achieved by scanning the rx_bits vector for a SSD (/J/K/). The MII RX_DV signal remains deasserted during this time, which ensures that the Reconciliation sublayer will ignore any signals on RXD <3:0>. Detection of the SSD causes the Receive process to enter the START OF STREAM J state.

Well-formed streams contain SSD (/J/K/) in place of the first eight preamble bits. In the event that something else is sensed immediately following detection of carrier, a False Carrier Indication is signaled to the MII by asserting RX_ER and setting RXD to 1110 while RX_DV remains deasserted. The associated carrier event, as terminated by 10 ONEs, is otherwise ignored.

24.2.4.4.3 Stream decoding

The Receive process substitutes a sequence of alternating ONE and ZERO data-bits for the SSD, which is consistent with the preamble pattern expected by the MAC.

The Receive process then performs the DECODE function on the incoming code-groups, passing decoded data to the MII, including those corresponding to the remainder of the MAC preamble and SFD. The MII signal RX_ER is asserted upon decoding any code-group following the SSD that is neither a valid Data code-group nor a valid stream termination sequence.

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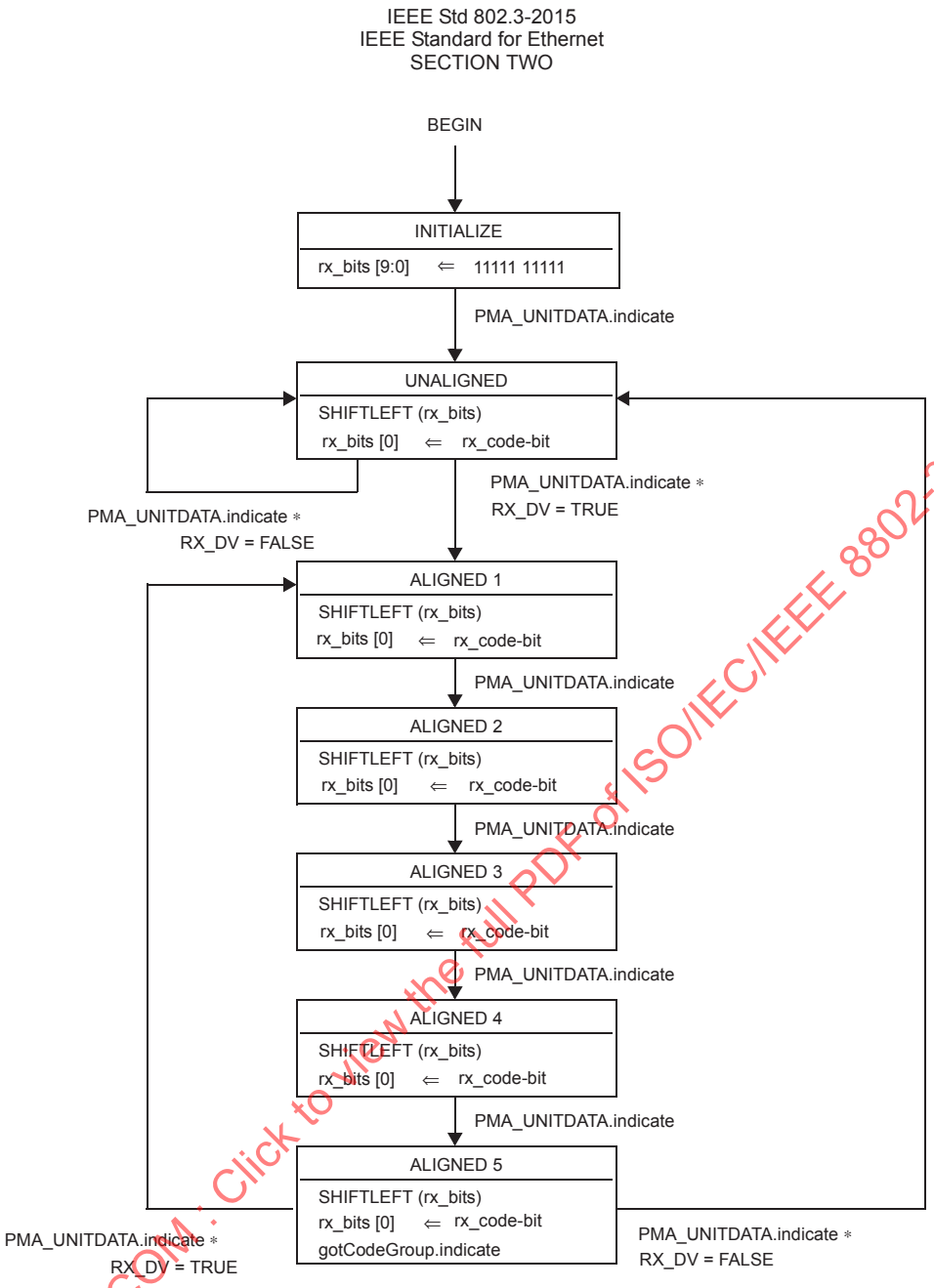

Figure 24–10—Receive Bits state diagram

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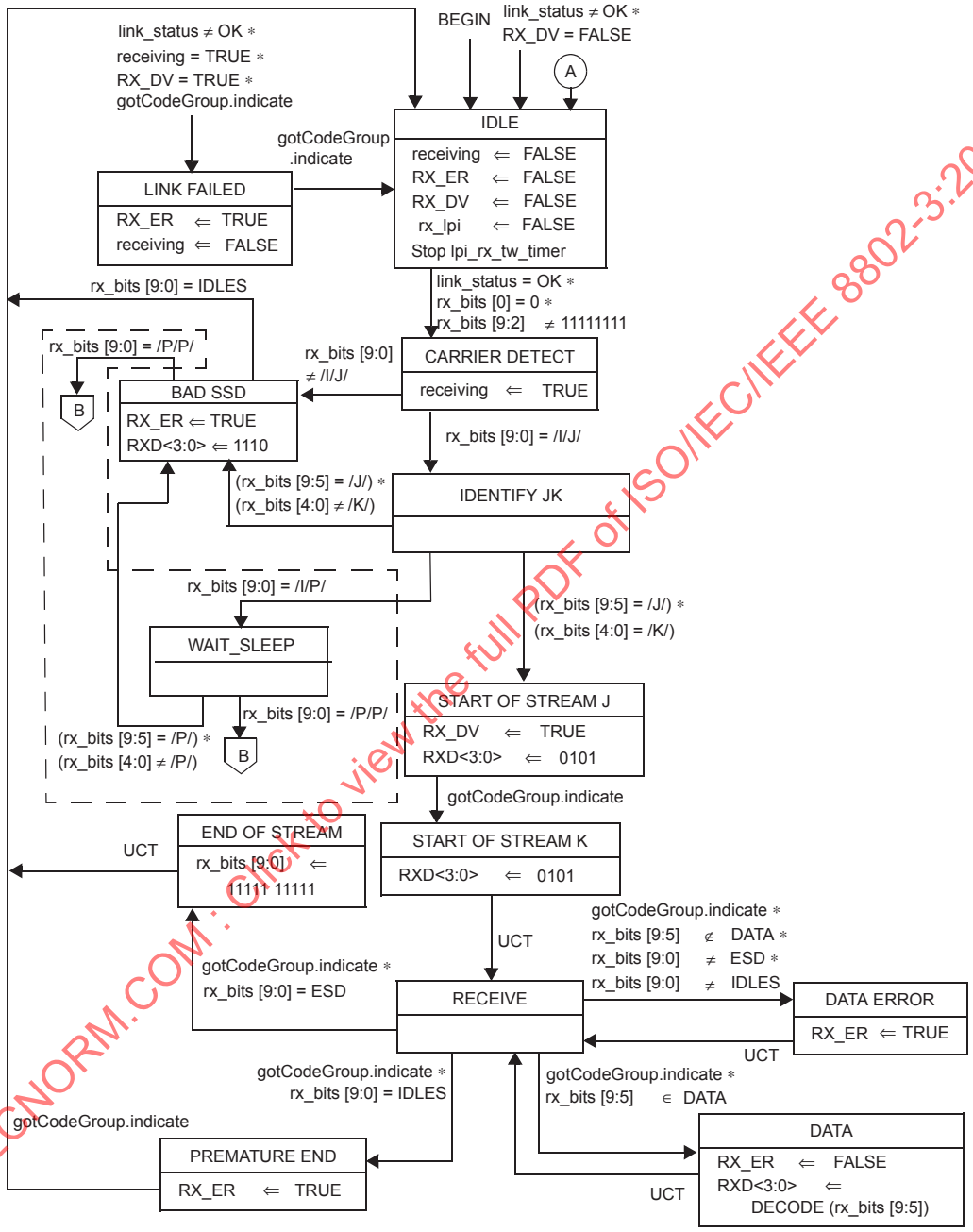
24.2.4.4.4 Stream termination

There are two means of effecting stream termination in the Receive process (Figure 24–11 and Figure 24–12) .



NOTE—States and state transitions shown within the dashed box are only required for the EEE capability

Figure 24–11—Receive state diagram, part a

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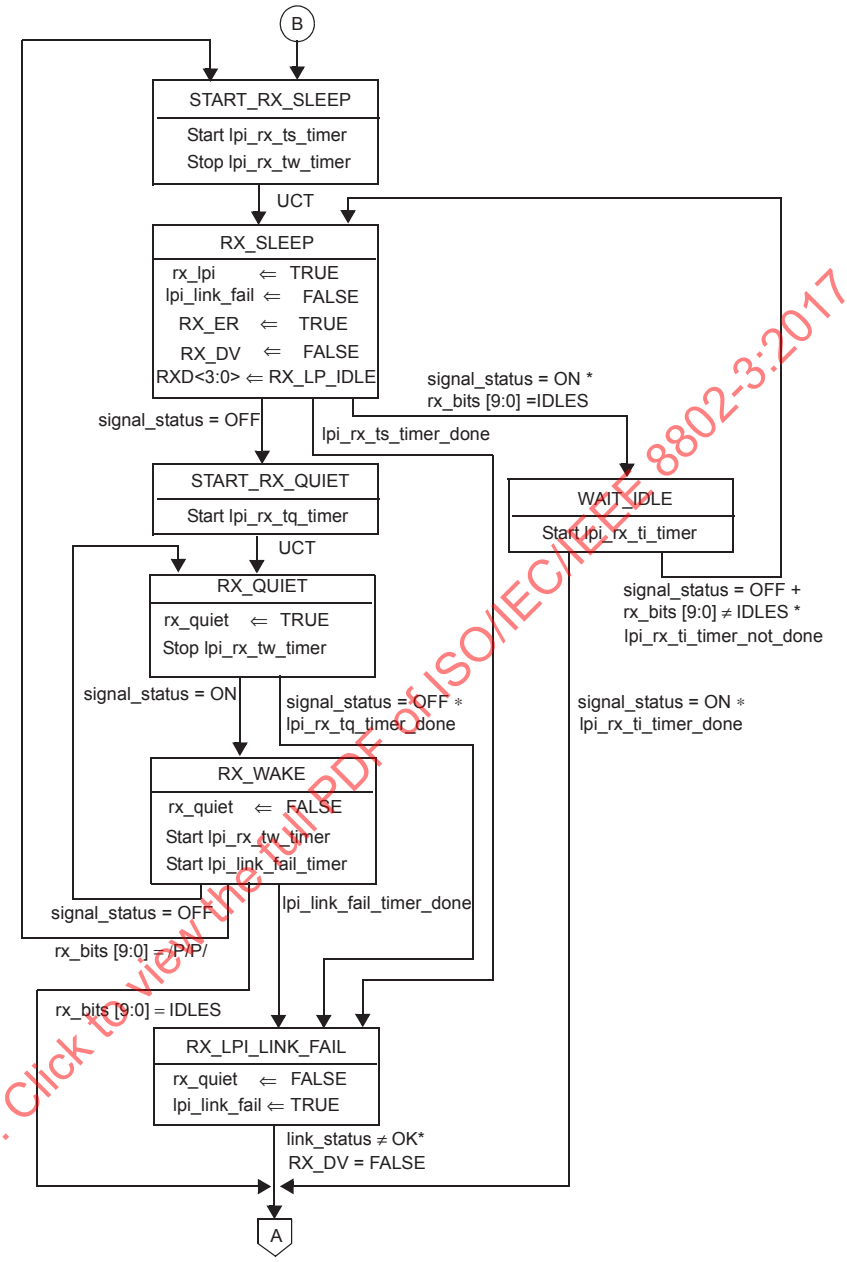

Figure 24–12—Receive state diagram, part b (only required for the EEE capability)

A normal stream termination is caused by detection of an ESD (/T/R/) in the rx_bits vector. In order to preserve the ability of the MAC to properly delimit the FCS at the end of the frame (that is, to avoid incorrect AlignmentErrors in the MAC) the internal signal receiving (and through it, the MII CRS signal, per Clause 22) is deasserted immediately following the last code-bit in the stream that maps to the FCS. Note that the condition link_status ≠ OK during stream reception (that is, when receiving = TRUE) causes an immediate transition to the LINK FAILED state and supersedes any other Receive process operations.

A premature stream termination is caused by the detection of two Idle code-groups (/I/I) in the rx_bits vector prior to an ESD. Note that RX_DV remains asserted during the nibble corresponding to the first five

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contiguous ONEs while RX_ER is signaled on the MII. RX_ER is also asserted in the LINK FAILED state, which ensures that RX_ER remains asserted for sufficient time to be detected.

Stream termination causes a transition to the IDLE state.

The PCS shall implement the Receive process as depicted in Figure 24–11 and Figure 24–12 including compliance with the associated state variables as specified in 24.2.3.

24.2.4.5 Carrier Sense

The Carrier Sense process generates the signal CRS on the MII, which (via the Reconciliation sublayer) a MAC operating in half duplex mode uses for deferral. The process operates by performing a logical OR operation on the internal messages receiving and transmitting, generated by the Receive and Transmit processes, respectively.

The PCS shall implement the Carrier Sense process as depicted in Figure 24–13 including compliance with the associated state variables as specified in 24.2.3.

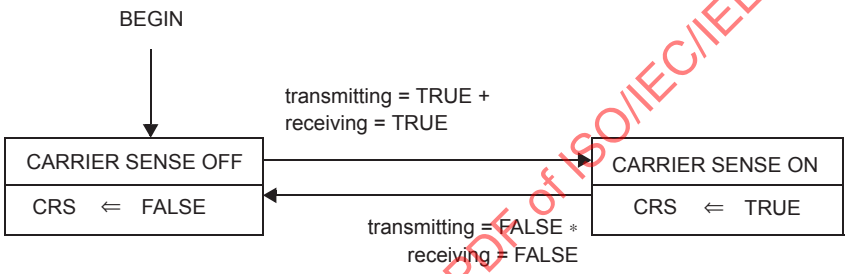

Figure 24–13—Carrier Sense state diagram

24.3 Physical Medium Attachment (PMA) sublayer

24.3.1 Service interface

The following specifies the service interface provided by the PMA to the PCS or another client, such as a repeater. These services are described in an abstract manner and do not imply any particular implementation.

The PMA Service Interface supports the exchange of code-bits between the PCS and/or Repeater entities. The PMA converts code-bits into NRZI format and passes these to the PMD, and vice versa. It also generates additional status indications for use by its client.

The following primitives are defined:

PMA_TYPE.indicate

PMA_UNITDATA.request

PMA_UNITDATA.indicate

PMA_CARRIER.indicate

PMA_LINK.indicate

PMA_LINK.request

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PMA_RXERROR.indicate

PMA_LPILINKFAIL.request

PMA_RXLPI.request

24.3.1.1 PMA_TYPE.indicate

This primitive is generated by the PMA to indicate the nature of the PMA instantiation. The purpose of this primitive is to allow clients to support connections to the various types of 100BASE-T PMA entities in a generalized manner.

24.3.1.1.1 Semantics of the service primitive

PMA_TYPE.indicate (pma_type)

The pma_type parameter for use with a 100BASE-X PMA is “X”.

24.3.1.1.2 When generated

The PMA continuously generates this primitive to indicate the value of pma_type.

24.3.1.1.3 Effect of receipt

The effect of receipt of this primitive by the client is unspecified by the PMA sublayer.

24.3.1.2 PMA_UNITDATA.request

This primitive defines the transfer of data (in the form of code-bits) from the PMA’s client to the PMA.

24.3.1.2.1 Semantics of the service primitive

PMA_UNITDATA.request (tx_code-bit)

This primitive defines the transfer of data (in the form of code-bits) from the PCS or other client to the PMA. The tx_code-bit parameter can take one of two values: ONE or ZERO.

24.3.1.2.2 When generated

The PCS or other client continuously sends, at a nominal 125 Mb/s rate, the appropriate code-bit for transmission on the medium.

24.3.1.2.3 Effect of receipt

Upon receipt of this primitive, the PMA generates a PMD_UNITDATA.request primitive, requesting transmission of the indicated code-bit, in NRZI format (tx_nrzi-bit), on the MDI.

24.3.1.3 PMA_UNITDATA.indicate

This primitive defines the transfer of data (in the form of code-bits) from the PMA to the PCS or other client.

24.3.1.3.1 Semantics of the service primitive

PMA_UNITDATA.indicate (rx_code-bit)

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The data conveyed by PMA_UNITDATA.indicate is a continuous code-bit sequence at a nominal 125 Mb/s rate. The rx_code-bit parameter can take one of two values: ONE or ZERO.

24.3.1.3.2 When generated

The PMA continuously sends code-bits to the PCS or other client corresponding to the PMD_UNITDATA.indicate primitives received from the PMD.

24.3.1.3.3 Effect of receipt

The effect of receipt of this primitive by the client is unspecified by the PMA sublayer.

24.3.1.4 PMA_CARRIER.indicate

This primitive is generated by the PMA to indicate that a non-squelched, non-IDLE code-bit sequence is being received from the PMD. The purpose of this primitive is to give clients the earliest reliable indication of activity on the underlying continuous-signaling channel.

24.3.1.4.1 Semantics of the service primitive

PMA_CARRIER.indicate (carrier_status)

The carrier_status parameter can take on one of two values, ON or OFF, indicating whether a non-squelched, non-IDLE code-bit sequence (that is, carrier) is being received (ON) or not (OFF).

24.3.1.4.2 When generated

The PMA generates this primitive to indicate a change in the value of carrier_status.

24.3.1.4.3 Effect of receipt

The effect of receipt of this primitive by the client is unspecified by the PMA sublayer.

24.3.1.5 PMA_LINK.indicate

This primitive is generated by the PMA to indicate the status of the underlying PMD receive link.

24.3.1.5.1 Semantics of the service primitive

PMA_LINK.indicate (link_status)

The link_status parameter can take on one of three values: READY, OK, or FAIL, indicating whether the underlying receive channel is intact and ready to be enabled by Auto-Negotiation (READY), intact and enabled (OK), or not intact (FAIL). Link_status is set to FAIL when the PMD sets signal_status to OFF; when Auto-Negotiation (optional) sets link_control to DISABLE; or when Far-End Fault Detect (optional) sets faulting to TRUE. When link_status ≠ OK, then rx_code-bit and carrier_status are undefined.

24.3.1.5.2 When generated

The PMA generates this primitive to indicate a change in the value of link_status.

24.3.1.5.3 Effect of receipt

The effect of receipt of this primitive by the client is unspecified by the PMA sublayer.

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24.3.1.6 PMA_LINK.request

This primitive is generated by the Auto-Negotiation algorithm, when implemented, to allow it to enable and disable operation of the PMA. See Clause 28. When Auto-Negotiation is not implemented, the primitive is never invoked and the PMA behaves as if link_control = ENABLE.

24.3.1.6.1 Semantics of the service primitive

PMA_LINK.request (link_control)

The link_control parameter takes on one of three values: SCAN_FOR_CARRIER, DISABLE, or ENABLE. Auto-Negotiation sets link_control to SCAN_FOR_CARRIER prior to receiving any fast link pulses, permitting the PMA to sense a 100BASE-X signal. Auto-Negotiation sets link_control to DISABLE when it senses an Auto-Negotiation partner (fast link pulses) and must temporarily disable the 100BASE-X PHY while negotiation ensues. Auto-Negotiation sets link_control to ENABLE when full control is passed to the 100BASE-X PHY.

24.3.1.6.2 When generated

Auto-Negotiation generates this primitive to indicate a change in link_control as described in Clause 28.

24.3.1.6.3 Effect of receipt

This primitive affects operation of the PMA Link Monitor function as described in 24.3.4.4.

24.3.1.7 PMA_RXERROR.indicate

This primitive is generated by the PMA to indicate that an error has been detected during a carrier event.

24.3.1.7.1 Semantics of the service primitive

PMA_RXERROR.indicate (rxerror_status)

The rxerror_status parameter can take on one of two values: ERROR or NO_ERROR, indicating whether the received carrier event contains a detectable error (ERROR) or not (NO_ERROR). A carrier event is considered to be in error when it is not started by a Start-of-Stream Delimiter.

24.3.1.7.2 When generated

The PMA generates this primitive whenever a new, non-squelched carrier event is not started by a Start-of-Stream Delimiter.

24.3.1.7.3 Effect of receipt

The effect of receipt of this primitive by the client is unspecified by the PMA sublayer.

24.3.1.8 PMA_LPILINKFAIL.request

This primitive is generated by the Receive Process of the PCS only if EEE is supported to control one of the link failure conditions of the Link Monitor in the PMA (see 24.2.4.3 and Figure 24–12).

24.3.1.8.1 Semantics of the service primitive

PMA_LPILINKFAIL.request (lpi_link_fail)

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The lpi_link_fail parameter takes on one of two values, TRUE or FALSE, indicating whether a link failure condition has been set (TRUE) or not (FALSE). The value of TRUE, when in the LPI mode, sets the link_status of the Link Monitor to FAIL (see 24.3.4.4 and Figure 24–15).

24.3.1.8.2 When generated

The PCS generates this primitive to indicate a link failure condition caused by the loss of Refresh signal when in the LPI mode.

24.3.1.8.3 Effect of receipt

This primitive affects operation of the PMA Link Monitor function as described in 24.3.4.4.

24.3.1.9 PMA_RXLPI.request

This primitive is generated by the Receive Process of the PCS only if EEE is supported to indicate that the receiver is in the LPI mode (see 24.2.4.3 and Figure 24–12).

24.3.1.9.1 Semantics of the service primitive

PMA_RXLPI.request (rx_lpi)

The rx_lpi parameter takes on one of two values, TRUE or FALSE, indicating whether the receiver is in the LPI mode (TRUE) or not (FALSE).

24.3.1.9.2 When generated

The PCS generates this primitive to indicate the LPI mode.

24.3.1.9.3 Effect of receipt

This primitive affects the operation of the PMA Link Monitor function as described in 24.3.4.4. Other use of receipt of this primitive by the client is unspecified by the PMA sublayer.

24.3.2 Functional requirements

The 100BASE-X PMA comprises the following functions:

a) Mapping of transmit and receive code-bits between the PMA Service Interface and the PMD Service Interface.
b) Link Monitor, which maps the PMD_SIGNAL.indicate primitive to the PMA_LINK.indicate primitive, indicating the availability of the underlying PMD.
c) Carrier Detection, which generates the PMA_CARRIER.indicate and PMA_RXERROR.indicate primitives from inspection of received PMD signals.
d) Far-End Fault (optional), comprised of the Far-End Fault Generate and Far-End Fault Detect processes, which sense receive channel failures and send the Far-End Fault Indication, and sense the Far-End Fault Indication.
e) EEE capability, which disables the Far-End Fault function and modifies the link down condition with the PMA_RXLPI.request primitive.

Figure 24–4 includes a functional block diagram of the PMA.

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24.3.2.1 Far-End fault

Auto-Negotiation provides a Remote Fault capability useful for detection of asymmetric link failures; i.e., channel error conditions detected by the far-end station but not the near-end station. Since Auto-Negotiation is specified only for media supporting eight-pin modular connectors, such as used by 100BASE-TX over twisted pair, Auto-Negotiation's Remote Fault capability is unavailable to other media for which it may be functionally beneficial, such as 100BASE-TX over shielded twisted pair or 100BASE-FX. A remote fault capability for 100BASE-FX is particularly useful due to this medium's applicability over longer distances (making end-station checking inconvenient) and for backbones (in which detection of link failures can trigger redundant systems).

For these reasons, 100BASE-X provides an optional Far-End Fault facility when Auto-Negotiation cannot be used. Far-End Fault shall not be implemented for media capable of supporting Auto-Negotiation.

When no signal is being received, as indicated by the PMD's signal detect function, the Far-End Fault feature permits the station to transmit a special Far-End Fault Indication to its far-end peer. The Far-End Fault Indication is sent only when a physical error condition is sensed on the receive channel. In all other situations, including reception of the Far-End Fault Indication itself, the PMA passes through tx_code-bit. (Note that the Far-End Fault architecture is such that IDLEs are automatically transmitted when the Far-End Fault Indication is detected. This is necessary to re-establish communication when the link is repaired.)

The Far-End Fault Indication is comprised of three or more repeating cycles, each of 84 ONEs followed by a single ZERO. This signal is sent in-band and is readily detectable but is constructed so as to not satisfy the 100BASE-X carrier sense criterion. It is therefore transparent to the PMA's client and to stations not implementing Far-End Fault.

As shown in Figure 24–4, Far-End Fault is implemented through the Far-End Fault Generate, Far-End Fault Detect, and the Link Monitor processes.

The Far-End Fault Generate process, which is interposed between the incoming tx_code-bit stream and the TX process, is responsible for sensing a receive channel failure (signal_status=OFF during the normal operation) and transmitting the Far-End Fault Indication in response. The transmission of the Far-End Fault Indication may start or stop at any time depending only on signal_status. The Far-End Fault shall not be generated when in the LPI mode.

The Far-End Fault Detect process continuously monitors rx_code-bits from the RX process for the Far-End Fault Indication. Detection of the Far-End Fault Indication disables the station by causing the Link Monitor process to deassert link_status, which in turn causes the station to source IDLEs. Far-End Fault detection can also be used by management functions not specified in this clause.

24.3.2.2 Comparison to previous IEEE 802.3 PMAs

Previous IEEE 802.3 PMAs perform the additional functions of SQE Test and Jabber. Neither of these functions is implemented in the 100BASE-X PMA.

SQE Test is provided in other Physical Layers to check the integrity of the Collision Detection mechanism independently of the Transmit and Receive capabilities of the Physical Layer. Since 100BASE-X effects collision detection by sensing receptions that occur during transmissions, collision detection is dependent on the health of the receive channel. By checking the ability to properly receive signals from the PMD, the Link Monitor function therefore functionally subsumes the functions previously implemented by SQE Test.

The Jabber function prevents a DTE from causing total network failure under certain classes of faults. When using mixing media (e.g., coaxial cables or passive optical star couplers), this function must naturally be implemented in the DTE. 100BASE-X requires the use of an active repeater, with one DTE or repeater

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attached to each port. As an implementation optimization, the Jabber function has therefore been moved to the repeater in 100BASE-X.

24.3.2.3 EEE capability

EEE capability, when communicated by the PMA_RXLPI.request primitive, affects the PMA in two ways. It disables the operation of the Far-End Fault processes to ignore the frequent on and off activity of signal_status. It receives link failure detection as communicated by the PMA_LPILINKFAIL.request primitive and changes the Link Monitor process to allow an exit from the LPI mode to a link down state. The EEE capability of the PMA is required only if the PCS supports EEE. If LPI is implemented, the operation of the PMA shall comply with the requirements in this subclause.

24.3.3 State variables

24.3.3.1 Constants

FEF_CYCLES

The number of consecutive cycles (of FEF_ONES ONEs and a single ZERO) necessary to indicate the Far-End Fault Indication. This value is 3.

FEF_ONES

The number of consecutive ONEs to be transmitted for each cycle of the Far-End Fault Indication. This value is 84.

24.3.3.2 Variables

carrier_status

The carrier_status parameter to be communicated by the Carrier Detect process through the PMA_CARRIER.indicate primitive. Carrier is defined as receipt of two noncontiguous ZEROs in 10 code-bits.

Values: ON; carrier is being received
OFF; carrier is not being received

faulting

The faulting variable set by the Far-End Fault Detect process, when implemented, indicating whether or not a Far-End Fault Indication is being sensed. This variable is used by the Link Monitor process to force link_status to FAIL.When Far-End Fault is not implemented, this variable is always FALSE.

Values: TRUE; Far-End Fault Indication is being sensed
FALSE; Far-End Fault Indication is not being sensed

link_control

The link_control parameter as communicated by the PMA_LINK.request primitive. When Auto-Negotiation is not implemented, the value of link_control is always ENABLE. See Clause 28 for a complete definition.

link_status

The link_status parameter as communicated by the Link Monitor process through the PMA_LINK.indicate primitive.

Values: FAIL; the receive channel is not intact

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READY; the receive channel is intact and ready to be enabled by Auto-Negotiation
OK; the receive channel is intact and enabled for reception

r_bits [9:0]

In Carrier Detect, a vector of the 10 most recently received code-bits from the PMD RX process. r_bits [0] is the most recently received (newest) code-bit; r_bits [9] is the least recently received code-bit (oldest). r_bits is an internal variable used exclusively by the Carrier Detect process.

rx_code-bit

The rx_code-bit parameter as delivered by the RX process, which operates in synchronism with the PMD_UNITDATA.indicate primitive. rx_code-bit is the most recently received code-bit from the PMD after conversion from NRZI.

rxerror_status

The rxerror_status parameter to be communicated by the Carrier Detect process through the PMA_RXERROR.indicate primitive.

Values: NO_ERROR; no error detected in the carrier event being received
ERROR; the carrier event being received is in error

signal_status

The signal_status parameter as communicated by the PMD_SIGNAL.indicate primitive.

Values: ON; the quality and level of the received signal is satisfactory
OFF; the quality and level of the received signal is not satisfactory

tx_code-bit_in

In Link Fault Generate, the tx_code-bit parameter as conveyed to the PMA from the PMA client by the PMA_UNITDATA.request.

tx_code-bit_out

In Link Fault Generate, the tx_code-bit parameter to be passed to the TX process. Note that this is called tx_code-bit by the TX process.

The following variables are required only for the optional EEE capability:

lpi_link_fail

The lpi_link_fail parameter is communicated by the PMA_LPILINKFAIL.request primitive. In the LPI mode, this variable is generated by the Receive process of the PCS to control the transition to a Link Down state. In the absence of the optional EEE capability, the PHY shall operate as if the value of this variable is FALSE.

Values: TRUE; local receiver has detected a link failure status when in an LPI state
FALSE; local receiver is functioning normally when in an LPI state

rx_lpi

The rx_lpi parameter is communicated by the PMA_RXLPI.request primitive. This variable is generated by the Receive process of the PCS to indicate the LPI mode. In the absence of the optional EEE capability, the PHY shall operate as if the value of this variable is FALSE.

Values: TRUE; local receiver is in the LPI mode
FALSE; local receiver is in the normal operation mode

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24.3.3.3 Functions

SHIFTLEFT (rx_bits)

In Carrier Detect, this function shifts rx_bits left one bit placing rx_bits [8] in rx_bits [9], rx_bits [7] in rx_bits [8] and so on until rx_bits [1] gets rx_bits [0].

24.3.3.4 Timers

stabilize_timer

An implementation-dependent delay timer between 330 µs and 1000 µs, inclusive, to ensure that the link is stable.

24.3.3.5 Counters

num_cycles

In Link Fault Detect, a counter containing the number of consecutive Far-End Fault cycles currently sensed. This counter gets reset on initialization or when the bit stream fails to qualify as a potential Far-End Fault Indication. It never exceeds FEF_CYCLES.

num_ones

This represents two separate and independent counters: In Link Fault Generate, a counter containing the number of consecutive ONEs already sent during this cycle of the Far-End Fault Indication. In Link Fault Detect, a counter containing the number of consecutive ONEs currently sensed; it gets reset whenever a ZERO is detected or when the bit stream fails to qualify as a potential Far-End Fault Indication. These counters never exceed FEF_ONES.

24.3.3.6 Messages

PMD_UNITDATA.indicate (rx_nrzi-bit)

A signal sent by the PMD signifying that the next nrzi-bit is available from the medium. nrzi-bit is converted (instantaneously) to code-bit by the RX process and used by the Carrier Detect process.

5xPMD_UNITDATA.indicates

In Carrier Detect, this shorthand notation represents repetition of the preceding state five times synchronized with five successive PMD_UNITDATA.indicates.

PMA_UNITDATA.request (tx_code-bit)

A signal sent by the PMA's client signifying that the next nrzi-bit is available for transmission. For this process, the tx_code-bit parameter is interpreted as tx_code-bit_in.

24.3.4 Process specifications and state diagrams

24.3.4.1 TX

The TX process passes data from the PMA's client directly to the PMD. The PMA shall implement the TX process as follows: Upon receipt of a PMA_UNITDATA.request (tx_code-bit), the PMA performs a conversion to NRZI format and generates a PMD_UNITDATA.request (tx_nrzi-bit) primitive with the same logical value for the tx_nrzi-bit parameter. Note that tx_code-bit is equivalent to tx_code-bit_out of the Link Fault Generate process when implemented.

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24.3.4.2 RX

The RX process passes data from the PMD directly to the PMA's client and to the Carrier Detect process. The PMA shall implement the RX process as follows: Upon receipt of a PMD_UNITDATA.indicate (rx_nrzi-bit), the PMA performs a conversion from NRZI format and generates a PMA_UNITDATA.indicate (rx_code-bit) primitive with the same logical value for the rx_code-bit parameter.

24.3.4.3 Carrier detect

The PMA Carrier Detect process provides repeater clients an indication that a carrier event has been sensed and an indication if it is deemed in error. A carrier event is defined as receipt of two non-contiguous ZEROS within any 10 rx_code-bits. A carrier event is in error if it does not start with an SSD. The Carrier Detect process performs this function by continuously monitoring the code-bits being delivered by the RX process, and checks for specific patterns that indicate non-IDLE activity and SSD bit patterns.

The Carrier Detect process collects code-bits from the PMD RX process. r_bits [9:0] represents a sliding, 10-bit window on the code-bit sequence, with newly received code-bits from the RX process being shifted into r_bits [0]. The process shifts the r_bits vector to the left, inserts the newly received code-bit into position 0, and waits for the next PMD.UNITDATA.indicate before repeating the operation. This is depicted in Figure 24–13. The Carrier Detect process monitors the r_bits vector until it detects two noncontiguous ZEROS in the incoming code-bit sequence. This signals a transition of carrier_status from OFF to ON. Each new carrier is further examined for a leading SSD (1100010001) with rxerror_status set to ERROR if it is not confirmed. A pattern of 10 contiguous ONEs in the stream indicates a return to carrier_status = OFF. Code-bit patterns of contiguous ONEs correspond to IDLE code-groups in the PCS, per the encoding specified in 24.2.2.1.

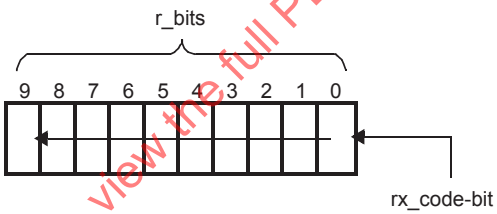

Figure 24–13—Carrier Detect reference diagram

The PMA shall, if it is supporting a repeater, implement the Carrier Detect process as depicted in Figure 24–14 including compliance with the associated state variables as specified in 24.3.3.

24.3.4.4 Link Monitor

The Link Monitor process is responsible for determining whether the underlying receive channel is providing reliable data. Failure of the underlying channel typically causes the PMA's client to suspend normal actions. The Link Monitor process takes advantage of the PMD sublayer's continuously signaled transmission scheme, which provides the PMA with a continuous indication of signal detection on the channel through signal_status as communicated by the PMD_SIGNAL.indicate primitive. It responds to control by Auto-Negotiation, when implemented, which is effected through the link_control parameter of PMA_SIGNAL.request.

The Link Monitor process monitors signal_status, setting link_status to FAIL whenever signal_status is OFF during the normal operation or when Auto-Negotiation sets link_control to DISABLE. If the EEE capability is supported, when the receiver is in the LPI mode, the assertion of lpi_link_fail shall set the link_status to FAIL and eventually brings the receiver out of the LPI mode. The link is deemed to be reliably operating

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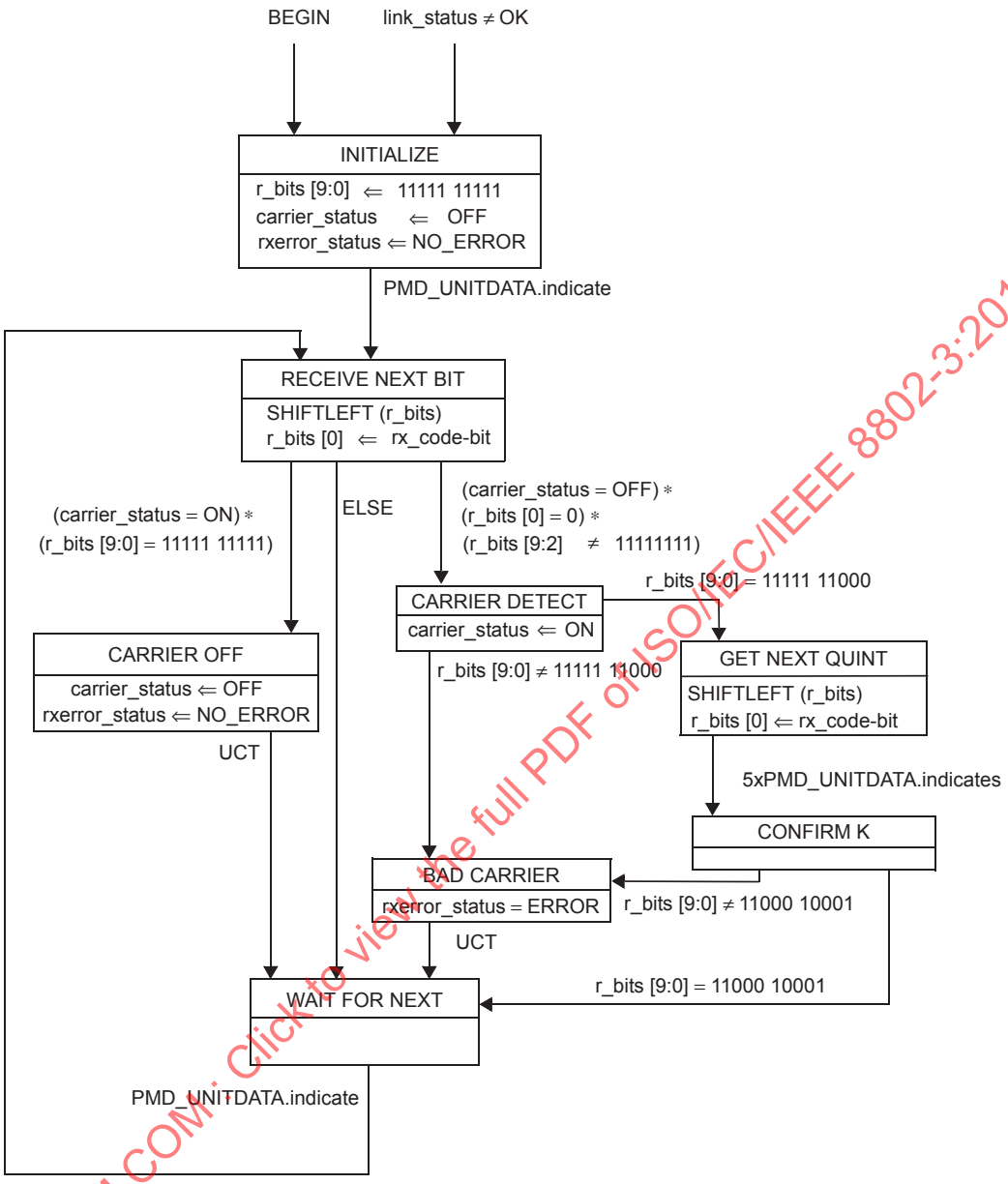

Figure 24–14—Carrier Detect state diagram

when signal_status has been continuously ON for a period of time. This period is implementation dependent but not less than 330 µs or greater than 1000 µs. If so qualified, Link Monitor sets link_status to READY in order to synchronize with Auto-Negotiation, when implemented. Auto-Negotiation permits full operation by setting link_control to ENABLE. When Auto-Negotiation is not implemented, Link Monitor operates with link_control always set to ENABLE.

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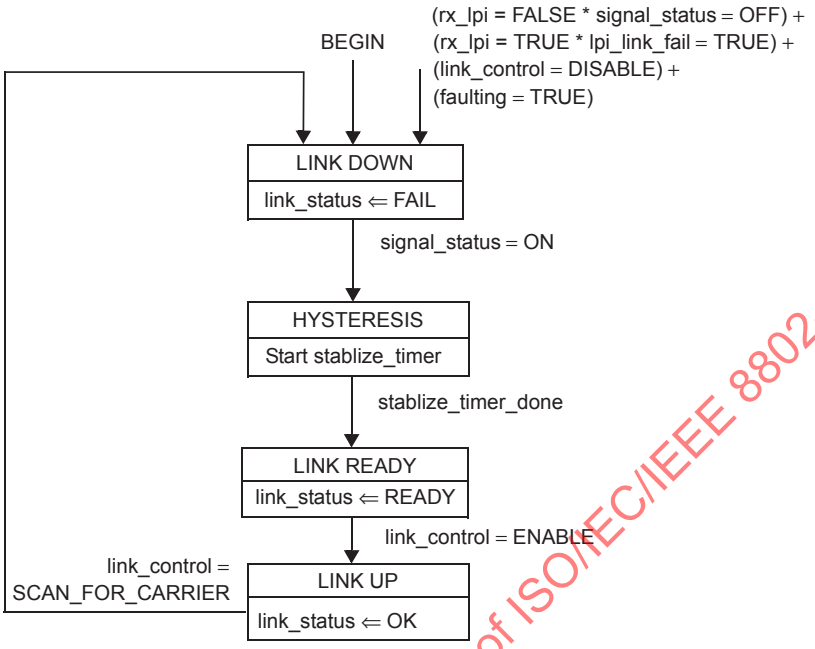
The PMA shall implement the Link Monitor process as depicted in Figure 24–15 including compliance with the associated state variables as specified in 24.3.3.



NOTE 1—The variables link_control and link_status are designated as link_control_[TX] and link_status_[TX], respectively, by the Auto-Negotiation Arbitration state diagram (Figure 28–18).

NOTE 2—The variables rx_lpi and lpi_link_fail are only required for the EEE capability and should be treated as if the value of these two variables is FALSE otherwise.

Figure 24–15—Link Monitor state diagram

24.3.4.5 Far-End Fault Generate

Far-End Fault Generate simply passes tx_code-bits to the TX process when signal_status=ON. When signal_status=OFF and not in the LPI mode, it repetitively generates each cycle of the Far-End Fault Indication until signal_status is reasserted.

If Far-End Fault is implemented, the PMA shall implement the Far-End Fault Generate process as depicted in Figure 24–16 including compliance with the associated state variables as specified in 24.3.3.

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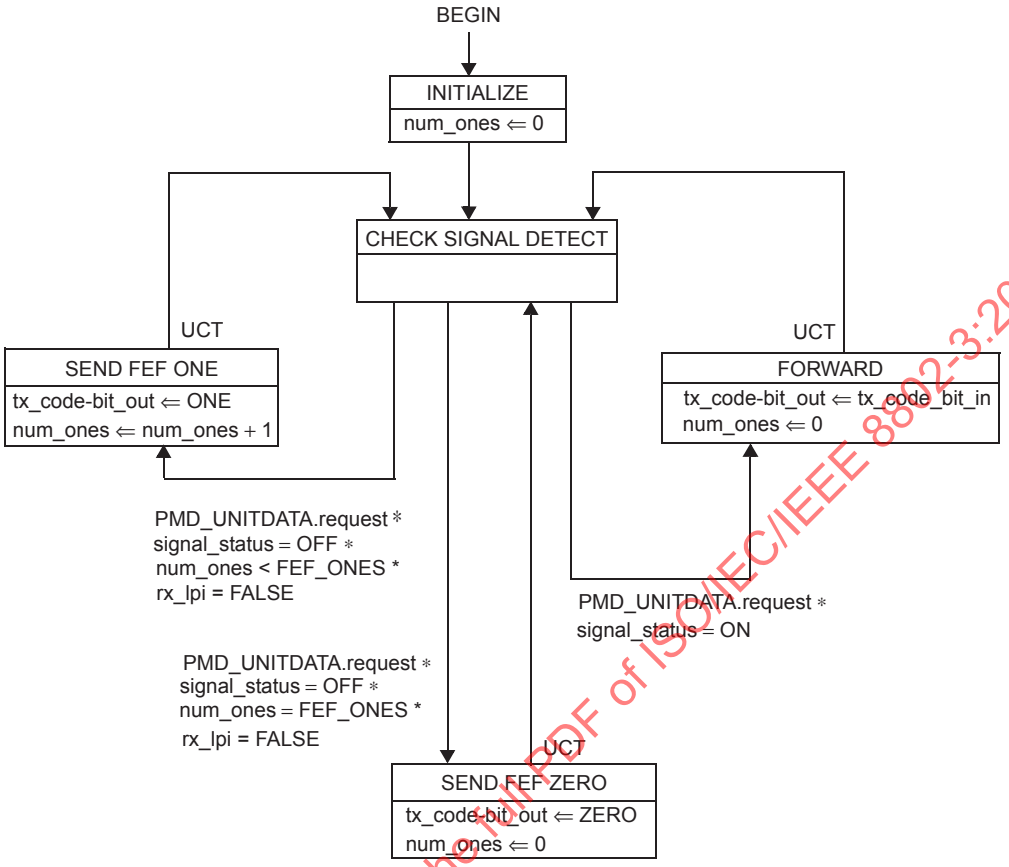

NOTE—The variable rx_lpi is only required for the EEE capability and should be treated as if the value of this variable is FALSE otherwise.

Figure 24–16—Far-End Fault Generation state diagram

24.3.4.6 Far-End Fault Detect

Far-End Fault Detect passively monitors the rx_code-bit stream from the RX process for the Far-End Fault Indication. It does so by maintaining counters for the number of consecutive ONEs seen since the last ZERO (num_ones) and the number of cycles of 84 ONEs and a single ZERO (num_cycles). The Far-End Fault Indication is denoted by three or more cycles, each of 84 ONEs and a single ZERO. Note that the number of consecutive ONEs may exceed 84 on the first cycle.

If Far-End Fault is implemented, the PMA shall implement the Far-End Fault Detect process as depicted in Figure 24–17 including compliance with the associated state variables as specified in 24.3.3.

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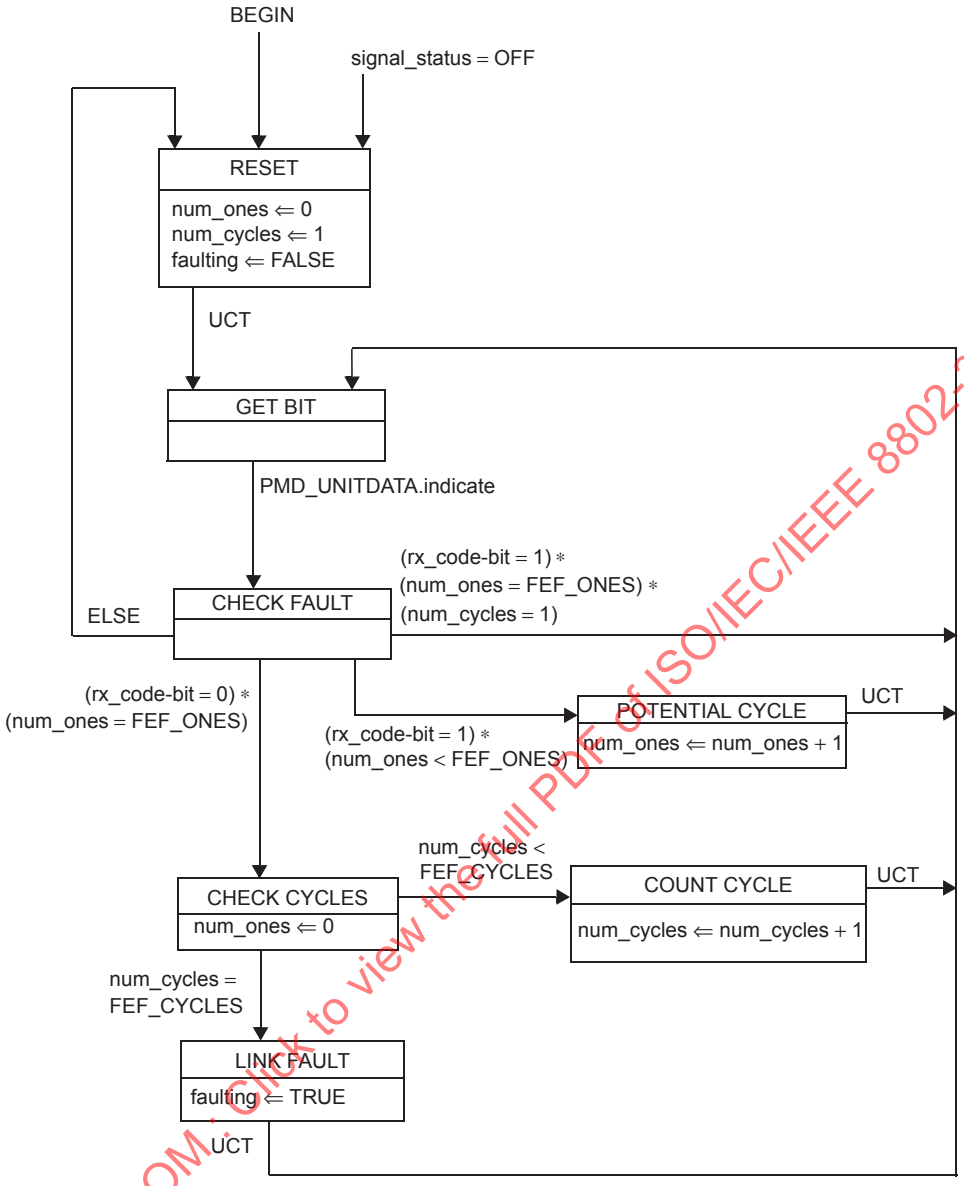

Figure 24–17—Far-End Fault Detect state diagram

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24.4 Physical Medium Dependent (PMD) sublayer service interface

24.4.1 PMD service interface

The following specifies the services provided by the PMD. The PMD is a sublayer within 100BASE-X and may not be present in other 100BASE-T PHY specifications. PMD services are described in an abstract manner and do not imply any particular implementation. It should be noted that these services are functionally identical to those defined in the FDDI standards, such as ISO/IEC 9314-3:1990 and ANSI X3.263-1995, with the following three exceptions:

a) 100BASE-X does not include a Station Management (SMT) function; therefore the PMD-to-SMT interface defined in ISO/IEC 9314-3:1990 and ANSI X3.263-1995.
b) 100BASE-X does not support multiple instances of a PMD in service to a single PMA; therefore, no qualifiers are needed to identify the unique PMD being referenced.
c) 100BASE-X may support LPI for the EEE capability.

There are also *editorial* differences between the interfaces specified here and in the referenced standards, as required by the context of 100BASE-X.

The PMD Service Interface supports the exchange of nrzi-bits between PMA entities. The PMD translates the nrzi-bits to and from signals suitable for the specified medium.

The following primitives are defined:

PMD_UNITDATA.request
PMD_UNITDATA.indicate
PMD_SIGNAL.indicate
PMD_RXQUIET.request
PMD_TXQUIET.request

24.4.1.1 PMD_UNITDATA.request

This primitive defines the transfer of data (in the form of nrzi-bits) from the PMA to the PMD.

24.4.1.1.1 Semantics of the service primitive

PMD_UNITDATA.request (tx_nrzi-bit)

The data conveyed by PMD_UNITDATA.request is a continuous sequence of nrzi-bits. The tx_nrzi-bit parameter can take one of two values: ONE or ZERO.

24.4.1.1.2 When generated

The PMA continuously sends, at a nominal 125 Mb/s rate, the PMD the appropriate nrzi-bits for transmission on the medium.

24.4.1.1.3 Effect of receipt

Upon receipt of this primitive, the PMD converts the specified nrzi-bit into the appropriate signals on the MDI.

24.4.1.2 PMD_UNITDATA.indicate

This primitive defines the transfer of data (in the form of nrzi-bits) from the PMD to the PMA.

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24.4.1.2.1 Semantics of the service primitive

PMD_UNITDATA.indicate (rx_nrzi-bit)

The data conveyed by PMD_UNITDATA.indicate is a continuous nrzi-bit sequence. The rx_nrzi-bit parameter can take one of two values: ONE or ZERO.

24.4.1.2.2 When generated

The PMD continuously sends nrzi-bits to the PMA corresponding to the signals received from the MDI.

24.4.1.2.3 Effect of receipt

The effect of receipt of this primitive by the client is unspecified by the PMD sublayer.

24.4.1.3 PMD_SIGNAL.indicate

This primitive is generated by the PMD to indicate the status of the signal being received from the MDI.

24.4.1.3.1 Semantics of the service primitive

PMD_SIGNAL.indicate (signal_status)

The signal_status parameter can take on one of two values: ON or OFF, indicating whether the quality and level of the received signal is satisfactory (ON) or unsatisfactory (OFF). When signal_status = OFF, then rx_nrzi-bit is undefined, but consequent actions based on PMD_SIGNAL.indicate, where necessary, interpret rx_nrzi-bit as logic ZERO.

24.4.1.3.2 When generated

The PMD generates this primitive to indicate a change in the value of signal_status.

24.4.1.3.3 Effect of receipt

The effect of receipt of this primitive by the client is unspecified by the PMD sublayer.

24.4.1.4 PMD_RXQUIET.request

This primitive is generated by the Receive Process of the PCS only if EEE is supported to indicate that the receiver is in the LPI mode and the line is in the Quiet state (see 24.2.4.3 and Figure 24–12).

24.4.1.4.1 Semantics of the service primitive

PMD_RXQUIET.request(rx_quiet)

The rx_quiet parameter takes on one of two values, TRUE or FALSE, indicating whether the receiver is in the Quiet state (TRUE) or not (FALSE).

24.4.1.4.2 When generated

The PCS generates this primitive to indicate a Quiet state of the transmitter in the LPI mode.

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24.4.1.4.3 Effect of receipt

This primitive affects operation of the PMD function of type 100BASE-TX as described in 25.5.2. Other use of receipt of this primitive by the client is unspecified by the PMD sublayer.

24.4.1.5 PMD_TXQUIET.request

This primitive is generated by the Transmit Process of the PCS only if EEE is supported to indicate that the transmitter is in the LPI mode and the line is in the Quiet state (see 24.2.4.2 and Figure 24–8).

24.4.1.5.1 Semantics of the service primitive

PMD_TXQUIETrequest(tx_quiet)

The tx_quiet parameter takes on one of two values, TRUE or FALSE, indicating whether the transmitter is in the Quiet state (TRUE) or not (FALSE).

24.4.1.5.2 When generated

The PCS generates this primitive to indicate a Quiet state of the transmitter in the LPI mode.

24.4.1.5.3 Effect of receipt

This primitive affects operation of the PMD function of type 100BASE-TX as described in 25.5.1. Other use of receipt of this primitive by the client is unspecified by the PMD sublayer.

24.4.2 Medium Dependent Interface (MDI)

The MDI, a physical interface associated with a PMD, is comprised of an electrical or optical medium connector. The 100BASE-X MDIs, defined in subsequent clauses, are specified by reference to the appropriate FDDI PMD, such as in ISO/IEC 9314-3:1990 and ANSI X3.263-1995, together with minor modifications (such as connectors and pin-outs) necessary for 100BASE-X.

24.5 Compatibility considerations

There is no requirement for a compliant device to implement or expose any of the interfaces specified for the PCS, PMA, or PMD. However, if an exposed interface is provided to the PCS, it shall comply with the requirements for the MII, as specified in Clause 22.

24.6 Delay constraints

In half duplex mode, proper operation of a CSMA/CD LAN demands that there be an upper bound on the propagation delays through the network. This implies that MAC, PHY, and repeater implementers must conform to certain delay minima and maxima, and that network planners and administrators conform to constraints regarding the cable topology and concatenation of devices.

In full duplex mode, predictable operation of the (optional) MAC Control PAUSE operation (Clause 31, Annex 31B) also demands that there be an upper bound on the propagation delays through the network. This implies that MAC, MAC Control sublayer, and PHY implementers must conform to certain delay maxima, and that network planners and administrators conform to constraints regarding the cable topology and concatenation of devices.

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MAC constraints are contained in Clause 21. Topological constraints are contained in Clause 29. MAC Control sublayer constraints are contained in Clause 31.

The reference point for all MDI measurements is the 50% point of the mid-cell transition corresponding to the reference code-bit, as measured at the MDI. Although 100BASE-TX output is scrambled, it is assumed that these measurements are made via apparatuses that appropriately account for this.

24.6.1 PHY delay constraints (exposed MII)

Every 100BASE-X PHY with an exposed MII shall comply with the bit delay constraints specified in Table 24–2 and Table 24–3. These figures apply for all 100BASE-X PMDs.

Table 24–2—Bit delay constraints

a) MDI to MII delay constraints (exposed MII, half duplex mode)

Sublayer measurement points	Event	Min (bits)	Max (bits)	Input timing reference	Output timing reference
MII ⇔ MDI	TX_EN sampled to MDI output	6	14	TX_CLK rising	1st bit of /J/
	MDI input to CRS assert		20	1st bit of /J/	
	MDI input to CRS deassert (aligned)	13	24	1st bit of /T/	
	MDI input to CRS deassert (unaligned)	13	24	1st ONE	
	MDI input to COL assert		20	1st bit of /J/	
	MDI input to COL deassert (aligned)	13	24	1st bit of /T/	
	MDI input to COL deassert (unaligned)	13	24	1st ONE	
	TX_EN sampled to CRS assert	0	4	TX_CLK rising	
	TX_EN sampled to CRS deassert	0	16	TX_CLK rising	

Table 24–3—Bit delay constraints *(continued)*

b) PHY delay constraints (exposed MII, full duplex mode)

Sublayer measurement points	Event	Min (bits)	Max (bits)	Input timing reference	Output timing reference
MII ⇔ MDI	TX_EN sampled to MDI output		14	TX_CLK rising	1st bit of /J/
	MDI Input to RX_DV deassert		32	first bit of /T/	RX_CLK rising

24.6.2 DTE delay constraints (unexposed MII)

Every 100BASE-X DTE with no exposed MII shall comply with the bit delay constraints specified in Table 24–4. These figures apply for all 100BASE-X PMDs.

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Table 24–4—DTE delay constraints (unexposed MII, half duplex mode)

Sublayer measurement points	Event	Min (bits)	Max (bits)	Input timing reference	Output timing reference
MAC ⇔ MDI	MAC transmit start to MDI output		18		1st bit of /J/
	MDI input to MDI output (worst-case nondeferred transmit)		54	1st bit of /J/	1st bit of /J/
	MDI input to collision detect		28	1st bit of /J/	
	MDI input to MDI output = Jam (worst case collision response)		54	1st bit of /J/	1st bit of jam

24.6.3 Carrier deassertion/assertion constraint (half duplex mode only)

To ensure fair access to the network, each DTE shall, additionally, satisfy the following:

(MAX MDI to MAC Carrier Deassert Detect) – (MIN MDI to MAC Carrier Assert Detect) < 13

24.7 Environmental specifications

All equipment subject to this clause shall conform to the requirements of 14.7 and applicable sections of ISO/IEC 11801.

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24.8 Protocol implementation conformance statement (PICS) proforma for Clause 24, Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 100BASE-X[6]

24.8.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 24, Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 100BASE-X, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

24.8.2 Identification

24.8.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

24.8.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-201x, Clause 24, Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 100BASE-X
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-201x.)	No [ ] Yes [ ]

Date of Statement	

[6]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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24.8.2.3 Major capabilities/options

Item	Feature	Subclause	Status	Support	Value/Comment
*DTE	Supports DTE without MII	24.4	O/1		
*REP	Supports Repeater without MII	24.4	O/1		
*MII	Supports exposed MII interface	24.4	O/1		
*PCS	Implements PCS functions	24.2	REP: O DTE: M MII: M		
PMA	Implements PMA RX, TX and Link Monitor functions	24.3	M		
*LPC	PCS implementation of LPI	24.2	PCS:O		
*LPM	PMA implementation of LPI	24.3	LPC:M		
*NWC	Medium capable of supporting Auto-Negotiation		O		See Clause 28
*FEF	Implements Far-End Fault	24.3.2.1	NWC: X LPM:X		
NWY	Supports Auto-Negotiation (Clause 28)	24.1.4.4	NWC:O LPC:M		See Clause 28

24.8.3 PICS proforma tables for the Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 100BASE-X

24.8.3.1 General compatibility considerations

Item	Feature	Subclause	Status	Support	Value/Comment
GN1	Compliance with MII requirements	24.4	MII:M		See Clause 22
GN2	Environmental specifications	24.7	M		

24.8.3.2 PCS functions

Item	Feature	Subclause	Status	Support	Value/Comment
PS1	Transmit Bits process	24.2.4.1	PCS:M		
PS2	Transmit process	24.2.4.2	PCS:M		
PS3	Receive Bits process	24.2.4.3	PCS:M		
PS4	Receive process	24.2.4.4	PCS:M		
PS5	Carrier Sense process	24.2.4.5	PCS:M		

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24.8.3.3 PMA functions

Item	Feature	Subclause	Status	Support	Value/Comment
PA1	TX process	24.3.4.1	M		
PA2	RX process	24.3.4.2	M		
PA3	Carrier Detect process	24.3.2.1	REP: M		
PA4	Link Monitor process	24.3.4.4	M		
PA5	Far-End Fault Generate process	24.3.4.5	FEF: M		
PA6	Far-End Fault Detect process	24.3.4.6	FEF: M		

24.8.3.4 Timing

Item	Feature	Subclause	Status	Support	Value/Comment
TM1	Support for MII signals TX_CLK and RX_CLK	24.2.2.3	MII:M		See Clause 22
TM2	Accuracy of code-bit_timer	24.2.3	M		
TM3	Compliance with PHY bit delay constraints	24.6.1	MII:M REP: O		
TM4	Compliance with DTE bit delay constraints	24.6.2	DTE:M		
TM5	Compliance with Carrier Deassert/Assert Constraint	24.6.3	DTE:M		

24.8.3.5 LPI functions

Item	Feature	Subclause	Status	Support	Value/Comment
LF1	lpi_rx_ti_timer	24.2.3.4	LPC:M		The timer has a period between 0.8–0.9 µs.
LF2	lpi_rx_tq_timer	24.2.3.4	LPC:M		The timer has a period between 24–26 ms.
LF3	lpi_rx_ts_timer	24.2.3.4	LPC:M		The timer has a period between 240–260 µs.
LF4	lpi_rx_tw_timer	24.2.3.4	LPC:M		The timer has a period that does not exceed 20.5 µs.
LF5	LPI wake error counter	24.2.3.4	LPC:M		Increment the wake error counter for each transition of lpi_rx_tw_timer_done from false to true.

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Item	Feature	Subclause	Status	Support	Value/Comment
LF6	lpi_tx_tq_timer	24.2.3.4	LPC:M		The timer has a period between 20–22 ms.
LF7	link failure caused by lpi_rx-_tq_timer	24.2.3.4	LPC:M		The receiver assumes a link failure if the PHY fails to receive a valid Refresh or Wake signal before the lpi_rx_tq_timer expires.
LF8	lpi_tx_ts_timer	24.2.3.4	LPC:M		The timer has a period between 200–220 µs.
LF9	lpi_link_fail_timer	24.2.3.4	LPC:M		The timer has a period between 90–110 µs.
LF11	lpi_link_fail	24.3.3.2	LPM:M		The PHY operates as if the value of this variable is FALSE in the absence of the optional EEE capability.
LF12	rx_lpi	24.3.3.2	LPM:M		The PHY operates as if the value of this variable is FALSE in the absence of the optional EEE capability.
LF13	link_status affected by lpi_link_fail	24.3.4.4	LPM:M		The assertion of lpi_link_fail sets the link_status to FAIL if the EEE is supported and the receiver is in the LPI mode.

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25. Physical Medium Dependent (PMD) sublayer and baseband medium, type 100BASE-TX

25.1 Overview

This clause specifies the 100BASE-X PMD (including MDI) and baseband medium for twisted-pair wiring, 100BASE-TX. In order to form a complete 100BASE-TX Physical Layer, the 100BASE-X PMD (including MDI) shall be integrated with the 100BASE-X PCS and PMA of Clause 24, which are assumed incorporated by reference. As such, the 100BASE-TX PMD shall comply with the PMD service interface specified in 24.4.1.

25.1.1 State diagram conventions

The body of this standard is comprised of state diagrams, including the associated definitions of variables, constants, and functions. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails. The notation used in the state diagrams follows the conventions of 21.5; state diagram timers follow the conventions of 14.2.3.2.

25.2 Functional specifications

The 100BASE-TX PMD (and MDI) is specified by incorporating the FDDI TP-PMD standard, ANSI X3.263: 1995 (TP-PMD), by reference, with the modifications noted below. This standard provides support for Category 5 twisted pair cabling. For improved legibility in this clause, ANSI X3.263: 1995 (TP-PMD), will henceforth be referred to as TP-PMD.

25.3 General exceptions

The 100BASE-TX PMD is precisely the PMD specified as TP-PMD, with the following general modifications:

a) The Scope and General description discussed in TP-PMD 1 and 5 relate to the use of those standards with an FDDI PHY, ISO/IEC 9314-1:1989, and MAC, ISO/IEC 9314-2:1989. These sections are not relevant to the use of the PMD with 100BASE-X.
b) The Normative references, Definitions and Conventions of TP-PMD 2, 3, and 4 are used only as necessary to interpret the applicable sections of TP-PMD referenced in this clause.
c) The PMD Service Specifications of TP-PMD 6 are replaced by those specified in 24.4.1. The 100BASE-TX PMD Service specification is a proper subset of the PMD Service Specification in TP-PMD.
d) The twisted-pair cabling specifications of TP-PMD 11.1 are replaced by those specified in 25.4.9.
e) 100BASE-TX optionally supports Energy-Efficient Ethernet (EEE), as described in Clause 78, with its Low Power Idle (LPI). Two new service primitives PMD_RXQUIET.request(rx_quiet) (see 24.4.1.4) and PMD_TXQUIET.request(tx_quiet) (see 24.4.1.5) are generated by the PCS to pass the energy saving requests.
f) There are minor terminology differences between this standard and TP-PMD that do not cause ambiguity. The terminology used in 100BASE-X was chosen to be consistent with other IEEE 802 standards, rather than with FDDI. Terminology is both defined and consistent within each standard. Special note should be made of the interpretations shown in Table 25–1.

25.4 Specific requirements and exceptions

The 100BASE-TX PMD (including MDI) shall comply to the requirements of TP-PMD, 7, 8, 9, 10, and 11, and normative Annex A with the exceptions listed below. In TP-PMD, informative annexes B, C, E, G, I, and

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Table 25–1—Interpretation of general FDDI terms and concepts

FDDI term or concept	Interpretation for 100BASE-TX
bypass	<unused>
Connection Management (CMT)	<no comparable entity>
frame	stream
Halt Line State (HLS)	<unused>
hybrid mode	<no comparable entity>
MAC (or MAC-2)	MAC
Master Line State (MLS)	<unused>
maximum frame size = 9000 symbols	maximum stream size = 4018 code-groups
PHY (or PHY-2)	PMA; i.e., PMD client
PHY Service Data Unit (SDU)	stream
PM_SIGNAL.indication (Signal_Detect)	PMD_SIGNAL.indication (signal_status)
PM_UNITDATA.indication (PM_Indication)	PMD_UNITDATA.indication (nrzi-bit)
PM_UNITDATA.request (PM_Request)	PMD_UNITDATA.request (nrzi-bit)
preamble	inter-packet IDLEs
Quiet Line State (QLS)	<unused>
SM_PM_BYPASS.request (Control_Action)	Assume: SM_PM_BYPASS.request(Control_Action = Insert)
SM_PM_CONTROL.request (Control_Action)	Assume: SM_PM_CONTROL.request (Control_Action = Transmit_Enable)
SM_PM_SIGNAL.indication (Signal_Detect)	<unused>
Station Management (SMT)	<no comparable entity>
symbol	code-group

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J, with exceptions listed below, provide additional information useful to PMD sublayer implementers. Where there is conflict between specifications in TP-PMD and those in this standard, those of this standard shall prevail.

25.4.1 Change to 7.2.3.1.1, “Line state patterns”

Descrambler synchronization on the Quiet Line State (QLS), Halt Line State (HLS), and Master Line State (MLS) Line State Patterns cited in TP-PMD 7.2.3.1.1 is optional.

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25.4.2 Change to 7.2.3.3, "Loss of synchronization"

The synchronization error triggered by PH_Invalid as defined in TP-PMD 7.2.3.3a is not applicable.

25.4.3 Change to Table 8-1, "Contact assignments for twisted pair"

100BASE-TX for twisted pair adopts the contact assignments of 10BASE-T. Therefore, the contact assignments shown in TP-PMD Table 8-1 shall instead be as depicted in Table 25–2.

Table 25–2—Twisted-pair MDI contact assignments

Contact	PHY without internal crossover MDI SIGNAL	PHY with internal crossover MDI SIGNAL
1	Transmit +	Receive +
2	Transmit –	Receive –
3	Receive +	Transmit +
4		
5		
6	Receive –	Transmit –
7		
8		

25.4.4 Deletion of 8.3, "Station labelling"

Clause 8.3 of TP-PMD shall not be applied to 100BASE-TX.

25.4.5 Change to 9.1.7, "Worst case droop of transformer"

A receiver in a Type 2 Endpoint PSE or Type 2 PD (see Clause 33) shall meet the requirements of 25.4.7. A transmitter in a Type 2 Endpoint PSE or Type 2 PD delivering or accepting more than 13.0 W average power shall meet either the Open Circuit Inductance (OCL) requirement in 9.1.7 of TP-PMD, or meet the requirements of 25.4.5.1.

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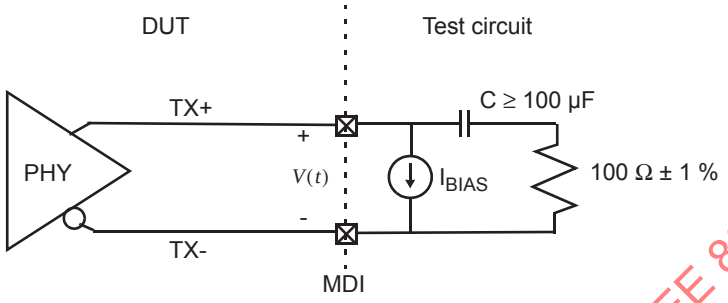
25.4.5.1 Equivalent system time constant

While transmitting the Data Dependent Jitter (DDJ) packet of TP-PMD A.2, using the test circuit shown in Figure 25–1, the equivalent system time constant, τ, shall be greater than 2.4 µs when calculated using measurement points A and C as shown in Figure 25–2.



DUT = Device under test

NOTE— I_{BIAS} is the current I_{unb} / 2 defined in Clause 33.

Figure 25–1—Type 2 System time constant test circuit

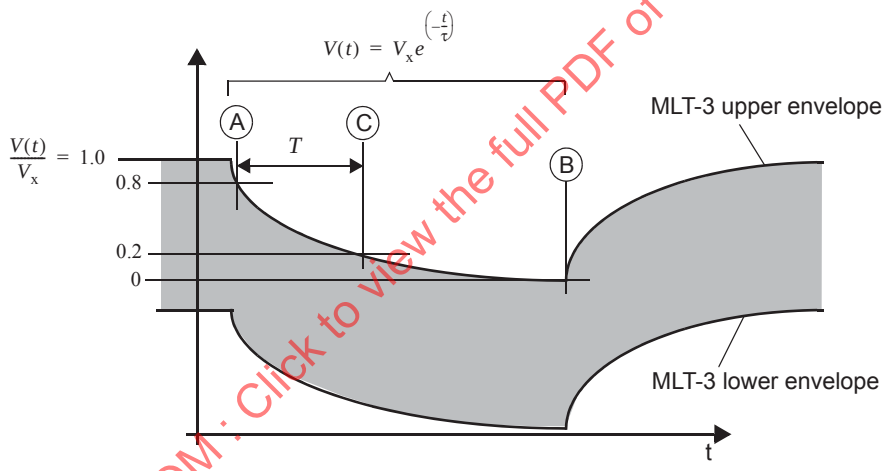


Figure 25–2—Type 2 System time constant measurement

Point B is the point of maximum baseline wander droop, and is the zero point for the vertical axis. Point A, with MDI voltage V_A, is earlier in time from B, with a magnitude that is 80 % of the MLT-3 upper envelope value. Point C, with MDI voltage V_C, is between A and B, with a magnitude that is 20 % of the MLT-3 upper envelope value. The time between A and C is *T*.

These measurements are to be made for the transmitter pair, observing the differential signal output at the MDI with intervening cable, meeting or exceeding the requirements of 25.4.7, less than 1 m long.

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The time constant of the transmitter MDI connected to the test circuit of Figure 25–1 is given by Equation (25–1).

$$\left\{ \tau = \frac{T}{\ln\left(\frac{V_A}{V_C}\right)} = \frac{2L}{R} \right\}_s \qquad (25\text{–}1)$$

where

τ	is the effective time constant of the transmitter
T	is the time in seconds from point A to point C as shown in Figure 25–2
V_A	is the MDI voltage at point A
V_C	is the MDI voltage at point C
L	is the open-circuit inductance of the Ethernet isolation transformer for all operating conditions
R	is the 100 Ω termination impedance

25.4.6 Replacement of 8.4.1, “UTP isolation requirements”

A PMD with a MDI that is a PI (see 33.1.3) shall meet the isolation requirements defined in 33.4.1.

A PMD with a MDI that is not a PI shall provide isolation between frame ground and all MDI leads including those not used by the 100BASE-TX PMD.

This electrical isolation shall withstand at least one of the following electrical strength tests.

a) 1500 V rms at 50 Hz to 60 Hz for 60 s, applied as specified in subclause 5.2.2 of IEC 60950-1:2001.
b) 2250 V dc for 60 s, applied as specified in subclause 5.2.2 of IEC 60950-1:2001.
c) A sequence of ten 2400 V impulses of alternating polarity, applied at intervals of not less than 1 s. The shape of the impulses shall be 1.2/50 µs (1.2 µs virtual front time, 50 µs virtual time of half value), as defined in IEC 60950-1:2001 Annex N.

There shall be no insulation breakdown, as defined in subclause 5.2.2 of IEC 60950-1:2001, during the test. The resistance after the test shall be at least 2 MΩ, measured at 500 V dc.

NOTE—In the case of a PMD with a MDI that is not a PI, these requirements are equivalent to those found in TP-PMD.

25.4.7 Addition to 10.1, “Receiver”

Differential voltage signals generated by a remote transmitter that meets the specifications of Clause 25; passed through a link specified in 25.4.8; and received at the MDI of a 100BASE-TX PMD in a Type 2 Endpoint PSE or a Type 2 PD shall be translated into one of the PMD_UNITDATA.indicate messages with a bit error ratio less than 10^{-9} after link reset completion.

25.4.8 Change to 9.1.9, “Jitter”

The jitter measurement specified in 9.1.9 of TP-PMD may be performed using scrambled IDLEs.

In the LPI mode, jitter shall be measured using scrambled SLEEP code-groups transmitted during the TX_SLEEP state (see Figure 24–8). Total transmit jitter with respect to a continuous unjittered reference shall not exceed 1.4 ns peak-to-peak with the exception that the jitter contributions from the clock transitions

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occurring during the TX_QUIET state and the first 5 µs of the TX_SLEEP state or the first 5 µs of the IDLE state following a TX_QUIET state are ignored. The jitter measurement time period shall be not less than 100 ms and not greater than 1 s.

25.4.9 Cable plant

The twisted-pair cabling specification of TP-PMD 11.1 is replaced by that specified in this subclause. The term "link segment" used in this subclause refers to a duplex channel of two pairs. Specifications for a link segment apply equally to each of the two pairs of a duplex channel. All implementations of the balanced cabling link shall be compatible at the MDI.

25.4.9.1 Cabling system characteristics

The cabling system used to support a 100BASE-TX duplex channel requires two pairs of Category 5 balanced cabling with a nominal impedance of 100 Ω. The cabling system components (cables, cords, and connectors) used to provide the link segment shall consist of Category 5 components as specified in ANSI/TIA/EIA-568-A:1995 and ISO/IEC 11801:1995 (Class D).

NOTE—ISO/IEC 11801:2002 provides a specification (Class D) for media that exceeds the minimum requirements of this standard.

25.4.9.2 Link transmission parameters

The transmission parameters contained in this subclause are specified to ensure that a Category 5 link segment of up to 100 m, will provide a reliable medium. The transmission parameters of the link segment include insertion loss, characteristics impedance, return loss, NEXT loss, and external coupled noise.

25.4.9.2.1 Insertion loss

The insertion loss of the link segment shall be less than,

$$\text{Insertion_Loss}(f) < 2.1f^{0.529} + 0.4/f \quad \text{(dB)}$$

at all frequencies from 1 MHz to 100 MHz. This includes the attenuation of the balanced cabling pairs, including work area and equipment cables plus connector losses within the link segment.

The insertion loss specification shall be met when the link segment is terminated in 100 Ω.

NOTE—The above equation approximates the insertion loss specification at 20°C for discrete frequencies of Category 5 100-meter links specified in ANSI/TIA/EIA-568-A Annex E and in TIA/EIA TSB-67.

25.4.9.2.2 Differential characteristic impedance

The nominal differential characteristic impedance of each link segment, which includes cable cords and connecting hardware, is 100 Ω for all frequencies between 1 MHz and 100 MHz.

25.4.9.2.3 Return loss

Each link segment shall meet or exceed the return loss specified in the following equation at all frequencies from 1 MHz to 100 MHz.

$$\text{Return_Loss}(f) \begin{cases} 15 & (1 - 20\ \text{MHz}) \\ 15 - 10\log_{10}(f/20) & (20 - 100\ \text{MHz}) \end{cases} \quad \text{(dB)}$$

where f is the frequency in MHz. The reference impedance shall be 100 Ω.

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25.4.9.2.4 Differential near-end crosstalk (NEXT)

In order to limit the crosstalk at the near end of a duplex channel, the differential pair-to-pair near-end crosstalk (NEXT) loss between the two pairs of a duplex channel shall be at least,

$27.1 - 16.8\log_{10}(f/100)$ (dB)

where f is the frequency over the range of 1 MHz to 100 MHz.

NOTE—The above equation approximates the NEXT loss specification at discrete frequencies for Category 5 100-meter links specified in ANSI/TIA/EIA-568-A Annex E and in TIA/EIA TSB-67.

25.4.9.3 Noise environment

The 100BASE-TX noise environment consists of noise from external sources and could impact the objective BER. This noise may consist of sources outside the cabling that couple into the link segment via electric and magnetic fields. In addition noise from adjacent cables, referred to as alien crosstalk, may couple into the link segment. This alien crosstalk is generally present when cables are bound tightly together. To ensure robust operation a 100BASE-TX PHY should operate in the presence of an external noise as specified in 25.4.9.3.1.

25.4.9.3.1 External coupled noise

The differential noise coupled from external sources that is measured at the output of a filter connected to the output of the near end of a disturbed link segment should not exceed 40 mV peak-to-peak. The filter for this measurement is a fifth order Butterworth filter with a 3 dB cutoff at 100 MHz.

25.4.10 Replacement of 11.2, “Crossover function”

Subclause 11.2 of TP-PMD is replaced with the following:

A crossover function compliant with 14.5.2 shall be implemented except that a) the signal names are those used in TP-PMD, and b) the contact assignments for STP are those shown in Table 8-2 of TP-PMD. Note that compliance with 14.5.2 implies a recommendation that crossover (for both UTP and STP) be performed within repeater PHYs.

25.4.11 Change to A.2, “DDJ test pattern for baseline wander measurements”

The length of the test pattern specified in TP-PMD A.2 may be shortened to accommodate feasible 100BASE-X measurements, but shall not be shorter than 3000 code-groups.

NOTE—This pattern is to be applied to the MII. (When applied to the MAC, the nibbles within each byte are to be swapped, e.g., as delivered to the MAC, the test pattern would start, "60 c9 16 ...".)

25.4.12 Change to Annex G, “Stream cipher scrambling function”

An example of a stream cipher scrambling implementation is shown in TP-PMD Annex G. This may be modified to allow synchronization solely on the IDLE sequences between packets.

25.4.13 Change to Annex I, “Common mode cable termination”

The contact assignments shown in TP-PMD Figures I-1 and I-2 shall instead comply with those specified in Table 25–2.

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25.5 EEE capability

TP-PMD does not have an option to support EEE. In order to add this capability to existing TP-PMD specification, the TP-PMD 7.1.2, 7.2.2, 10.1.2, 10.1.3, and Table 4 are modified to incorporate the LPI function. This subclause only applies to the optional EEE capability. If LPI is implemented, the operation of the PMD shall comply with the requirements in this subclause.

25.5.1 Change to TP-PMD 7.1.2 “Encoder”

The Encoder receives the scrambled NRZ data stream from the scrambler (see TP-PMD 7.1.1) and encodes the stream into MLT3 code for presentation to the driver (see TP-PMD 7.1.3). MLT3 coding is similar to NRZI coding, but three instead of two levels are transmitted. The Encoder can be deactivated when in the LPI mode. The PMD Encoder function of the 100BASE-TX with EEE capability is identical to that of the TP-PMD except that the output of the Encoder is set to a value ZERO_VOLTAGE when the transmitter is in the Quiet state of the LPI mode (TX_QUIET, see Figure 24–8).

The PMD in the LPI mode shall implement the Encoder state diagram as depicted in Figure 25–3.

25.5.1.1 State variables

25.5.1.1.1 Variables

encoder_input
: Indicates the value of each scrambled NRZ bit to be encoded.

  Values: ZERO; the NRZ bit from the scrambler has a logical value 0
  ONE; the NRZ bit from the scrambler has a logical value 1

encoder_output
: Indicates the value from the encoder for each MLT-3 encoded bit.

  Values: POSITIVE_VOLTAGE; the output indicates a positive value of voltage to TP-PMD driver
  ZERO_VOLTAGE; the output indicates a zero value of voltage to TP-PMD driver
  NEGATIVE_VOLTAGE; the output indicates a negative value of voltage to TP-PMD driver

tx_quiet
: The tx_quiet parameter as communicated by the PMD_TXQUIET.request (tx_quiet) primitive. This variable is generated by the Transmit process of the PCS to control the power-saving function of the local transmitter. It sets the Encoder state diagram to an initial state of ZERO_V.

  Values: TRUE; the local transmitter is in the Quiet state
  FALSE; the local transmitter is not in the Quiet state

le_flag
: A Boolean set by the Encoder process to indicate whether the last non-zero value of encoder_output was POSITIVE_VOLTAGE. The flag le_flag is set upon entry to the PLUS_V state and is cleared upon entry to the MINUS_V state.

  Values: ONE; the encoder is in the PLUS_V state
  ZERO; the encoder is in the MINUS_V state

25.5.1.1.2 Messages

gotNRZbit.indicate

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A signal sent to the Encoder process by the scrambler after a scrambled NRZ text bit has been generated using recursive linear function by the scrambler from plaintext bit stream and is ready to transmit.

25.5.1.2 State diagram

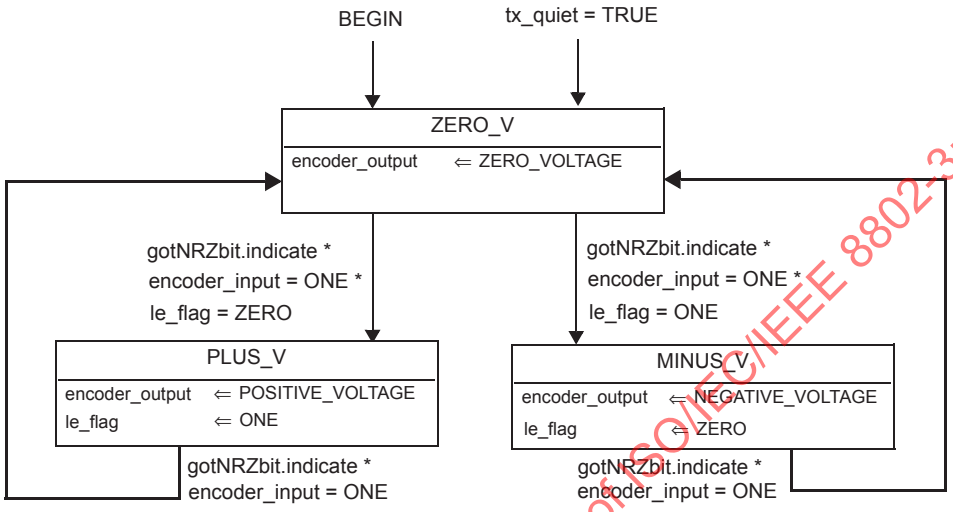

Figure 25–3—Encoder state diagram

25.5.2 Change to TP-PMD 7.2.2 “Decoder”

The Decoder receives the MLT3 encoded bit stream from the receiver (see TP-PMD 7.2.1), and decodes it into a NRZ encoded bit stream for presentation to the descrambler (see TP-PMD 7.2.3). The Decoder can be deactivated when in the LPI mode. The PMD Decoder function of the 100BASE-TX with EEE capability is identical to that of the TP-PMD except that the output of the Decoder is set to a value ZERO when the receiver is in the Quiet state of the LPI mode (RX_QUIET, Figure 24–12).

The PMD in the LPI mode shall implement the Decoder state diagram as depicted in Figure 25–4.

25.5.2.1 State variables

25.5.2.1.1 Variables

decoder_input
: Indicates the value of the MLT-3 encoded bit from the receiver.

  Values: ZERO; the MLT3 bit from the receiver has a logical value 0
  NONZERO; the MLT3 bit from the receiver has a non-zero logical value

decoder_output
: Indicates the value of the NRZ encoded bit.

  Values: ZERO; the output indicates a logical value of 0 to the descrambler
  ONE; the output indicates a logical value of 1 to the descrambler

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rx_quiet

The rx_quiet parameter as communicated by the PMD_RXQUIET.request (rx_quiet) primitive. This variable is generated by the Receive process of the PCS to control the power-saving function of local receiver. It sets the Decoder state diagram to an initial state of ZERO_VALUE.

Values: TRUE; the local receiver is in the Quiet state
FALSE; the local receiver is not in the Quiet state

prev_data

Indicates whether the last value of decoder_input was ZERO or NONZERO.

Values: ZERO; the last value of MLT3 bit of decoder_input has a logical value 0
NONZERO; the last value of MLT3 bit of decoder_input has a non-zero logical value

25.5.2.1.2 Messages

sentNRZbit.indicate

A signal sent to the Decoder process by the descrambler after an NRZ bit from ciphertext bit stream has been processed using recursive linear function and is ready to process the next bit from Decoder.

25.5.2.2 State diagram

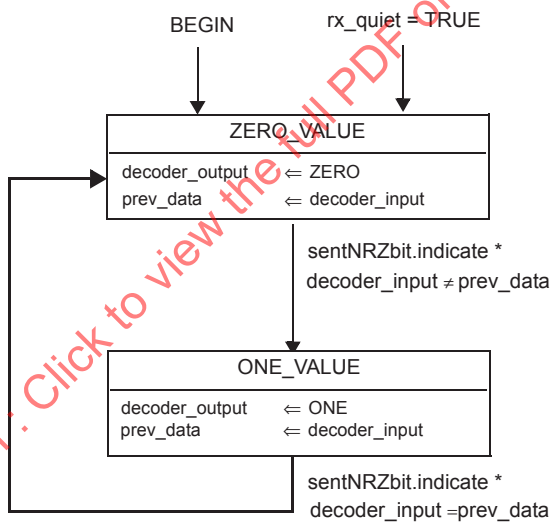

Figure 25–4—Decoder state diagram

25.5.3 Changes to 10.1.1.1 “Signal_Detect assertion threshold”

The TP-PMD 10.1.1.1 is applicable to the normal operation. In the LPI mode, when rx_lpi as communicated by the PMA_RXLPI.request primitive is asserted, Signal_Detect shall be asserted per 25.5.5 for any valid peak-to-peak signal, VSDA, of greater than 400 mV.

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25.5.4 Changes to 10.1.1.2 “Signal_Detect deassertion threshold”

The TP-PMD 10.1.1.2 is applicable to the normal operation. In the LPI mode, when rx_lpi is deasserted, Signal_Detect shall be deasserted per 25.5.6 for any valid peak-to-peak signal, VSDD, of smaller than 200 mV.

25.5.5 Change to 10.1.2 “Signal_Detect timing requirements on assertion”

The TP-PMD 10.1.2 is applicable to the normal operation. In the LPI mode, when rx_lpi is asserted, Signal_Detect output shall be asserted within 5 µs under the same quality requirement of the received signal as in normal operation. The new definition of conditional parameter AS_Max is inserted in TP-PMD Table 4 as depicted in Table 25–3.

25.5.6 Change to 10.1.3 “Signal_Detect timing requirements on deassertion”

The TP-PMD 10.1.3 is applicable to the normal operation. In the LPI mode, when rx_lpi is asserted, Signal_Detect output shall be deasserted within 5 µs under the same quality requirement of the received signal as in normal operation. The new definition of conditional parameter ANS_Max is inserted in TP-PMD Table 4 as depicted in Table 25–3.

25.5.7 Changes to TP-PMD 10.2 “Transmitter”

For the optional EEE capability, when tx_quiet (as communicated by the PMD_TXQUIET.request primitive) is set to FALSE, the transmitter output shall deliver a signal that exceeds Signal_Detect assertion threshold within 2 µs. The scrambler shall continue to operate for the first 5 µs following tx_quiet = TRUE. Transmit functions may be deactivated after this period. The transmitter shall deliver a fully compliant signal when tx_quiet is set to FALSE less than 5 µs after being set to TRUE. If tx_quiet is set to FALSE more than 5 µs after being set to TRUE, then the transmitter shall deliver a fully compliant signal within 5 µs (see 25.4.8).

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25.5.8 Replace TP-PMD Table 4 “Signal_Detect summary” with Table 25–3

The requirement of signal detection time and threshold are different between the normal operation mode and the LPI mode. In order to share one Signal_Detect, the timing and threshold characteristics may be qualified by LPI signal rx_lpi as communicated by the PMA_RXLPI.request primitive.

Table 25–3—Signal_Detect summary

Characteristic	Minimum	Maximum	Units
Assert time Normal operation mode		1000	µs
Deassert time Normal operation mode		350	µs
Assert time LPI mode		5	µs
Deassert time LPI mode		5	µs
Assert threshold VSDA 100 Ω balanced cable Normal operation mode		1000	mV peak to peak
Deassert threshold VSDD 100 Ω balanced cable Normal operation mode	200		mV peak to peak
Assert threshold VSDA 150 Ω balanced shielded cable Normal operation mode		1225	mV peak to peak
Deassert threshold VSDD 150 Ω balanced shielded cable Normal operation mode	245		mV peak to peak
Assert threshold VSDA LPI mode		400	mV peak to peak
Deassert threshold VSDD LPI mode	200		mV peak to peak

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25.6 Protocol implementation conformance statement (PICS) proforma for Clause 25, Physical Medium Dependent (PMD) sublayer and baseband medium, type 100BASE-TX[7]

25.6.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 25, Physical Medium Dependent (PMD) sublayer and baseband medium, type 100BASE-TX, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

25.6.2 Identification

25.6.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

25.6.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 25, Physical Medium Dependent (PMD) sublayer and baseband medium, type 100BASE-TX
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	No [ ] Yes [ ]

Date of Statement	

[7] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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25.6.3 Major capabilities/options

Item	Feature	Subclause	Status	Support	Value/Comment
*TXU	Supports unshielded twisted pair	25.2	O/1		
TXS	Supports shielded twisted pair	25.2	O/1		
*LPI	Implementation of LPI	25.5	O		

25.6.3.1 DTE Power via MDI major capabilities/options

Item	Feature	Subclause	Status	Support	Value/Comment
*PSET2	Type 2 PSE implementation	33.1.4	O	Yes [ ] No [ ]	Optional
*PDT2	Type 2 PD implementation	33.3.2	O	Yes [ ] No [ ]	Optional

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25.6.4 PICS proforma tables for the Physical Medium Dependent (PMD) sublayer and baseband medium, type 100BASE-TX

25.6.4.1 General compatibility considerations

Item	Feature	Subclause	Status	Support	Value/Comment
GN1	Integrates 100BASE-X PMA and PCS	25.1	M		See Clause 24

25.6.4.2 PMD compliance

Item	Feature	Subclause	Status	Support	Value/Comment
PD1	Compliance with 100BASE-X PMD Service Interface	25.1	M		See 24.2.3
PD2	Compliance with ANSI X3.263-1995, 7, 8 (excluding 8.3), 9, 10, 11 and normative annex A, with listed exceptions	25.4 25.4.8	M		
PD3	Precedence over ANSI X3.263-1995	25.4	M		
PD4	MDI contact assignments for twisted pair	25.4.4 25.4.3	TXU: M		
PD5	Compliance with crossover function of 14.5.2 with listed adaptations	25.4.11	M		
PD6	Minimum jitter test pattern length	25.4.12	M		3000 code-groups
PD7	Isolation requirements	25.4.6	M		

25.6.4.3 Characteristics of link segment

Item	Feature	Subclause	Status	Support	Value/Comment
LKS1	Implementations of balanced cabling link	25.4.9	M		Compatible at the MDI.
LKS2	100BASE-T links	25.4.9.1	M		Category 5 components as specified in ANSI/TIA/EIA-568-A:1995 and ISO/IEC 11801:1995 (Class D).

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Item	Feature	Subclause	Status	Support	Value/Comment
LKS3	Insertion loss	25.4.9.2.1	M		As specified in 25.4.9.2.1 at all frequencies from 1 MHz to 100 MHz when link segment is terminated in 100 Ω.
LKS4	Return loss	25.4.9.2.3	M		As specified in 25.4.9.2.3 at all frequencies from 1 MHz to 100 MHz when link segment is terminated in 100 Ω.
LKS5	Differential Near-End Crosstalk (NEXT)	25.4.9.2.4	M		As specified in 25.4.9.2.4 at all frequencies from 1 MHz to 100 MHz.

25.6.4.4 DTE Power via MDI compliance

Item	Feature	Subclause	Status	Support	Value/Comment
DTEP1	Type 2 PD receiver worst-case droop transformer	25.4.5	PDT2:M	Yes [ ] No [ ]	Meet requirements of 25.4.7: differential voltage signals translated into one of the PMD_UNITDATA.indicate messages with a bit error ratio less than 10^{-9} after link reset completion
DTEP2	Type 2 Endpoint PSE receiver worst-case droop transformer	25.4.5	PSET2:M	Yes [ ] No [ ]	Meet requirements of 25.4.7: differential voltage signals translated into one of the PMD_UNITDATA.indicate messages with a bit error ratio less than 10^{-9} after link reset completion
DTEP3	Type 2 PD transmitter worst-case droop transformer while accepting more than 13 W average power	25.4.5	PDT2:M	Yes [ ] No [ ]	Meet OCL requirements of 9.1.7 or requirements in 25.4.5.1
DTEP4	Type 2 Endpoint PSE transmitter worst-case droop transformer while delivering more than 13 W average power	25.4.5	PSET2:M	Yes [ ] No [ ]	Meet OCL requirements in 9.1.7 or requirements in 25.4.5.1
DTEP5	Equivalent system time constant	25.4.5.1	M	Yes [ ] N/A [ ]	Greater than 2.4 µs when calculated using measurement points A and C in Figure 25–2

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25.6.4.5 LPI functions

Item	Feature	Subclause	Status	Support	Value/Comment
LP1	Jitter measurement in the LPI mode	25.4.8	LPI:M	Yes [ ]	1.4 ns peak to peak
LP2	Code-groups used to measure jitter in the LPI mode	25.4.8	LPI:M	Yes [ ]	Scrambled SLEEP code-groups
LP3	Jitter measurement time interval in the LPI mode	25.4.8	LPI:M	Yes [ ]	No less than 100 ms and no greater than 1 s.
LP4	Encoder function in the LPI mode	25.5.1	LPI:M	Yes [ ]	Comply with the state diagram shown in Figure 25–3.
LP5	Decoder function in the LPI mode	25.5.2	LPI:M	Yes [ ]	Comply with the state diagram shown in Figure 25–4.
LP6	Signal_Detect assertion threshold in the LPI mode	25.5.3	LPI:M	Yes [ ]	Minimum 400 mV peak to peak
LP7	Signal_Detect deassertion threshold in the LPI mode	25.5.4	LPI:M	Yes [ ]	Maximum 200 mV peak to peak
LP8	Signal_Detect assertion time in the LPI mode	25.5.5	LPI:M	Yes [ ]	Maximum 5 µs
LP9	Signal_Detect deassertion time in the LPI mode	25.5.6	LPI:M	Yes [ ]	Maximum 5 µs
LP10	Scrambler and transmit functions deactivation time	25.5.7	LPI:M	Yes [ ]	The scrambler and transmit functions continue to operate for the first 5 µs following tx_quiet = TRUE.
LP11	Transmitter output amplitude initial ramp up time	25.5.7	LPI:M	Yes [ ]	The transmitter output delivers a signal that exceeds Signal_Detect assertion threshold within 2 µs when tx_quiet is set to TRUE.
LP12	Transmitter output recovery time after a short Quiet state	25.5.7	LPI:M	Yes [ ]	The transmitter delivers a fully compliant signal promptly if tx_quiet is set to FALSE less than 5 µs after being set to TRUE.
LP13	Transmitter output recovery time after a long Quiet state	25.5.7	LPI:M	Yes [ ]	The transmitter delivers a fully compliant signal within 5 µs if tx_quiet is set to FALSE more than 5 µs after being set to TRUE.

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26. Physical Medium Dependent (PMD) sublayer and baseband medium, type 100BASE-FX

26.1 Overview

This clause specifies the 100BASE-X PMD (including MDI) and fiber optic medium for multimode fiber, 100BASE-FX. In order to form a complete 100BASE-FX Physical Layer it shall be integrated with the 100BASE-X PCS and PMA of Clause 24, which are assumed incorporated by reference. As such, the 100BASE-FX PMD shall comply with the PMD service interface specified in 24.4.1.

26.2 Functional specifications

The 100BASE-FX PMD (and MDI) is specified by incorporating the FDDI PMD standard, ISO/IEC 9314-3:1990, by reference, with the modifications noted below. This standard provides support for two optical fibers. For improved legibility in this clause, ISO/IEC 9314-3:1990 will henceforth be referred to as fiber-PMD.

26.3 General exceptions

The 100BASE-FX PMD is precisely the PMD specified as fiber-PMD, with the following general modifications:

a) The scope and general description discussed in fiber-PMD 1 and 5 relate to the use of those standards with an FDDI PHY, ISO/IEC 9314-1:1989, and MAC, ISO/IEC 9314-2:1989. These clauses are not relevant to the use of the PMD with 100BASE-X.
b) The normative references, definitions, and conventions of fiber-PMD 2, 3, and 4 are used only as necessary to interpret the applicable sections of fiber-PMD referenced in this clause.
c) The PMD Service Specifications of fiber-PMD 6 are replaced by those specified in 24.4.1. The 100BASE-FX PMD Service specification is a proper subset of the PMD service specification in fiber-PMD.
d) There are minor terminology differences between this standard and fiber-PMD that do not cause ambiguity. The terminology used in 100BASE-X was chosen to be consistent with other IEEE 802 standards, rather than with FDDI. Terminology is both defined and consistent within each standard. Special note should be made of the interpretations shown in Table 26–1.

Table 26–1—Interpretation of general FDDI terms and concepts

FDDI term or concept	Interpretation for 100BASE-X
bypass	<unused>
Connection Management (CMT)	<no comparable entity>
frame	stream
Halt Line State (HLS)	<unused>
hybrid mode	<no comparable entity>
MAC (or MAC-2)	MAC
Master Line State (MLS)	<unused>
maximum frame size = 9000 symbols	maximum stream size = 4018 code-groups

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Table 26–1—Interpretation of general FDDI terms and concepts *(continued)*

FDDI term or concept	Interpretation for 100BASE-X
PHY (or PHY-2)	PMA; i.e., PMD client
PHY Service Data Unit (SDU)	stream
PM_SIGNAL.indication (Signal_Detect)	PMD_SIGNAL.indication (signal_status)
PM_UNITDATA.indication (PM_Indication)	PMD_UNITDATA.indication (nrzi-bit)
PM_UNITDATA.request (PM_Request)	PMD_UNITDATA.request (nrzi-bit)
preamble	inter-packet IDLEs
Quiet Line State (QLS)	<unused>
SM_PM_BYPASS.request (Control_Action)	Assume: SM_PM_BYPASS.request (Control_Action = Insert)
SM_PM_CONTROL.request (Control_Action)	Assume: SM_PM_CONTROL.request (Control_Action = Transmit_Enable)
SM_PM_SIGNAL.indication (Signal_Detect)	<unused>
Station Management (SMT)	<no comparable entity>
symbol	code-group

26.4 Specific requirements and exceptions

The 100BASE-FX PMD (including MDI) and baseband medium shall conform to the requirements of fiber-PMD Clauses 8, 9, and 10. In the referenced standard, fiber-PMD, informative Annex A through Annex G provide additional information useful to PMD sublayer implementers. Where there is conflict between specifications in fiber-PMD and those in this standard, those of this standard shall prevail.

26.4.1 Medium Dependent Interface (MDI)

The 100BASE-FX medium dependent interface (MDI) shall conform to one of the following connectors. The recommended alternative is the duplex SC connector.

a) The duplex SC connector as specified in IEC 61754-4 [B25] and IEC 61754-4, Interface 4-2. (See 38.11.3).
b) Media Interface Connector (MIC) as specified in fiber-PMD 7 and Annex F. When the MIC is used, the receptacle shall be keyed as “M”.
c) Optical Medium Connector Plug and Socket (commonly called ST[8] connector) as specified in 15.3.2.

26.4.2 Crossover function

A crossover function shall be implemented in every cable-pair link. The crossover function connects the transmitter of one PHY to the receiver of the PHY at the other end of the cable-pair link. For 100BASE-FX, the crossover function is realized in the cable plant.

[8]ST is a registered trademark of Lucent Technologies.

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26.5 Protocol implementation conformance statement (PICS) proforma for Clause 26, Physical Medium Dependent (PMD) sublayer and baseband medium, type 100BASE-FX[9]

26.5.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 26, Physical Medium Dependent (PMD) sublayer and baseband medium, type 100BASE-FX, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

26.5.2 Identification

26.5.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

26.5.3 Protocol summary

Identification of protocol standard	IEEE Std 802.3-201x, Clause 26, Physical Medium Dependent (PMD) sublayer and baseband medium, type 100BASE-FX
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-201x.)	No [ ] Yes [ ]

Date of Statement	

[9]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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26.5.4 Major capabilities/options

Item	Feature	Subclause	Status	Support	Value/Comment
FSC	Supports duplex SC connector	26.4.1	O/1		Recommended. See IEC 61754-4 [B25] and IEC 61754-4, Interface 4-2. (See 38.11.3).
*FMC	Supports Media Interface Connector (MIC)	26.4.1	O/1		See ISO/IEC 9314-3:1990, 7 and Annex F
FST	Supports Optical Medium Connector Plug and Socket (ST)	26.4.1	O/1		See 15.3.2

26.5.5 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and baseband medium, type 100BASE-FX

26.5.5.1 General compatibility considerations

Item	Feature	Subclause	Status	Support	Value/Comment
GN1	Integrates 100BASE-X PMA and PCS	26.1	M		See Clause 24

26.5.5.2 PMD compliance

Item	Feature	Subclause	Status	Support	Value/Comment
PD1	Compliance with 100BASE-X PMD Service Interface	26.1	M		See 24.4.1
PD2	Compliance with ISO/IEC 9314-3:1990 8, 9, and 10	26.4	M		
PD3	Precedence over ISO/IEC 9314-3:1990	26.4	M		
PD4	MIC receptacle keying	26.4.1	FMC: M		“M”
PD5	Crossover function in cable	26.4.2	M		

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27. Repeater for 100 Mb/s baseband networks

NOTE—This repeater is not recommended for new installations. Since September 2011, maintenance changes are no longer being considered for this clause.

27.1 Overview

27.1.1 Scope

Clause 27 defines the functional and electrical characteristics of a repeater for use with 100BASE-T 100 Mb/s baseband networks. A repeater for any other IEEE 802.3 network type is beyond the scope of this clause. The relationship of this standard to the OSI Reference Model is shown in Figure 27–1. The purpose of the repeater is to provide a simple, inexpensive, and flexible means of coupling two or more segments.

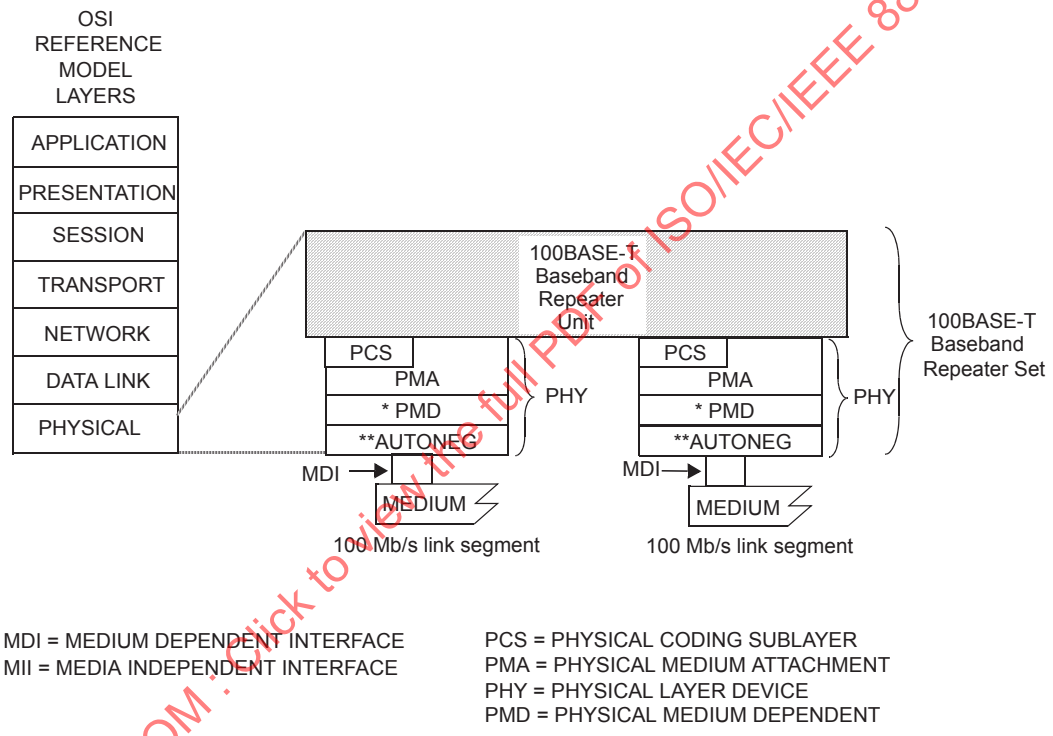

Figure 27–1—100BASE-T repeater set relationship to the ISO/IEC OSI reference model

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27.1.1.1 Repeater set

Repeater sets are an integral part of all 100 Mb/s baseband networks with more than two DTEs and are used to extend the physical system topology by providing a means of coupling two or more segments. Multiple repeater sets are permitted within a single collision domain to provide the maximum connection path length. Segments may be connected directly by a repeater or a pair of repeaters that are, in turn, connected by a inter-repeater link (IRL). Allowable topologies shall contain only one operative signal path between any two

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points on the network. A repeater set is not a station and does not count toward the overall limit of 1024 stations on a network.

A repeater set can receive, and if necessary decode, data from any segment under worst-case noise, timing, and signal amplitude conditions. It retransmits the data to all other segments attached to it with timing, amplitude, and, if necessary, coding restored. The retransmission of data occurs simultaneously with reception. If a collision occurs, the repeater set propagates the collision event throughout the network by transmitting a Jam signal. A repeater set also provides a degree of protection to a network by isolating a faulty segment's carrier activity from propagating through the network.

27.1.1.2 Repeater unit

A repeater unit is a subset of a repeater set containing all the repeater-specific components and functions, exclusive of PHY components and functions. A repeater unit connects to the PMA and, if necessary, the PCS sublayers of its PHYs.

27.1.1.3 Repeater classes

Two classes of repeater sets are defined—Class I and Class II.

Class I:

A type of repeater set specified such that in a maximum length segment topology, only one such repeater set may exist between any two DTEs within a single collision domain.

Class II:

A type of repeater set specified such that in a maximum length segment topology, only two such repeater sets may exist between any two DTEs within a single collision domain.

More complex topologies are possible in systems that do not use worst-case cable. See Clause 29 for requirements.

27.1.2 Application perspective

This subclause states the broad objectives and assumptions underlying the specification defined through Clause 27.

27.1.2.1 Objectives

a) Provide physical means for coupling two or more LAN segments at the Physical Layer.
b) Support interoperability of independently developed physical, electrical, and optical interfaces.
c) Provide a communication channel with a mean bit error ratio, at the physical service interface equivalent to that for the attached PHY.
d) Provide for ease of installation and service.
e) Ensure that fairness of DTE access is not compromised.
f) Provide for low-cost networks, as related to both equipment and cabling.
g) Make use of building wiring appropriate for the supported PHYs and telephony wiring practices.

27.1.2.2 Compatibility considerations

All implementations of the repeater set shall be compatible at the MDI. The repeater set is defined to provide compatibility among devices designed by different manufacturers. Designers are free to implement circuitry within the repeater set in an application-dependent manner provided the appropriate PHY specifications are met.

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27.1.2.2.1 Internal segment compatibility

Implementations of the repeater set that contain a MAC layer for network management or other purposes, irrespective of whether they are connected through an exposed repeater port or are internally ported, shall conform to the requirements of Clause 30 on that port if repeater management is implemented.

27.1.3 Relationship to PHY

A close relationship exists between Clause 27 and the PHY clauses, Clause 23 for the 100BASE-T4 PHY and Clause 24 to Clause 26 for the 100BASE-X PHYs, and Clause 32 for the 100BASE-T2 PHY. The PHY's PMA, PCS, and MDI specifications provide the actual medium attachment, including drivers, receivers, and Medium Interface Connectors for the various supported media. The repeater clause does not define a new PHY; it utilizes the existing PHYs complete and without modification.

27.2 PMA interface messages

The messages between the repeater unit and the PMA in the PHY utilizes the PMA service interface defined in 23.3, 24.3, and 32.4.2. The PMA service interface primitives are summarized below:

PMA_TYPE.indication
PMA_UNITDATA.request
PMA_UNITDATA.indication
PMA_CARRIER.indication
PMA_LINK.indication
PMA_RXERROR.indication

27.3 Repeater functional specifications

A repeater set provides the means whereby data from any segment can be received under worst case noise, timing, and amplitude conditions and then retransmitted with timing and amplitude restored to all other attached segments. Retransmission of data occurs simultaneously with reception. If a collision occurs, the repeater set propagates the collision event throughout the network by transmitting a Jam signal. If an error is received by the repeater set, no attempt is made to correct it and it is propagated throughout the network by transmitting an invalid signal.

The repeater set provides the following functional capability to handle data flow between ports:

a) *Signal restoration.* Provides the ability to restore the timing and amplitude of the received signal prior to retransmission.
b) *Transmit function.* Provides the ability to output signals on the appropriate port and encoded appropriately for that port. Details of signal processing are described in the specifications for the PHYs.
c) *Receive function.* Provides the ability to receive input signals presented to the ports. Details of signal processing are described in the specifications for the PHYs.
d) *Data Handling function.* Provides the ability to transfer code-elements between ports in the absence of a collision.
e) *Received Event Handling requirement.* Provides the ability to derive a carrier signal from the input signals presented to the ports.
f) *Collision Handling function.* Provides the ability to detect the simultaneous reception of frames at two or more ports and then to propagate a Jam message to all connected ports.
g) *Error Handling function.* Provides the ability to prevent substandard links from generating streams of false carrier and interfering with other links.
h) *Partition function.* Provides the ability to prevent a malfunctioning port from generating an excessive number of consecutive collisions and indefinitely disrupting data transmission on the network.

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i) *Receive Jabber function.* Provides the ability to interrupt the reception of abnormally long streams of input data.

27.3.1 Repeater functions

The repeater set shall provide the Signal Restoration, Transmit, Receive, Data Handling, Received Event Handling, Collision Handling, Error Handling, Partition, and Receive Jabber functions. The repeater is transparent to all network acquisition activity and to all DTEs. The repeater will not alter the basic fairness criterion for all DTEs to access the network or weigh it toward any DTE or group of DTEs regardless of network location.

The Transmit and Receive functional requirements are specified by the PHY clauses, Clause 23 for 100BASE-T4, Clause 24 to Clause 26 for 100BASE-X, and Clause 32 for 100BASE-T2.

27.3.1.1 Signal restoration functional requirements

27.3.1.1.1 Signal amplification

The repeater set (including its integral PHYs) shall ensure that the amplitude characteristics of the signals at the MDI outputs of the repeater set are within the tolerances of the specification for the appropriate PHY type. Therefore, any loss of signal-to-noise ratio due to cable loss and noise pickup is regained at the output of the repeater set as long as the incoming data is within system specification.

27.3.1.1.2 Signal wave-shape restoration

The repeater set (including its integral PHYs) shall ensure that the wave-shape characteristics of the signals at the MDI outputs of a repeater set are within the specified tolerance for the appropriate PHY type. Therefore, any loss of wave-shape due to PHYs and media distortion is restored at the output of the repeater set.

27.3.1.1.3 Signal retiming

The repeater set (including its integral PHYs) shall ensure that the timing of the encoded data output at the MDI outputs of a repeater set are within the specified tolerance for the appropriate PHY type. Therefore, any receive jitter from the media is removed at the output of the repeater set.

27.3.1.2 Data handling functional requirements

27.3.1.2.1 Data frame forwarding

The repeater set shall ensure that the data frame received on a single input port is distributed to all other output ports in a manner appropriate for the PHY type of that port. The data frame is that portion of the packet after the SFD and before the end-of-frame delimiter. The only exceptions to this rule are when contention exists among any of the ports, when the receive port is partitioned as defined in 27.3.1.6, when the receive port is in the Jabber state as defined in 27.3.1.7, or when the receive port is in the Link Unstable state as defined in 27.3.1.5.1. Between unpartitioned ports, the rules for collision handling (see 27.3.1.4) take precedence.

27.3.1.2.2 Received code violations

The repeater set shall ensure that any code violations received while forwarding a packet are propagated to all outgoing segments. These code violations shall be forwarded as received or replaced by bad_code (see 23.2.1.2), /H/ (see 24.2.2.1), or (ESC/0, 0/ESC) (see Figure 32–9) code-groups, as appropriate for the outgoing PHY type. Once a received code violation has been replaced by the bad_code, /H/, or (ESC/0, 0/ESC) code-groups, this substitution shall continue for the remainder of the packet regardless of its content. The only exception to this rule is when contention exists among any of the ports, where the rules for collision handling (see 27.3.1.4) then take precedence.

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27.3.1.3 Received event handling functional requirements

27.3.1.3.1 Received event handling

For all its ports, the repeater set shall implement a function (scarrier_present) that represents a received event. Received events include both the Data Frame and any encapsulation of the Data Frame such as Preamble, SFD, and the code-groups /H/, /J/, /K/, bad_code, eop, /T/, /R/, SSD, ESD, etc. A received event is exclusive of the IDLE pattern. Upon detection of scarrier_present from one port, the repeater set repeats all received signals in the Data Frame from that port to the other port (or ports) as described in Figure 27–2.

27.3.1.3.2 Preamble regeneration

The repeater set shall output preamble as appropriate for the outgoing PHY type followed by the SFD.

27.3.1.3.3 Start-of-packet propagation delay

The start-of-packet propagation delay for a repeater set is the time delay between the start of the packet (see 24.6, 23.11.3, and 32.12.1) on its repeated-from (input) port to the start of the packet on its repeated-to (output) port (or ports). This parameter is referred to as the SOP delay. The maximum value of this delay is constrained by Table 27–2.

27.3.1.3.4 Start-of-packet variability

The start-of-packet variability for a repeater set is defined as the total worst-case difference between start-of-packet propagation delays for successive packets separated by 104 bit times (BT) or less at the same input port. The variability shall be less than or equal to those specified in Table 27–1.

Table 27–1—Start-of-packet variability

Input port type	Variability (BT)
100BASE-FX	7.0
100BASE-TX	7.0
100BASE-T4	8.0
100BASE-T2	8.0

27.3.1.4 Collision handling functional requirements

27.3.1.4.1 Collision detection

The repeater performs collision detection by monitoring all its enabled input ports for received events. When the repeater detects received events on more than one input port, it shall enter a collision state and transmit the Jam message to all of its output ports.

27.3.1.4.2 Jam generation

While a collision is occurring between any of its ports, the repeater unit shall transmit the Jam message to all of the PMAs to which it is connected. The Jam message shall be transmitted in accordance with the repeater state diagram in Figure 27–4 and Figure 27–5.

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27.3.1.4.3 Collision-jam propagation delay

The start-of-collision Jam propagation delay for a repeater set is the time delay between the start of the second packet input signals to arrive at its port and the start of Jam (see 24.6, 23.11, and 32.12.1) out on all ports. This parameter is referred to as the SOJ delay. The delay shall be constrained by Table 27–2. Note that a device defined by two columns in Table 27–2 must meet the performance requirements specified in both columns.

Table 27–2—Start-of-packet propagation and start-of-collision jam propagation delays

Class I repeater	Class II repeater with all ports TX/FX	Class II repeater with any port T4	Class II repeater with any port T2
SOP + SOJ ≤ 140 BT	SOP ≤ 46 BT, SOJ ≤ 46 BT	SOP+SOJ ≤ 67 BT	SOP+SOJ ≤ 90 BT

27.3.1.4.4 Cessation-of-collision Jam propagation delay

The cessation-of-collision Jam propagation delay for a repeater set is the time delay between the end of the packet (see 24.6 and 23.11.3) that creates a state such that Jam should end at a port and the end of Jam (see 24.6 and 23.11.3) at that port. The states of the input signals that should cause Jam to end are covered in detail in the repeater state diagrams. This parameter is referred to as the EOJ delay. The delay shall be constrained by Table 27–3.

Table 27–3—Cessation-of-collision Jam propagation delay

Class I repeater	Class II repeater
EOJ ≤ SOP	EOJ ≤ SOP

27.3.1.5 Error handling functional requirements

27.3.1.5.1 100BASE-X and 100BASE-T2 carrier integrity functional requirements

In 100BASE-TX, 100BASE-FX, and 100BASE-T2 systems, it is desirable that the repeater set protect the network from some transient fault conditions that would disrupt network communications. Potential likely causes of such conditions are DTE and repeater power-up and power-down transients, cabling disconnects, and faulty wiring.

Each 100BASE-TX, 100BASE-FX, and 100BASE-T2 repeater PMA interface shall contain a self-interrupt capability, as described in Figure 27–9, to prevent a segment's spurious carrier activity from reaching the repeater unit and hence propagating through the network.

The repeater PMA interface shall count consecutive false carrier events. A false carrier event is defined as a carrier event that does not begin with a valid start of stream delimiter (see 24.2.2.1.4 and 32.3.1.2.3). The count shall be incremented on each false carrier event and shall be reset on reception of a valid carrier event. In addition, each PMA interface shall contain a false carrier timer, which is enabled at the beginning of a false carrier event and reset at the conclusion of such an event. A repeater unit shall transmit the JAM message to all of the PMAs to which it is connected for the duration of the false carrier event or until the duration of the event exceeds the time specified by the false_carrier_timer (see 27.3.2.1.4), whichever is shorter. The JAM message shall be transmitted in accordance with the Repeater state diagram in Figure 27–4 and Figure 27–5. The LINK UNSTABLE condition shall be detected when the False Carrier Count exceeds

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the value FCCLimit (see 27.3.2.1.1) or the duration of a false carrier event exceeds the time specified by the false_carrier_timer. In addition, the LINK UNSTABLE condition shall be detected upon power-up reset.

Upon detection of LINK UNSTABLE, the port shall perform the following:

a) Inhibit sending further messages to the repeater unit.
b) Inhibit sending further output messages from the repeater unit.
c) Continue to monitor activity on that PMA interface.

The repeater shall exit the LINK UNSTABLE condition when one of the following is met:

a1) The repeater has detected no activity (Idle) for more than the time specified by ipg_timer plus idle_timer (see 27.3.2.1.4) on Port X.
b1) A valid carrier event with a duration greater than the time specified by valid_carrier_timer (see 27.3.2.1.4) has been received, preceded by no activity (Idle) for more than the time specified by ipg_timer (see 27.3.2.1.4) on Port X.

27.3.1.5.2 Speed handling

If the PHY has the capability of detecting speeds other than 100 Mb/s, then the repeater set shall have the capability of blocking the flow of non-100 Mb/s signals. The incorporation of 100 Mb/s and 10 Mb/s repeater functionality within a single repeater set is beyond the scope of this standard.

27.3.1.6 Partition functional requirements

In large multisegment networks it may be desirable that the repeater set protect the network from some fault conditions that would disrupt network communications. A potentially likely cause of this condition could be due to a cable fault.

Each repeater PMA interface shall contain a self-interrupt capability, as described in Figure 27–8, to prevent a faulty segment's carrier activity from reaching the repeater unit and hence propagating through the network. The repeater PMA interface shall count collisions. The count shall be incremented on each transmission that suffers a collision. The count shall be reset on a carrier event of duration in excess of no_collision_timer (see 27.3.2.1.4) without incurring a collision. If this count reaches the value CCLimit (see 27.3.2.1.1), the Partition condition shall be detected.

Upon detection of Partition, the port shall perform the following:

a) Inhibit sending further input messages to the repeater unit.
b) Continue to output messages from the repeater unit.
c) Continue to monitor activity on that PMA interface.

The repeater shall reset the Partition function when one of the following conditions is met:

a1) On power-up reset.
b1) The repeater has transmitted on the port for a duration in excess of no_collision_timer (see 27.3.2.1.4) without incurring a collision.

NOTE—It is possible that under some network conditions the partition state diagram will partition a port due to normal network collisions rather than a fault condition. It is also possible that some double fault conditions will remain undetected. To reduce the likelihood of these events occurring, the following optional measures, as described in Figure 27–8, are recommended:

a2) The collision count is additionally reset when the repeater has transmitted on the port for a duration in excess of no_collision_timer without detecting a collision.

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b2) The Partition function is additionally reset when the repeater has received activity on the port for a duration in excess of no_collision_timer without detecting a collision.
c2) The Partition condition is additionally detected due to a carrier event of duration in excess of jabber_timer (see 27.3.1.7) in which a collision has occurred.

27.3.1.7 Receive jabber functional requirements

Each repeater PMA interface shall contain a self-interrupt capability, as described in Figure 27–7, to prevent an illegally long reception of data from reaching the repeater unit. The repeater PMA interface shall provide a window of duration jabber_timer bit times (see 27.3.2.1.4) during which the input messages may be passed on to other repeater unit functions. If a reception exceeds this duration, the jabber condition shall be detected.

Upon detection of jabber, the port shall perform the following:

a) Inhibit sending further input messages to the repeater unit.
b) Inhibit sending further output messages from the repeater unit.

The repeater PMA interface shall reset the Jabber function and re-enable data transmission and reception when either one of the following conditions is met:

a1) On power-up reset.
b1) When carrier is no longer detected.

27.3.2 Detailed repeater functions and state diagrams

A precise algorithmic definition is given in this subclause, providing a complete procedural model for the operation of a repeater, in the form of state diagrams. Note that whenever there is any apparent ambiguity concerning the definition of repeater operation, the state diagrams should be consulted for the definitive statement.

The model presented in this subclause is intended as a primary specification of the functions to be provided by any repeater unit. It is important to distinguish, however, between the model and a real implementation. The model is optimized for simplicity and clarity of presentation, while any realistic implementation should place heavier emphasis on such constraints as efficiency and suitability to a particular implementation technology.

It is the functional behavior of any repeater unit implementation that shall match the standard, not the internal structure. The internal details of the procedural model are useful only to the extent that they help specify the external behavior clearly and precisely. For example, the model uses a separate Receive Port Jabber state diagram for each port. However, in actual implementation, the hardware may be shared.

The notation used in the state diagram follows the conventions of 1.2.1. Note that transitions shown without source states are evaluated at the completion of every state and take precedence over other transition conditions.

27.3.2.1 State diagram variables

27.3.2.1.1 Constants

CCLimit

The number of consecutive collisions that must occur before a segment is partitioned.

Values: Positive integer greater than 60.

FCCLimit

The number of consecutive False Carrier events that must occur before a segment is isolated.

Value: 2.

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27.3.2.1.2 Variables

activity(Port designation)

Indicates port activity status. The repeater core effects a summation of this variable received from all its attached ports and responds accordingly.

Values: 0; no frame or packet activity at any port.
1; exactly 1 port of the repeater set has frame or packet activity input.
>1; more than 1 port of the repeater set has frame or packet activity input. Alternately, one or more ports has detected a carrier that is not valid.

all_data_sent

Indicates if all received data frame bits or code-groups from the current frame have been sent. During or after collision the all_data_sent variable follows the inverse of the carrier of port N.

Values: true; all received data frame bits or code-groups have been sent.
false; all received data frame bits or code-groups have not been sent.

begin

The Interprocess flag controlling state diagram initialization values.

Values: true
false

carrier_status(X)

Signal received from PMA; indicates the status of sourced Carrier input at Port X.

Values: ON; the carrier_status parameter of the PMA_CARRIER.indication primitive for Port X is ON.
OFF; the carrier_status parameter of the PMA_CARRIER.indication primitive for Port X is OFF.

data_ready

Indicates if the repeater has detected and/or decoded the MAC SFD and is ready to send the received data.

Values: true; the MAC SFD has been detected and/or decoded.
false; the MAC SFD has not been detected nor decoded.

force_jam(X)

Flag from Carrier Integrity state diagram for Port X, which determines whether all ports should transmit Jam.

Values: true; the Carrier Integrity Monitor has determined that it requires all ports be forced to transmit Jam.
false; the Carrier Integrity Monitor has determined that it does not require all ports be forced to transmit Jam.

Default: for T4 ports: false

isolate(X)

Flag from Carrier Integrity state diagram for Port X, which determines whether a port should be enabled or disabled.

Values: true; the Carrier Integrity Monitor has determined the port should be disabled.
false; the Carrier Integrity Monitor has determined the port should be enabled.

jabber(X)

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Flag from Receive Timer state diagram for Port X, which indicates that the port has received excessive length activity.

Values: true; port has exceeded the continuous activity limit.
false; port has not exceeded the continuous activity limit.

link_status(X)

Signal received from PMA; indicates link status for Port X (see 23.3.5, 24.3.1.5, and 32.4.1.3.1).

Values: OK; the link_status parameter of the PMA_LINK.indication primitive for Port X is OK.
READY; the link_status parameter of the PMA_LINK.indication primitive for Port X is READY (for 100BASE-TX and 100BASE-T4).
FAIL; the link_status parameter of the PMA_LINK.indication primitive for Port X is FAIL.

opt(X)

Implementation option. Either value may be chosen for repeater implementation.

Values: true; port will emit the JamT4 pattern in response to collision conditions.
false; port will append Jam pattern after preamble and SFD in response to collision conditions.

OUT(X)

Type of output repeater is sourcing at Port X.

Values: Idle; repeater is transmitting an IDLE pattern as described by 23.4.1.2, 24.2.2.1.2, or 32.3.1.2.3.
In(N); repeater is transmitting rx_code_bit(s) as received from Port (N) except /J/K/ (see 24.3.4.2), or recoded rx_symbol_vector as received from Port (N) except SSD (see 32.3.5.2).
Pream; repeater is sourcing preamble pattern as defined by the PMA or PCS of the port type (see 23.2.1.2, 24.2.2.2, 32.3.1.2, Figure 23–6 and Figure 24–9.)
Data; repeater is transmitting data frame on Port X. This data represents the original MAC source data field, properly encoded for the PHY type (see 23.2.1.2, 24.2.2.2, and 32.3.1.2.3).
Jam; repeater is sourcing well formed arbitrary data encodings, excluding SFD, to the port PMA.
JamX; repeater is sourcing a pattern representing 010101... repetitively on Port X.
JamT4; repeater is sourcing the pattern +-+-... repetitively on Port X.

JamT2; repeater is sending a pattern representing 010101... repetitively on Port X.
SFD; repeater is sourcing the Start Frame Delimiter on Port X encoded as defined by the appropriate PHY (see 23.2.3, Figure 24–9, and 32.3.1.2).
/J/K/; repeater is sourcing the code-groups /J/K/ as defined by the PMA on Port X (see 24.2.2.1.4).
/T/R/; repeater is sourcing the code-groups /T/R/ as defined by the PMA on Port X (see 24.2.2.1.5).

SSD; repeater is sourcing the code-groups SSD as defined by the PMA on Port X (see 32.4.2.5).

ESD; repeater is sourcing the code-groups ESD as defined by the PMA on Port X (see 32.3.1.2.3).
DF; repeater is sourcing the Data Frame of the packet on Port X. These are code elements originating on Port N exclusive of EOP1-5, SOSA and SOSB (see 23.2.3 and 23.2.4).
EOP; repeater is sourcing end of packet delimiter (EOP1-5) as defined by the appropriate PMA on Port X (see 23.2.1.2 and 23.2.4.1).

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bad_code; repeater is sourcing bad_code as defined by the PMA of the transmit port (see 23.2.4.1).
tx_err; repeater is sourcing a transmit error code element, either bad_code (see 23.2.4.1) or the code-group /H/ (see 24.2.2.1), or (ESC/0, 0/ESC) (see Figure 32–12) as appropriate to the outgoing PHY type.

partition(X)

Flag from Partition state diagram for Port X, which determines whether a port receive path should be enabled or disabled.

Values: true; port has exceeded the consecutive collision limit.
false; port has not exceeded the consecutive collision limit.

part_opt(X)

Implementation option. Either value may be chosen for repeater implementation (see 27.3.1.6).

Values: true; port supports the recommended optional measures in the partition state diagram.
false; port does not support the recommended optional measures in the partition state diagram.

rxerror_status(X)

Signal received from PMA; indicates if Port X has detected an error condition from the PMA (see 23.3.7.1, Figure 24–14, and Figure 32–14).The repeater need not propagate this error condition during collision events.

Values: ERROR; the rxerror_status parameter of the PMA_RXERROR.indication primitive for Port X is ERROR.
NO_ERROR; the rxerror_status parameter of the PMA_RXERROR.indication primitive for Port X is NO_ERROR.

RX_ER(X)

Signal received from PCS; indicates if Port X has detected an error condition from the PCS (see 23.2.1.4, 24.2.3.2, 32.3.4.1, Figure 23–10, Figure 24–15, and Figure 32–13). The repeater need not propagate this error condition during collision events.

Values: true; the PCS RX_ER signal for Port X is asserted.
false; the PCS RX_ER signal for Port X is negated.

scarrier_present(X)

Signal received from PMA; indicates the status of sourced Carrier input at Port X.

Values: true; the carrier_status parameter of the PMA_CARRIER.indication primitive for Port X is ON.
false; the carrier_status parameter of the PMA_CARRIER.indication primitive for Port X is OFF.

source_type(X)

Signal received from PMA; indicates PMA type for Port X. The first port to assert activity maintains the source type status for all transmitting port(s) until activity is deasserted. Repeaters may optionally force nonequality on comparisons using this variable. It must then follow the behavior of the state diagrams accordingly and meet all the delay parameters as applicable for the real implemented port type(s).

Values: FXTX; the pma_type parameter of the PMA_TYPE.indication primitive for Port X is X.
T4; the pma_type parameter of the PMA_TYPE.indication primitive for Port X is T4.
T2; the pma_type parameter of the PMA_TYPE.indication primitive for Port X is T2.

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27.3.2.1.3 Functions

command(X)

A function that passes an inter-process flag to all ports specified by X.

Values: copy; indicates that the repeater core has summed the activity levels of its active ports and is in the ACTIVE state.
collision; indicates that the repeater core has summed the activity levels of its active ports and is in the JAM state.
quiet; indicates that the repeater core has summed the activity levels of its active ports and is in the IDLE state.

port(Test)

A function that returns the designation of a port passing the test condition. For example, port(activity = scarrier_present) returns the designation: X for a port for which scarrier_present = true. If multiple ports meet the test condition, the Port function will be assigned one and only one of the acceptable values.

27.3.2.1.4 Timers

All timers operate in the same fashion. A timer is reset and starts timing upon entering a state where "start x_timer" is asserted. At time "x" after the timer has been started, "x_timer_done" is asserted and remains asserted until the timer is reset. At all other times, "x_timer_not_done" is asserted.

When entering a state where "start x_timer" is asserted, the timer is reset and restarted even if the entered state is the same as the exited state.

The timers used in the repeater state diagrams are defined as follows:

false_carrier_timer

Timer for length of false carrier (27.3.1.5.1) that must be present before the ISOLATION state is entered. The timer is done when it reaches 450 – 500 BT.

idle_timer

Timer for length of time without carrier activity that must be present before the ISOLATION state is exited (27.3.1.5.1). The timer is done when it reaches 33 000 BT ± 25% BT.

ipg_timer

Timer for length of time without carrier activity that must be present before carrier integrity tests (27.3.1.5.1) are re-enabled. The timer is done when it reaches 64 – 86 BT.

jabber_timer

Timer for length of carrier that must be present before the Jabber state (27.3.1.7), and optionally during a collision the Partition state (27.3.1.6), is entered. The timer is done when it reaches 40 000 – 75 000 BT.

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no_collision_timer

Timer for length of packet without collision before the Partition state is exited (27.3.1.6). The timer is done when it reaches 450 – 560 BT.

valid_carrier_timer

Timer for length of valid carrier that must be present before the Isolation state is exited (27.3.1.5.1). The timer is done when it reaches 450 – 500 BT.

27.3.2.1.5 Counters

CC(X)

Consecutive port collision count for Port X. Partitioning occurs on a terminal count of CCLimit being reached.

Values: Non-negative integers up to a terminal count of CCLimit.

FCC(X)

False Carrier Counter for Port X. Isolation occurs on a terminal count of FCCLimit being reached.

Values: Non-negative integers up to a terminal count of FCCLimit.

27.3.2.1.6 Port designation

Ports are referred to by number. Port information is obtained by replacing the X in the desired function with the number of the port of interest. Ports are referred to in general as follows:

X

Generic port designator. When X is used in a state diagram, its value is local to that diagram and not global to the set of state diagrams.

N

Is defined by the Port function on exiting the IDLE or JAM states of Figure 27–2. It indicates a port that caused the exit from these states.

ALL

Indicates all repeater ports are to be considered. All ports shall meet test conditions in order for the test to pass.

ALLXN

Indicates all ports except N should be considered. All ports considered shall meet the test conditions in order for the test to pass.

ANY

Indicates all ports are to be considered. One or more ports shall meet the test conditions in order for the test to pass.

ANYXN

Indicates any port other than N meeting the test conditions shall cause the test to pass.

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27.3.2.2 State diagrams

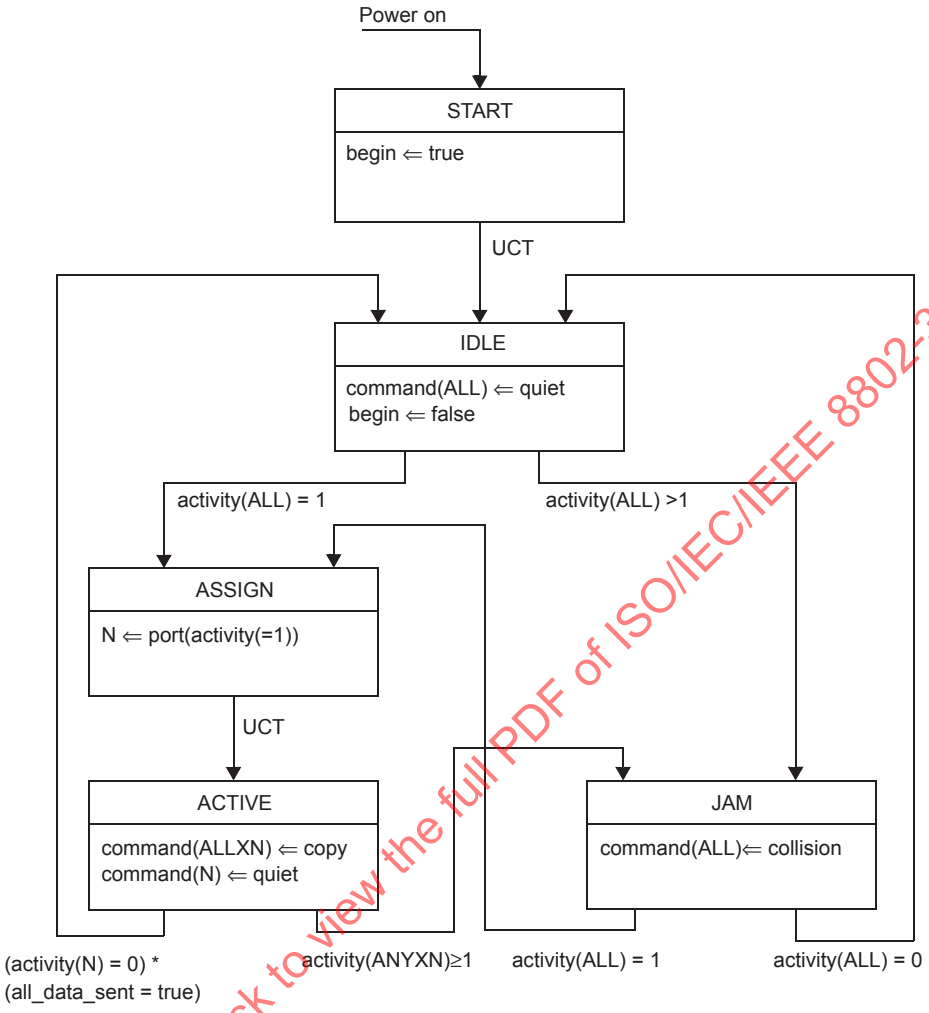

Figure 27–2—Repeater Core state diagram

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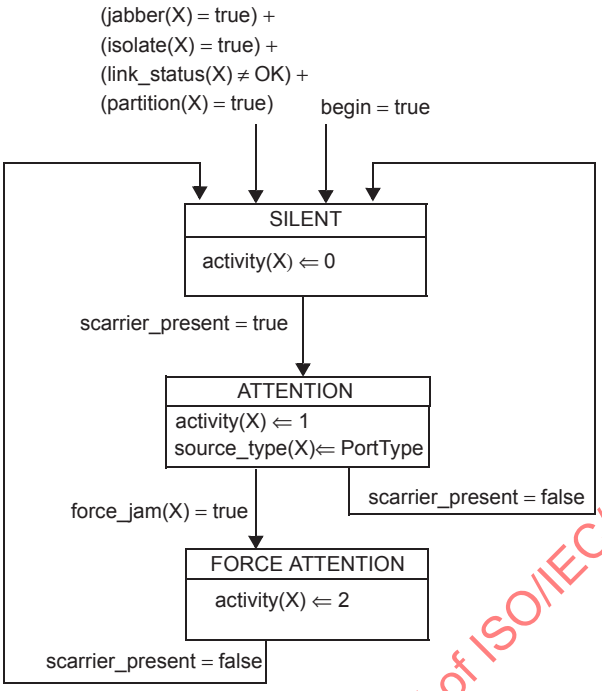

Figure 27–3—Receive state diagram for Port X

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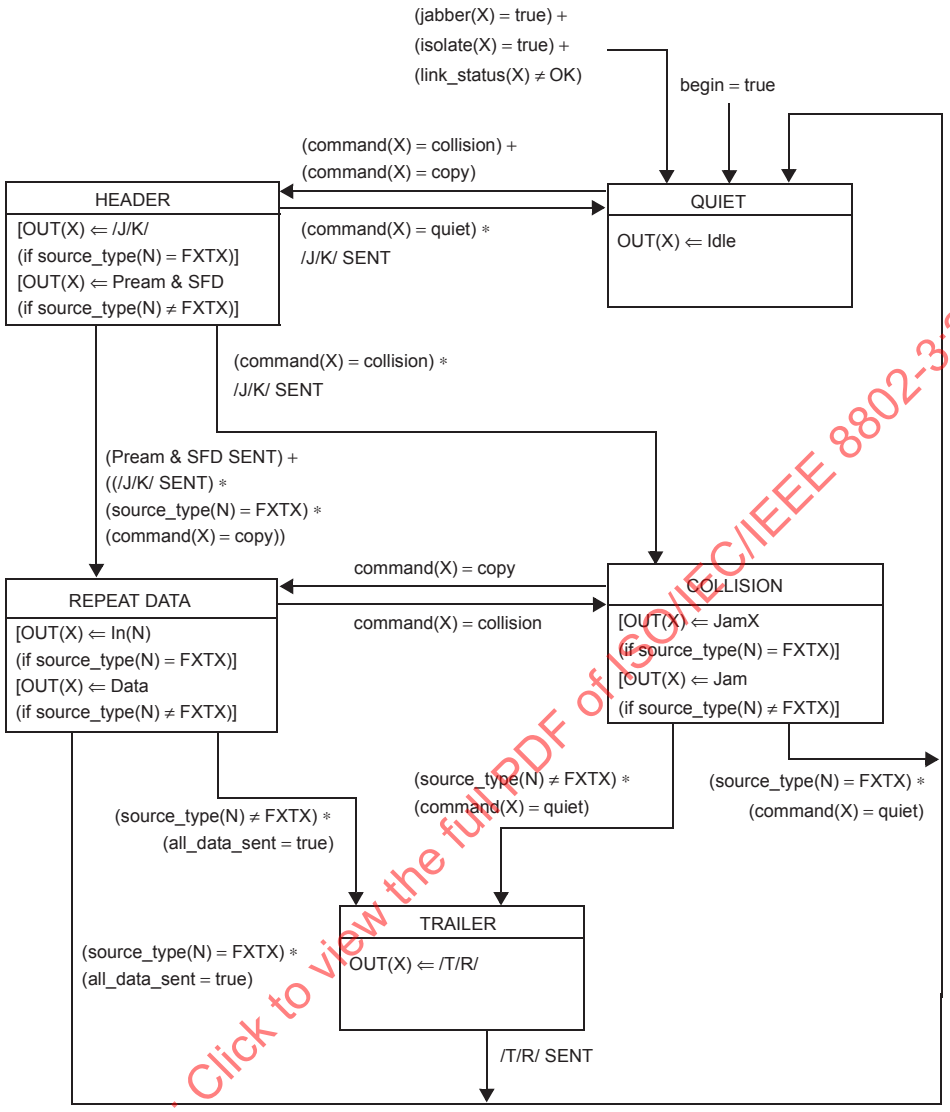

Figure 27–4—100BASE-TX and 100BASE-FX Transmit state diagram for Port X

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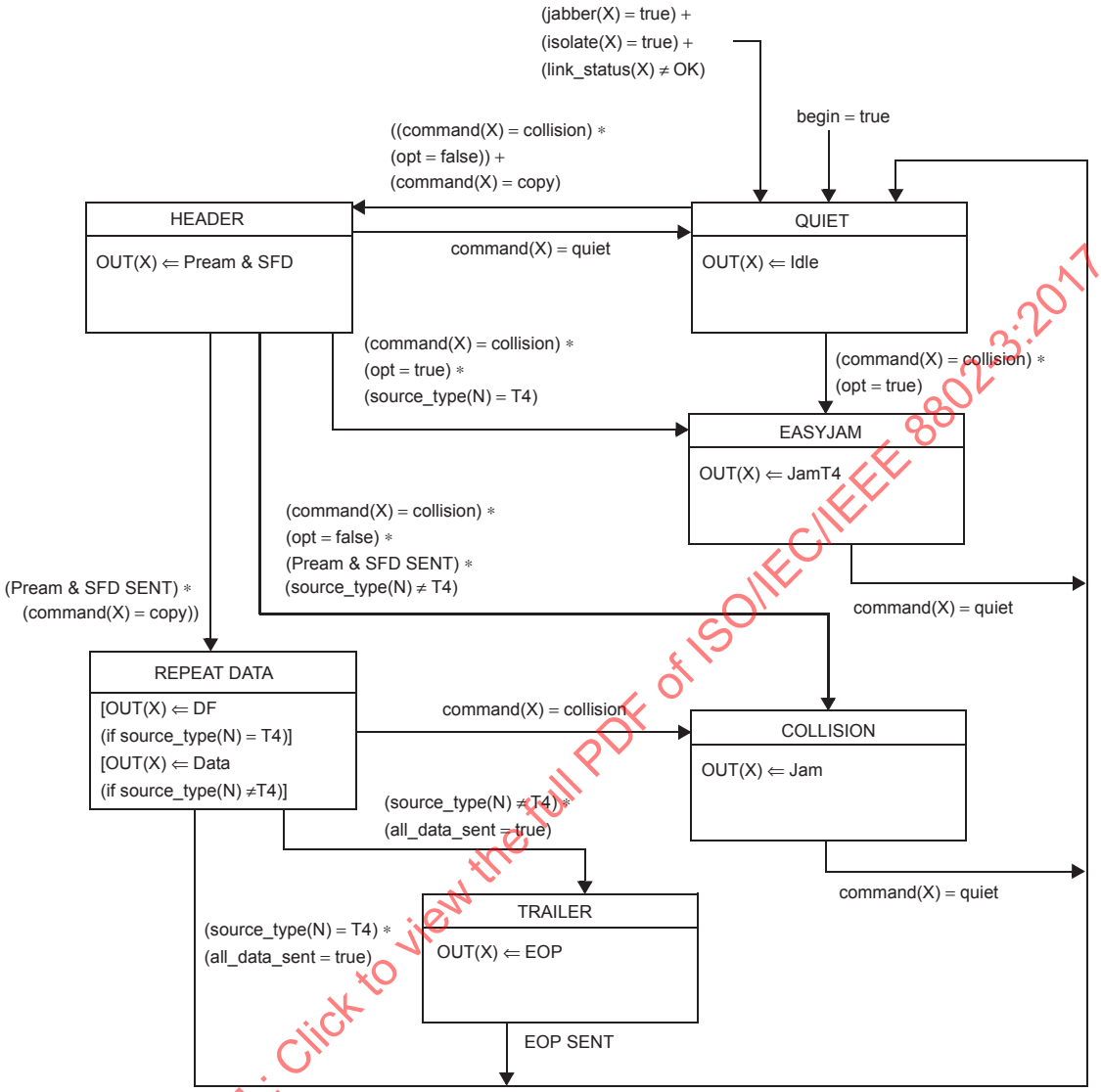

Figure 27–5—100BASE-T4 Transmit state diagram for Port X

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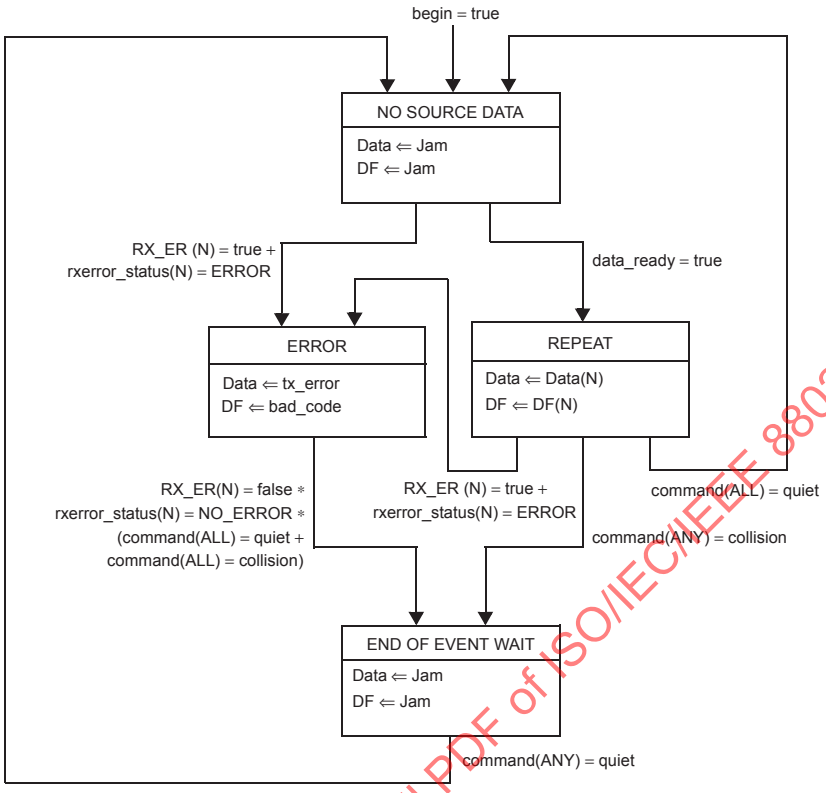

Figure 27–6—Repeater Data Handler state diagram

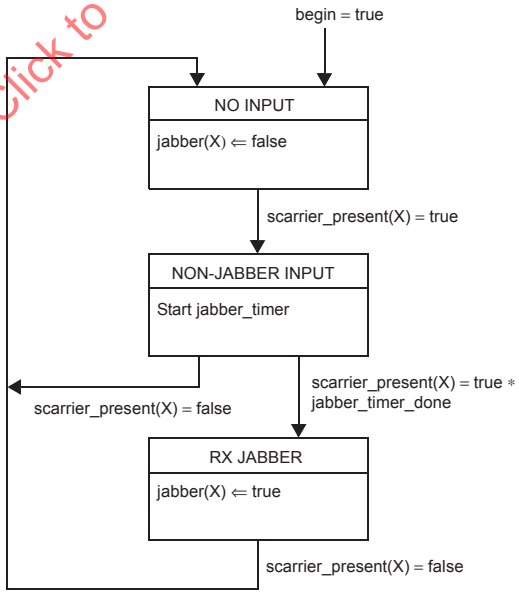

Figure 27–7—Receive Timer state diagram for Port X

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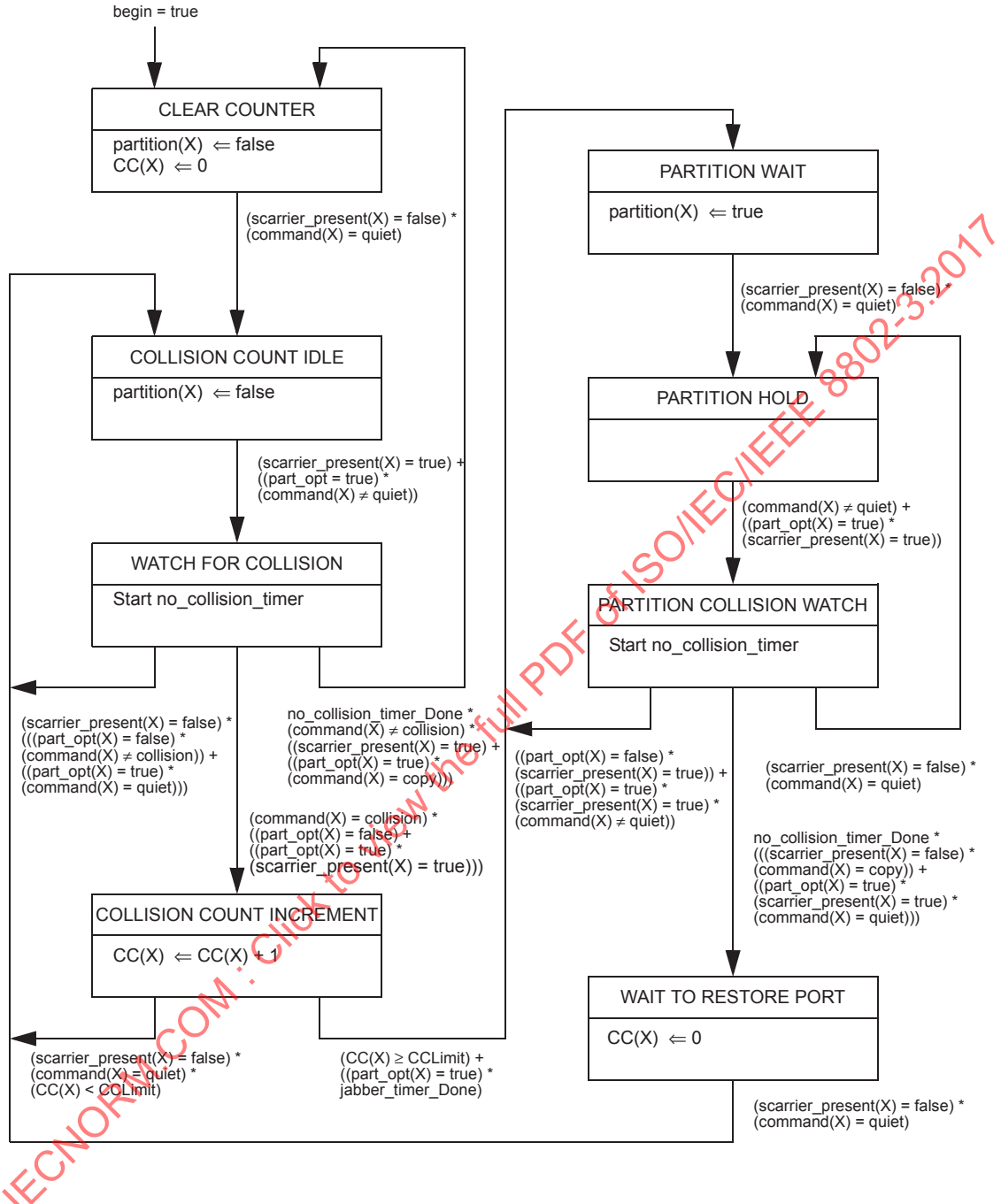

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Figure 27–8—Partition state diagram for Port X

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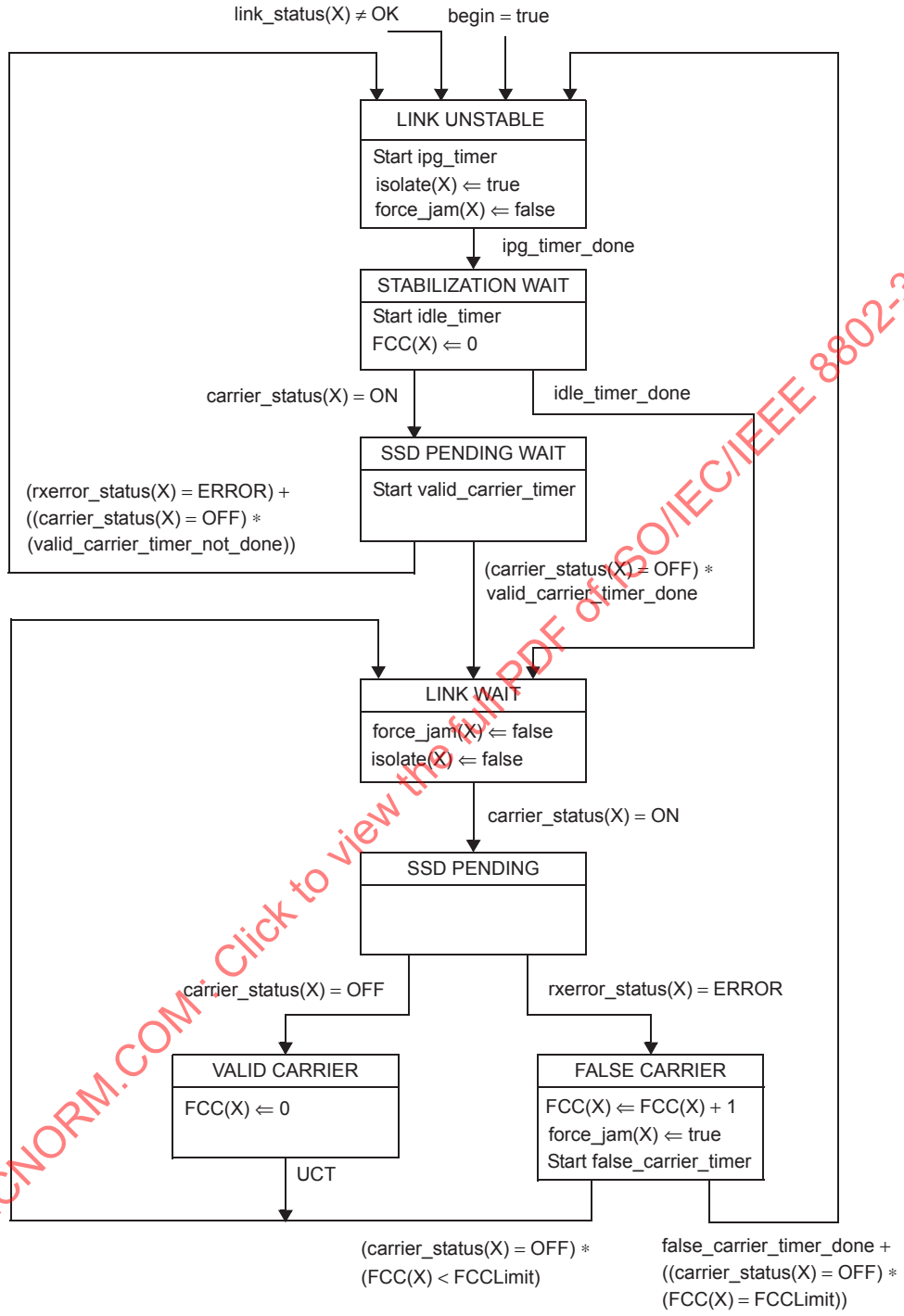

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Figure 27–9—100BASE-X/T2 Carrier Integrity Monitor state diagram for Port X

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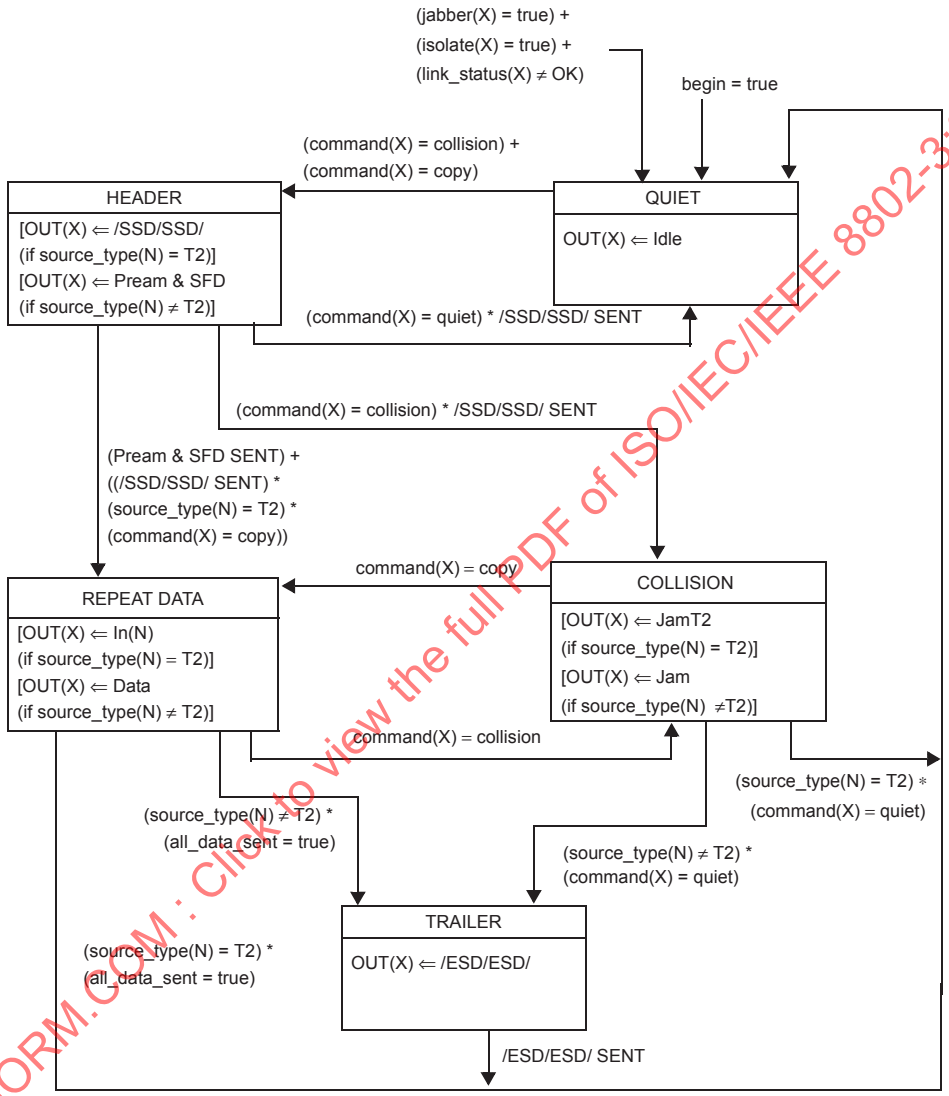

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Figure 27–10—100BASE-T2 Transmit state diagram for Port X

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27.4 Repeater electrical specifications

27.4.1 Electrical isolation

Network segments that have different isolation and grounding requirements shall have those requirements provided by the port-to-port isolation of the repeater set.

27.5 Environmental specifications

27.5.1 General safety

All equipment meeting this standard shall conform to IEC 60950-1.

27.5.2 Network safety

This subclause sets forth a number of recommendations and guidelines related to safety concerns; the list is neither complete nor does it address all possible safety issues. The designer is urged to consult the relevant local, national, and international safety regulations to ensure compliance with the appropriate requirements.

LAN cable systems described in this subclause are subject to at least four direct electrical safety hazards during their installation and use. These hazards are as follows:

a) Direct contact between LAN components and power, lighting, or communications circuits.
b) Static charge buildup on LAN cables and components.
c) High-energy transients coupled onto the LAN cable system.
d) Voltage potential differences between safety grounds to which the various LAN components are connected.

Such electrical safety hazards must be avoided or appropriately protected against for proper network installation and performance. In addition to provisions for proper handling of these conditions in an operational system, special measures must be taken to ensure that the intended safety features are not negated during installation of a new network or during modification or maintenance of an existing network. Isolation requirements are defined in 27.5.3.

27.5.2.1 Installation

Sound installation practice, as defined by applicable local codes and regulations, shall be followed in every instance in which such practice is applicable.

27.5.2.2 Grounding

The safety ground, or chassis ground for the repeater set, shall be provided through the main ac power cord via the third wire ground as defined by applicable local codes and regulations. It is recommended that an external PHY to the repeater should also be mechanically grounded to the repeater unit through the power and ground signals in the MII connection and via the metal shell and shield of the MII connector if available.

If the MDI connector should provide a shield connection, the shield may be connected to the repeater safety ground. A network segment connected to the repeater set through the MDI may use a shield. If both ends of the network segment have a shielded MDI connector available, then the shield may be grounded at both ends according to local regulations and ISO/IEC 11801:1995, and as long as the ground potential difference between both ends of the network segment is less than 1 V rms. The same rules apply towards an inter-repeater link between two repeaters. Multiple repeaters should reside on the same power main; if not, then it is highly recommended that the repeaters be connected via fiber.

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WARNING

It is assumed that the equipment to which the repeater is attached is properly grounded and not left floating nor serviced by a "doubly insulated ac power distribution system." The use of floating or insulated equipment, and the consequent implications for safety, are beyond the scope of this standard.

27.5.2.3 Installation and maintenance guidelines

During installation and maintenance of the cable plant, care should be taken to ensure that uninsulated network cable connectors do not make electrical contact with unintended conductors or ground.

27.5.3 Electrical isolation

There are two electrical power distribution environments to be considered that require different electrical isolation properties:

a) *Environment A.* When a LAN or LAN segment, with all its associated interconnected equipment, is entirely contained within a single low-voltage power distribution system and within a single building.
b) *Environment B.* When a LAN crosses the boundary between separate power distribution systems or the boundary of a single building.

27.5.3.1 Environment A requirements

Attachment of network segments via repeater sets requires electrical isolation of 500 V rms, one-minute withstand, between the segment and the protective ground of the repeater unit.

27.5.3.2 Environment B requirements

The attachment of network segments that cross Environment B boundaries requires electrical isolation of 1500 V rms, one-minute withstand, between each segment and all other attached segments and also the protective ground of the repeater unit.

The requirements for interconnected electrically conducting LAN segments that are partially or fully external to a single building environment may require additional protection against lightning strike hazards. Such requirements are beyond the scope of this standard. It is recommended that the above situation be handled by the use of nonelectrically conducting segments (e.g., fiber optic).

It is assumed that any nonelectrically conducting segments will provide sufficient isolation within that media to satisfy the isolation requirements of Environment B.

27.5.4 Reliability

A two-port repeater set shall be designed to provide a mean time between failure (MTBF) of at least 50 000 hours of continuous operation without causing a communications failure among stations attached to the network medium. Repeater sets with more than two ports shall add no more than 3.46×10^{-6} failures per hour for each additional port.

The repeater set electronics should be designed to minimize the probability of component failures within the repeater electronics that prevent communications among other PHYs on the individual segments. Connectors and other passive components comprising the means of connecting the repeater to the cable should be designed to minimize the probability of total network failure.

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27.5.5 Environment

27.5.5.1 Electromagnetic emission

The repeater shall comply with applicable local and national codes for the limitation of electromagnetic interference.

27.5.5.2 Temperature and humidity

The repeater is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

It is recommended that manufacturers indicate in the literature associated with the repeater the operating environmental conditions to facilitate selection, installation, and maintenance.

27.6 Repeater labeling

It is required that each repeater (and supporting documentation) shall be labeled in a manner visible to the user with these parameters:

a) Crossover ports appropriate to the respective PHY should be marked with an X.
b) The repeater set class type should be labeled in the following manner:
    1) Class I: a Roman numeral “I” centered within a circle.
    2) Class II: a Roman numeral “II” centered within a circle.

Additionally, it is recommended that each repeater (and supporting documentation) also be labeled in a manner visible to the user with at least these parameters:

c) Data rate capability in Mb/s
d) Any applicable safety warnings
e) Port type, i.e., 100BASE-TX, 100BASE-T4, or 100BASE-T2
f) Worst-case bit time delays between any two ports appropriate for
    1) Start-of-packet propagation delay
    2) Start-of-collision Jam propagation delay
    3) Cessation-of-collision Jam propagation delay

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27.7 Protocol implementation conformance statement (PICS) proforma for Clause 27, Repeater for 100 Mb/s baseband networks[10]

27.7.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 27, Repeater for 100 Mb/s baseband networks, shall complete the following protocol implementation conformance statement (PICS) proforma.

27.7.2 Identification

27.7.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

27.7.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 27, Repeater for 100 Mb/s baseband networks
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	No [ ] Yes [ ]

Date of Statement	

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[10] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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27.7.3 Major capabilities/options

Item	Feature	Subclause	Status	Support	Value/Comment
*FXP	Repeater supports 100BASE-FX connections	27.1.2.2	O		
*TXP	Repeater supports 100BASE-TX connections	27.1.2.2	O		
*T4P	Repeater supports 100BASE-T4 connections	27.1.2.2	O		
*T2P	Repeater supports 100BASE-T2 connections	27.1.2.2	O		
*CLI	Repeater meets Class I delays	27.1.1.3	O		
*CLII	Repeater meets Class II delays	27.1.1.3	O		
*PHYS	PHYs capable of detecting non 100BASE-T signals	27.3.1.5.2	O		
*OPF	Partition function supports the recommended optional measures as described	27.3.1.6	O		

In addition, the following predicate name is defined for use when different implementations from the set above have common parameters:

*XP:FXP or TXP

27.7.4 PICS proforma tables for the repeater for 100 Mb/s baseband networks

27.7.4.1 Compatibility considerations

Item	Feature	Subclause	Status	Support	Value/Comment
CC1	100BASE-FX port compatible at the MDI	27.1.2.2	FXP:M		
CC2	100BASE-TX port compatible at the MDI	27.1.2.2	TXP:M		
CC3	100BASE-T4 port compatible at the MDI	27.1.2.2	T4P:M		
CC4	Internal segment compatibility	27.1.2.2.1	M		Internal port meets Clause 30 when repeater management implemented
CC5	100BASE-T2 port compatible at the MDI	27.1.2.2	T2P:M		

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27.7.4.2 Repeater functions

Item	Feature	Subclause	Status	Support	Value/Comment
RF1	Signal Restoration	27.3.1	M		
RF2	Data Handling	27.3.1	M		
RF3	Received Event Handling	27.3.1	M		
RF4	Collision Handling	27.3.1	M		
RF5	Error Handling	27.3.1	M		
RF6	Partition	27.3.1	M		
RF7	Received Jabber	27.3.1	M		

27.7.4.3 Signal Restoration function

Item	Feature	Subclause	Status	Support	Value/Comment
SR1	Output amplitude as required by 100BASE-FX	27.3.1.1.1	FXP:M		
SR2	Output amplitude as required by 100BASE-TX	27.3.1.1.1	TXP:M		
SR3	Output amplitude as required by 100BASE-T4	27.3.1.1.1	T4P:M		
SR4	Output signal wave-shape as required by 100BASE-FX	27.3.1.1.2	FXP:M		
SR5	Output signal wave-shape as required by 100BASE-TX	27.3.1.1.2	TXP:M		
SR6	Output signal wave-shape as required by 100BASE-T4	27.3.1.1.2	T4P:M		
SR7	Output data timing as required by 100BASE-FX	27.3.1.1.3	FXP:M		
SR8	Output data timing as required by 100BASE-TX	27.3.1.1.3	TXP:M		
SR9	Output data timing as required by 100BASE-T4	27.3.1.1.3	T4P:M		
SR10	Output amplitude as required by 100BASE-T2	27.3.1.1.1	T2P:M		
SR11	Output signal wave-shape as required by 100BASE-T2	27.3.1.1.2	T2P:M		
SR12	Output data timing as required by 100BASE-T2	27.3.1.1.3	T2P:M		

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27.7.4.4 Data Handling function

Item	Feature	Subclause	Status	Support	Value/Comment
DH1	Data frames forwarded to all ports except receiving port	27.3.1.2.1	M		
DH2	Data frames transmitted as appropriate for 100BASE-FX	27.3.1.2.1	FXP:M		
DH3	Data frames transmitted as appropriate for 100BASE-TX	27.3.1.2.1	TXP:M		
DH4	Data frames transmitted as appropriate for 100BASE-T4	27.3.1.2.1	T4P:M		
DH5	Code Violations forwarded to all transmitting ports	27.3.1.2.2	M		
DH6	Code Violations forwarded as received	27.3.1.2.2	O.1		
DH7	Received Code Violation forwarded as /H/ or as received	27.3.1.2.2	XP:O.1		
DH8	Received Code Violation forwarded as bad_code or as received	27.3.1.2.2	T4P:O.1		
DH9	Code element substitution for remainder of packet after received Code Violation	27.3.1.2.2	M		
DH10	Data frames transmitted as appropriate for 100BASE-T2	27.3.1.2.1	T2P:M		

27.7.4.5 Receive Event Handling function

Item	Feature	Subclause	Status	Support	Value/Comment
RE1	scarrier_present detect implemented	27.3.1.3.1	M		
RE2	Repeat all received signals	27.3.1.3.1	M		
RE3	Preamble encoded as required by 100BASE-FX	27.3.1.3.2	FXP:M		
RE4	Preamble encoded as required by 100BASE-TX	27.3.1.3.2	TXP:M		
RE5	Preamble encoded as required by 100BASE-T4	27.3.1.3.2	T4P:M		
RE6	Start-of-packet propagation delay, Class I repeater	27.3.1.3.3	CLI:M		
RE7	Start-of-packet propagation delay, Class II repeater	27.3.1.3.3	CLII:M		
RE8	Start-of-packet variability for 100BASE-FX input port	27.3.1.3.4	FXP:M		7.0 BT

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27.7.4.5 Receive Event Handling function *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
RE8	Start-of-packet variability for 100BASE-TX input port	27.3.1.3.4	TXP:M		7.0 BT
RE9	Start-of-packet variability for 100BASE-T4 input port	27.3.1.3.4	T4P:M		8.0 BT
RE10	Preamble encoded as required by 100BASE-T2	27.3.1.3.2	T2P:M		
RE11	Start of packet variability for 100BASE-T2 input port	27.3.1.3.4	T2P:M		8.0 BT

27.7.4.6 Collision Handling function

Item	Feature	Subclause	Status	Support	Value/Comment
CO1	Collision detection	27.3.1.4.1	M		Receive event on more than one port
CO2	Jam generation	27.3.1.4.2	M		Transmit Jam message while collision is detected
CO3	Collision-jam propagation delay, Class I repeater	27.3.1.4.3	CLI:M		SOP + SOJ ≤ 140 BT
CO4	Collision-jam propagation delay, Class II repeater with any port T4	27.3.1.4.3	CLII:M		SOP + SOJ ≤ 67 BT
CO5	Collision-jam propagation delay, Class II repeater, all TX/FX ports	27.3.1.4.3	CLII:M		SOP ≤ 46, SOJ ≤ 46 BT
CO6	Cessation of collision propagation delay, Class I repeater	27.3.1.4.4	CLI:M		EOJ ≤ SOP
CO7	Cessation of collision propagation delay, Class II repeater	27.3.1.4.4	CLII:M		EOJ ≤ SOP
CO8	Collision-jam propagation delay, Class II repeater with any port T2	27.3.1.4.3	CLII * T2P:M		SOP + SOJ ≤ 90 BT

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27.7.4.7 Error Handling function

Item	Feature	Subclause	Status	Support	Value/Comment
EH1	Carrier Integrity function implementation	27.3.1.5.1	XP:M		Self-interrupt of data reception
EH2	False carrier count for Link Unstable detection	27.3.1.5.1	XP:M		False carrier count in excess of FCCLimit
EH3	False carrier count reset	27.3.1.5.1	XP:M		Count reset on valid carrier
EH4	False carrier timer for Link Unstable detection	27.3.1.5.1	XP:M		False carrier of length in excess of false_carrier_timer
EH5	Jam message duration	27.3.1.5.1	XP:M		Equals duration of false carrier event, but not greater than duration of false_carrier_timer
EH6	Link Unstable detection	27.3.1.5.1	XP:M		False Carrier count exceed FCCLimit or False carrier exceeds the false_carrier_timer or power-up reset
EH7	Messages sent to repeater unit in Link Unstable state	27.3.1.5.1	XP:M		Inhibited sending messages to repeater unit
EH8	Messages sent from repeater unit in Link Unstable state	27.3.1.5.1	XP:M		Inhibited sending output messages
EH9	Monitoring activity on PMA interface in Link Unstable state	27.3.1.5.1	XP:M		Continue monitoring activity at PMA interface
EH10	Reset of Link Unstable state	27.3.1.5.1	XP:M		No activity for more than ipg_timer plus idle_timer or Valid carrier event of duration greater than valid_carrier_timer preceded by Idle of duration greater than ipg_timer
EH11	Block flow of non-100 Mb/s signals	27.3.1.5.2	PHYS:M		

27.7.4.8 Partition functions

Item	Feature	Subclause	Status	Support	Value/Comment
PA1	Partition function implementation	27.3.1.6	M		Self-interrupt of data reception
PA2	Collision count for entry into partition state	27.3.1.6	M		Collision count greater than or equal to CCLimit
PA3	Collision counter incrementing	27.3.1.6	M		Count incremented on a collision
PA4	*Collision counter reset*	*27.3.1.6*	*M*		*Count reset on receive activity in excess of no_collision_timer without collision*

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27.7.4.8 Partition functions *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
PA5			OPF:M		Count reset on transmission in excess of no_collision_timer without collision
PA6	Messages sent to repeater unit in Partition state	27.3.1.6	M		Inhibited sending messages to repeater unit
PA7	Messages sent from repeater unit in Partition state	27.3.1.6	M		Continue sending output messages
PA8	Monitoring activity on PMA interface in Partition state	27.3.1.6	M		Continue monitoring activity at PMA interface
PA9	Reset of Partition state	27.3.1.6	M		Power-up reset or transmission in excess of no_collision_timer without collision
PA10			OPF:M		Receive activity in excess of no_collision_timer without collision
PA11	Excessive carrier entry into Partition state	27.3.1.6	OPF:M		Carrier duration in excess of jabber_timer in which a collision occurs

27.7.4.9 Receive Jabber function

Item	Feature	Subclause	Status	Support	Value/Comment
RJ1	Receive Jabber function implementation	27.3.1.7	M		Self-interrupt of data reception
RJ2	Excessive receive duration timer for Receive Jabber detection	27.3.1.7	M		Reception duration in excess of jabber_timer
RJ3	Messages sent to repeater unit in Receive Jabber state	27.3.1.7	M		Inhibit sending input messages to repeater unit
RJ4	Messages sent from repeater unit in Receive Jabber state	27.3.1.7	M		Inhibit sending output messages
RJ5	Reset of Receive Jabber state	27.3.1.7	M		Power-up reset or Carrier no longer detected

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27.7.4.10 Repeater state diagrams

Item	Feature	Subclause	Status	Support	Value/Comment
SD1	Repeater Core state diagram	27.3.2.2	M		Meets the requirements of Figure 27–2
SD2	Receive state diagram for Port X	27.3.2.2	M		Meets the requirements of Figure 27–3
SD3	100BASE-TX and 100BASE-FX Transmit state diagram for Port X	27.3.2.2	XP:M		Meets the requirements of Figure 27–4
SD4	100BASE-T4 Transmit state diagram for Port X	27.3.2.2	T4P:M		Meets the requirements of Figure 27–5
SD5	Repeater Data Handler state diagram	27.3.2.2	M		Meets the requirements of Figure 27–6
SD6	Receive Timer for Port X state diagram	27.3.2.2	M		Meets the requirements of Figure 27–7
SD7	Repeater Partition state diagram for Port X	27.3.2.2	M		Meets the requirements of Figure 27–8
SD8	Carrier Integrity Monitor for Port X state diagram	27.3.2.2	M		Meets the requirements of Figure 27–9
SD9	100BASE-T2 Transmit state diagram for Port X	27.3.2.2	T2P:M		Meets the requirements of Figure 27–10

27.7.4.11 Repeater electrical

Item	Feature	Subclause	Status	Support	Value/Comment
EL1	Port-to-port isolation	27.4.1	M		Satisfies isolation and grounding requirements for attached network segments
EL2	Safety	27.5.1	M		IEC 60950:1991
EL3	Installation practices	27.5.2.1	M		Sound, as defined by local code and regulations
EL4	Grounding	27.5.2.2	M		Chassis ground provided through ac mains cord
EL5	2-port repeater set MTBF	27.5.4	M		At least 50 000 hours
EL6	Additional port effect on MTBF	27.5.4	M		No more than 3.46×10^{-6} increase in failures per hour
EL7	Electromagnetic interference	27.5.5.1	M		Comply with local or national codes

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27.7.4.12 Repeater labeling

Item	Feature	Subclause	Status	Support	Value/Comment
LB1	Crossover ports	27.6	M		Marked with an X
LB2	Class I repeater	27.6	CLI:M		Marked with a Roman numeral I centered within a circle
LB3	Class II repeater	27.6	CLII:M		Marked with Roman numerals II centered within a circle
LB4	Data rate	27.6	O		100 Mb/s
LB5	Safety warnings	27.6	O		Any applicable
LB6	Port types	27.6	O		100BASE-FX or 100BASE-TX or 100BASE-T4 or 100BASE-T2
LB7	Worse-case start-of-packet propagation delay	27.6	O		Value in bit times
LB8	Worse-case start-of-collision-Jam propagation delay	27.6	O		Value in bit times
LB9	Worse-case cessation-of-collision Jam propagation delay	27.6	O		Value in bit times

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28. Physical Layer link signaling for Auto-Negotiation on twisted pair

28.1 Overview

28.1.1 Scope

Clause 28 describes the Auto-Negotiation function that allows a device to advertise enhanced modes of operation it possesses to a device at the remote end of a link segment and to detect corresponding enhanced operational modes that the other device may be advertising. The normative definitions for all extensions to Auto-Negotiation and all related register assignments for this standard are documented in Annex 28D.

The objective of the Auto-Negotiation function is to provide the means to exchange information between two devices that share a link segment and to automatically configure both devices to take maximum advantage of their abilities. Auto-Negotiation is performed using a modified 10BASE-T link integrity test pulse sequence, such that no packet or upper layer protocol overhead is added to the network devices (see Figure 28–1). Auto-Negotiation does not test the link segment characteristics (see 28.1.4).

The function allows the devices at both ends of a link segment to advertise abilities, acknowledge receipt and understanding of the common mode(s) of operation that both devices share, and to reject the use of operational modes that are not shared by both devices. Where more than one common mode exists between the two devices, a mechanism is provided to allow the devices to resolve to a single mode of operation using a predetermined priority resolution function. The Auto-Negotiation function allows the devices to switch between the various operational modes in an ordered fashion, permits management to disable or enable the Auto-Negotiation function, and allows management to select a specific operational mode. The Auto-Negotiation function also provides a Parallel Detection function to allow 10BASE-T, 100BASE-TX, and 100BASE-T4 compatible devices to be recognized, even though they may not provide Auto-Negotiation.

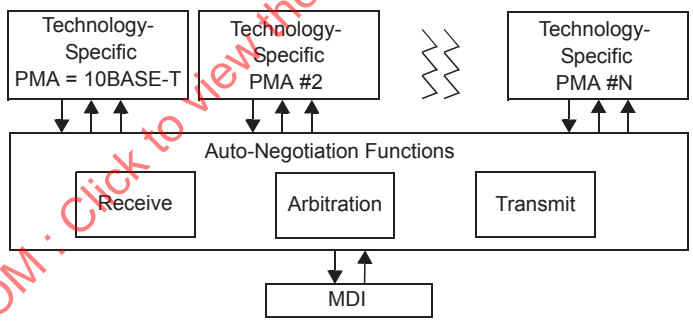

Figure 28–1—High-level model

The basic mechanism to achieve Auto-Negotiation is to pass information encapsulated within a burst of closely spaced link integrity test pulses that individually meet the 10BASE-T Transmitter Waveform for Link Test Pulse (Figure 14–13). This burst of pulses is referred to as a Fast Link Pulse (FLP) Burst. Each device capable of Auto-Negotiation issues FLP Bursts at power up, on command from management, or due to user interaction. The FLP Burst consists of a series of link integrity test pulses that form an alternating clock/data sequence. Extraction of the data bits from the FLP Burst yields a link codeword that identifies the operational modes supported by the remote device, as well as some information used for the Auto-Negotiation function's handshake mechanism.

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To maintain interoperability with existing 10BASE-T devices, the function also supports the reception of 10BASE-T compliant link integrity test pulses. 10BASE-T link pulse activity is referred to as the Normal Link Pulse (NLP) sequence and is defined in 14.2.1.1. A device that fails to respond to the FLP Burst sequence by returning only the NLP sequence is treated as a 10BASE-T compatible device.

28.1.2 Application perspective/objectives

The Auto-Negotiation function is designed to be expandable and allow IEEE 802.3 compatible devices using an eight-pin modular connector to self-configure a jointly compatible operating mode. Implementation of the Auto-Negotiation function is optional. However, it is highly recommended that this method alone be utilized to perform the negotiation of the link operation.

The following are the objectives of Auto-Negotiation:

a) Must interoperate with the IEEE 802.3 10BASE-T installed base.
b) Must allow automatic upgrade from the 10BASE-T mode to the desired "High-Performance Mode."
c) Requires that the 10BASE-T data service is the Lowest Common Denominator (LCD) that can be resolved. A 10BASE-T PMA is not required to be implemented, however, Only the NLP Receive Link Integrity Test function is required.
d) Reasonable and cost-effective to implement.
e) Must provide a sufficiently extensible code space to
    1) Meet existing and future requirements.
    2) Allow simple extension without impacting the installed base.
    3) Accommodate remote fault signals.
    4) Accommodate Link Partner ability detection.
f) Must allow manual or Network Management configuration to override the Auto-Negotiation.
g) Must be capable of operation in the absence of Network Management.
h) Must not preclude the ability to negotiate "back" to the 10BASE-T operational mode.
i) Must operate when
    1) The link is initially electrically connected.
    2) A device at either end of the link is powered up, reset, or a renegotiation request is made.
j) The Auto-Negotiation function may be enabled by automatic, manual, or Network Management intervention.
k) Completes the Base Page Auto-Negotiation function in a bounded time period.
l) Will provide the basis for the link establishment process in future CSMA/CD compatible LAN standards that use an eight-pin modular connector.
m) Must not cause corruption of IEEE 802.3 Layer Management statistics.
n) Operates using a peer-to-peer exchange of information with no requirement for a master device (not master-slave).
o) Must be robust in the UTP cable noise environment.
p) Must not significantly impact EMI/RFI emissions.

28.1.3 Relationship to architectural layering

The Auto-Negotiation function is provided at the Physical Layer of the OSI reference model as shown in Figure 28–2. Devices that support multiple modes of operation may advertise this fact using this function. The actual transfer of information of ability is observable only at the MDI or on the medium. Auto-Negotiation signaling does not occur across either the AUI or MII. Control of the Auto-Negotiation function may be supported through the Management Interface of the MII or equivalent. If an explicit embodiment of the MII is supported, the control and status registers to support the Auto-Negotiation function shall be implemented in accordance with the definitions in Clause 22 and 28.2.4. If a physical embodiment of the MII management is not present, then it is strongly recommended that the implementation provide control and status mechanisms equivalent to those described in Clause 22 and 28.2.4 for manual and/or management interaction.

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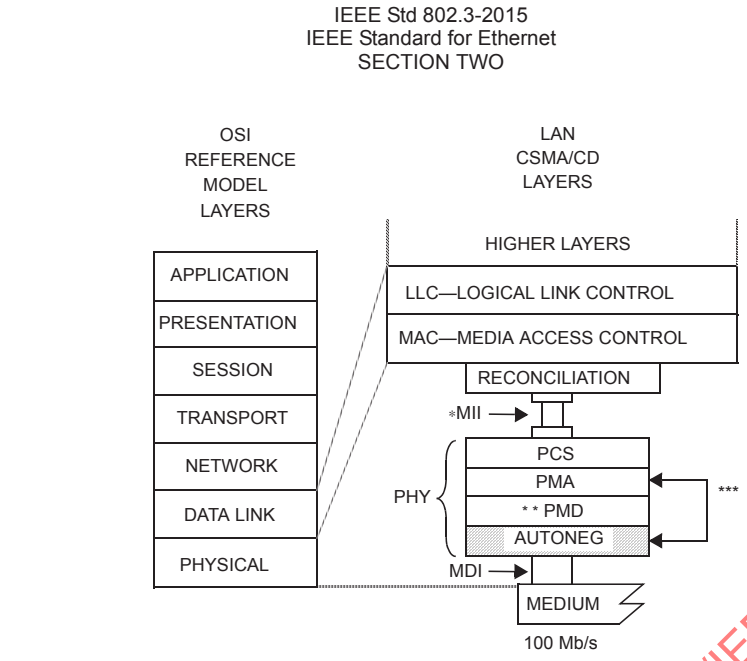

Figure 28–2—Location of Auto-Negotiation function within the ISO/IEC OSI reference model

28.1.4 Compatibility considerations

The Auto-Negotiation function is designed to be completely backwards compatible and interoperable with 10BASE-T compliant devices. In order to achieve this, a device supporting the Auto-Negotiation function must provide the NLP Receive Link Integrity Test function as defined in Figure 28–19. The Auto-Negotiation function also supports connection to 100BASE-TX and 100BASE-T4 devices without Auto-Negotiation through the Parallel Detection function. Connection to technologies other than 10BASE-T, 100BASE-TX, or 100BASE-T4 that do not incorporate Auto-Negotiation is not supported.

Implementation of the Auto-Negotiation function is optional. For CSMA/CD compatible devices that use the eight-pin modular connector of IEC 60603-7 and that also encompass multiple operational modes, if a signaling method is used to automatically configure the preferred mode of operation, then the Auto-Negotiation function shall be used in compliance with Clause 28. If the device uses 10BASE-T compatible link signaling to advertise non-CSMA/CD abilities, the device shall implement the Auto-Negotiation function as administered by this specification. All future CSMA/CD implementations that use an eight-pin modular connector shall be interoperable with devices supporting Clause 28. If the implementer of a non-CSMA/CD eight-pin modular device wishes to assure that its operation does not conflict with CSMA/CD devices, then adherence to Clause 28 is recommended.

While this Auto-Negotiation function must be implemented in CSMA/CD compatible devices that utilize the eight-pin modular connector, encompass multiple operational modes, and offer an Auto-Negotiation mechanism, the use of this function does not mandate that the 10BASE-T packet data communication service must exist. A device that employs this function must support the 10BASE-T Link Integrity Test

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function through the NLP Receive Link Integrity Test state diagram. The device may also need to support other technology-dependent link test functions depending on the modes supported. Auto-Negotiation does not perform cable tests, such as detect number of conductor pairs (if more than two pairs are required) or cable performance measurements. Some PHYs that explicitly require use of high-performance cables, may require knowledge of the cable type, or additional robustness tests (such as monitoring CRC or framing errors) to determine if the link segment is adequate.

28.1.4.1 Interoperability with existing 10BASE-T devices

During Auto-Negotiation, FLP Bursts separated by 16 ms ± 8 ms are transmitted. The FLP Burst itself is a series of pulses separated by 62.5 µs ± 7 µs. The timing of FLP Bursts will cause a 10BASE-T device that is in the LINK TEST PASS state to remain in the LINK TEST PASS state while receiving FLP Bursts. An Auto-Negotiation able device must recognize the NLP sequence from a 10BASE-T Link Partner, cease transmission of FLP Bursts, and enable the 10BASE-T PMA, if present. If the NLP sequence is detected and if the Auto-Negotiation able device does not have a 10BASE-T PMA, it will cease transmission of FLP Bursts, forcing the 10BASE-T Link Partner into the LINK TEST FAIL state(s) as indicated in Figure 14–6.

NOTE—Auto-Negotiation does not support the transmission of the NLP sequence. The 10BASE-T PMA provides this function if it is connected to the MDI. In the case where an Auto-Negotiation able device without a 10BASE-T PMA is connected to a 10BASE-T device without Auto-Negotiation, the NLP sequence is not transmitted because the Auto-Negotiation function has no 10BASE-T PMA to enable that can transmit the NLP sequence.

28.1.4.2 Interoperability with Auto-Negotiation compatible devices

An Auto-Negotiation compatible device decodes the base link codeword from the FLP Burst, and examines the contents for the highest common ability that both devices share. Both devices acknowledge correct receipt of each other's base link codewords by responding with FLP Bursts containing the Acknowledge Bit set. After both devices complete acknowledgment, and optionally, Next Page exchange, both devices enable the highest common mode negotiated. The highest common mode is resolved using the priority resolution hierarchy specified in Annex 28B. It may subsequently be the responsibility of a technology-dependent link integrity test function to verify operation of the link prior to enabling the data service.

28.1.4.3 Cabling compatibility with Auto-Negotiation

Provision has been made within Auto-Negotiation to limit the resulting link configuration in situations where the cabling may not support the highest common capability of the two end points. The system administrator/installer must take the cabling capability into consideration when configuring a repeater port's advertised capability. That is, the advertised capability of a hub port should not result in an operational mode that is not compatible with the cabling.

28.2 Functional specifications

The Auto-Negotiation function provides a mechanism to control connection of a single MDI to a single PMA type, where more than one PMA type may exist. Management may provide additional control of Auto-Negotiation through the Management function, but the presence of a management agent is not required.

The Auto-Negotiation function shall provide the Auto-Negotiation Transmit, Receive, and Arbitration functions and comply with the state diagrams of Figure 28–16 to Figure 28–19. The Auto-Negotiation function shall provide the NLP Receive Link Integrity Test function and comply with the state diagram of Figure 28–19 if the PHY supports 10BASE-T operation.The Auto-Negotiation functions shall interact with the technology-dependent PMAs through the Technology-Dependent Interface. Technology-dependent PMAs include, but are not limited to, 100BASE-TX and 100BASE-T4. Technology-dependent link integrity test functions shall be implemented and interfaced to only if the device supports the given technology. For example, a 10BASE-T and 100BASE-TX Auto-Negotiation able device must implement and interface to the

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100BASE-TX PMA/link integrity test function, but does not need to include the 100BASE-T4 PMA/Link Integrity Test function. The Auto-Negotiation function shall provide an optional Management function that provides a control and status mechanism.

28.2.1 Transmit function requirements

The Transmit function provides the ability to transmit FLP Bursts. The first FLP Bursts exchanged by the local device and its Link Partner after Power-On, link restart, or renegotiation contain the base link codeword defined in 28.2.1.2. The local device may modify the link codeword to disable an ability it possesses, but will not transmit an ability it does not possess. This makes possible the distinction between local abilities and advertised abilities so that multimode devices may Auto-Negotiate to a mode lower in priority than the highest common local ability.

28.2.1.1 Link pulse transmission

Auto-Negotiation's method of communication builds upon the link pulse mechanism employed by 10BASE-T MAUs to detect the status of the link. Compliant 10BASE-T MAUs transmit link integrity test pulses as a mechanism to determine if the link segment is operational in the absence of packet data. The 10BASE-T NLP sequence is a pulse (Figure 14–13) transmitted every 16 ms ± 8 ms while the data transmitter is idle.

Auto-Negotiation substitutes the FLP Burst in place of the single 10BASE-T link integrity test pulse within the NLP sequence (Figure 28–3). The FLP Burst encodes the data that is used to control the Auto-Negotiation function. FLP Bursts shall not be transmitted when Auto-Negotiation is complete and the highest common denominator PMA has been enabled.

FLP Bursts were designed to allow use beyond initial link Auto-Negotiation, such as for a link monitor type function. However, use of FLP Bursts beyond the current definition for link startup shall be prohibited. Definition of the use of FLP Bursts while in the FLP LINK GOOD state is reserved.

Figure 28–3—FLP Burst sequence to NLP sequence mapping

28.2.1.1.1 FLP burst encoding

All link test pulses in the FLP Burst sequence shall meet the template requirements of Figure 14–13 when measured across each of the test loads defined in Figure 14–12; both with the load connected directly to the TD circuit and with the load connected through all of the cable types and distances supported by the advertised capabilities. A Fast Link Pulse Burst consists of 33 pulse positions. The 17 odd-numbered pulse positions shall contain a link pulse and represent clock information. The 16 even-numbered pulse positions shall represent data information as follows: a link pulse present in an even-numbered pulse position represents a logic one, and a link pulse absent from an even-numbered pulse position represents a logic zero. Clock pulses are differentiated from data pulses by the spacing between pulses as shown in Figure 28–5 and

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enumerated in Table 28–1. An extended FLP Burst contains 97 similarly defined pulse positions with 49 odd-numbered clock pulses and 48 even-numbered data pulses.

Table 28–1—FLP Burst timing summary

	Parameter	Min.	Typ.	Max.	Units
T1	Clock/Data Pulse Width (Figure 14–13)		100		ns
T2	Clock Pulse to Clock Pulse	111	125	139	µs
T3	Clock Pulse to Data Pulse (Data = 1)	55.5	62.5	69.5	µs
T4	Pulses in a Burst	17 for 16-bit 49 for 48-bit		33 for 16-bit 97 for 48-bit	—
T5	Burst Width		2 for 16-bit 6 for 48-bit		ms
T6	FLP Burst to FLP Burst	8	16	24	ms
T7	Optimized FLP Burst to FLP Burst	8		8.5	ms

The encoding of data using pulses in an FLP Burst is illustrated in Figure 28–4.

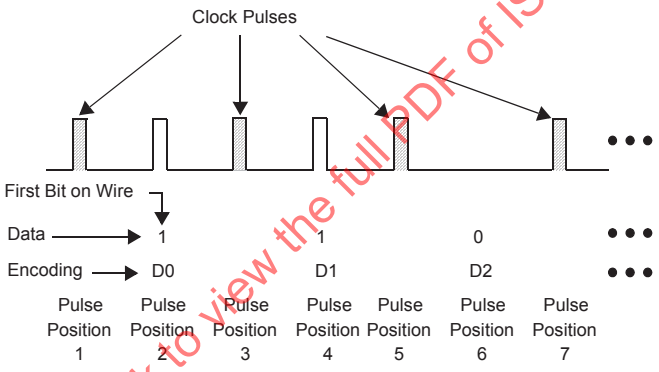

Figure 28–4—Data bit encoding within FLP Bursts

28.2.1.1.2 Transmit timing

The first pulse in an FLP Burst shall be defined as a clock pulse. Clock pulses within an FLP Burst shall be spaced at 125 µs ± 14 µs. If the data bit representation of logic one is to be transmitted, a pulse shall occur 62.5 µs ± 7 µs after the preceding clock pulse. If a data bit representing logic zero is to be transmitted, there shall be no link integrity test pulses within 111 µs of the preceding clock pulse.

The first link pulse in consecutive FLP Bursts shall occur at a 16 ms ± 8 ms interval when using non-optimized FLP Burst to FLP Burst timing, see parameter T6 (Figure 28–6). Devices supporting Extended Next Pages shall use optimized FLP Burst to FLP Burst timing. The first link pulse in consecutive FLP Bursts shall occur at a 8.25 ms ± 0.25 ms interval when using optimized FLP Burst to FLP Burst timing, see parameter T7 (Figure 28–6). Optimized FLP Burst to FLP Burst limits are intended to reduce negotiation time.

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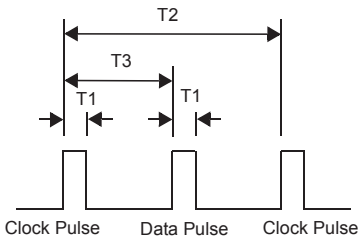

Figure 28–5—FLP Burst pulse-to-pulse timing

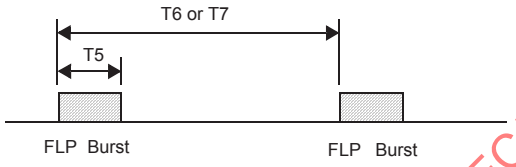

Figure 28–6—FLP Burst to FLP Burst timing

28.2.1.2 Link codeword encoding

The base link codeword (Base Page) transmitted within an FLP Burst shall convey the encoding shown in Figure 28–7. The Auto-Negotiation function may support additional pages using the Next Page function. Encodings for the link codeword(s) used in Next Page exchange are defined in 28.2.3.4. In an FLP Burst, D0 shall be the first bit transmitted.

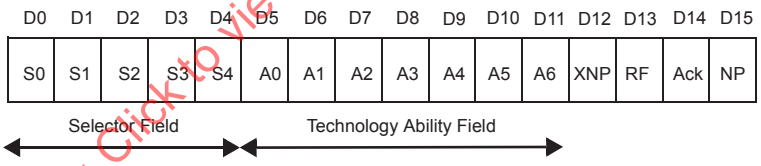

Figure 28–7—Base Page encoding

28.2.1.2.1 Selector Field

Selector Field (S[4:0]) is a five bit wide field, encoding 32 possible messages. Selector Field encoding definitions are shown in Annex 28A. Combinations not specified are reserved for future use. Reserved combinations of the Selector Field shall not be transmitted.

28.2.1.2.2 Technology Ability Field

Technology Ability Field (A[6:0]) is a seven-bit wide field containing information indicating supported technologies specific to the selector field value. These bits are mapped to individual technologies such that abilities are advertised in parallel for a single selector field value. The Technology Ability Field encoding for the IEEE 802.3 selector is described in Annex 28B.2 and in Annex 28D. Multiple technologies may be advertised in the link codeword. A device shall support the data service ability for a technology it advertises.

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It is the responsibility of the Arbitration function to determine the common mode of operation shared by a Link Partner and to resolve multiple common modes.

NOTE—While devices using a Selector Field value other than the IEEE 802.3 Selector Field value are free to define the Technology Ability Field bits, it is recommended that the 10BASE-T bit be encoded in the same bit position as in the IEEE 802.3 selector. A common bit position can be important if the technology using the other selector will ever coexist on a device that also offers a 10BASE-T mode.

28.2.1.2.3 Extended Next Page

Extended Next Page (XNP) is encoded in bit D12 of the base link codeword. The Extended Next Page bit indicates that the local device supports transmission of Extended Next Pages when set to a logic one, and indicates that the local device does not support Extended Next Pages when set to a logic zero. The use of Extended Next Page is orthogonal to the negotiated data rate, medium, or link technology. The Extended Next Page bit is used in accordance with the Extended Next Page function specifications in 28.2.3.4.

When the selector field value is the IEEE Std 802.5v-2001 (withdrawn) value or the IEEE Std 802.9a-1995 (withdrawn) value the Extended Next Page function is not supported and bit D12 is defined as being an additional Technology Ability Field bit A7, extending the Technology Ability Field to be an eight bit wide field (A[7:0]).

28.2.1.2.4 Remote Fault

Remote Fault (RF) is encoded in bit D13 of the base link codeword. The default value is logic zero. The Remote Fault bit provides a standard transport mechanism for the transmission of simple fault information. When the RF bit in the Auto-Negotiation advertisement register (Register 4) is set to logic one, the RF bit in the transmitted base link codeword is set to logic one. When the RF bit in the received base link codeword is set to logic one, the Remote Fault bit in the MII status register (Register 1) will be set to logic one, if the MII management function is present.

The Remote Fault bit shall be used in accordance with the Remote Fault function specifications (28.2.3.5).

28.2.1.2.5 Acknowledge

Acknowledge (Ack) is used by the Auto-Negotiation function to indicate that a device has successfully received its Link Partner's link codeword. The Acknowledge Bit is encoded in bit D14 regardless of the value of the Selector Field or link codeword encoding. If no Next Page information is to be sent, this bit shall be set to logic one in the link codeword after the reception of at least three consecutive and consistent FLP Bursts (ignoring the Acknowledge bit value). If Next Page information is to be sent, this bit shall be set to logic one after the device has successfully received at least three consecutive and matching FLP Bursts (ignoring the Acknowledge bit value), and will remain set until the Next Page information has been loaded into the Auto-Negotiation Next Page transmit register (Register 7). In order to save the current received link codeword, it must be read from the Auto-Negotiation Link Partner ability register (Register 6) before the Next Page of transmit information is loaded into the Auto-Negotiation Next Page transmit register. After the COMPLETE ACKNOWLEDGE state has been entered, the link codeword shall be transmitted six to eight (inclusive) times.

28.2.1.2.6 Next Page

Next Page (NP) is encoded in bit D15 regardless of the Selector Field value or link codeword encoding. Support for transmission and reception of additional link codeword encodings is optional. If Next Page ability is not supported, the NP bit shall always be set to logic zero. If a device implements Next Page ability and wishes to engage in Next Page exchange, it shall set the NP bit to logic one. A device may implement Next Page ability and choose not to engage in Next Page exchange by setting the NP bit to a logic zero. The Next Page function is defined in 28.2.3.4.

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28.2.1.3 Transmit Switch function

The Transmit Switch function shall enable the transmit path from a single technology-dependent PMA to the MDI once a highest common denominator choice has been made and Auto-Negotiation has completed.

During Auto-Negotiation, the Transmit Switch function shall connect only the FLP Burst generator controlled by the Transmit State Diagram, Figure 28–16, to the MDI.

When a PMA is connected to the MDI through the Transmit Switch function, the signals at the MDI shall conform to all of the PHY's specifications.

28.2.2 Receive function requirements

The Receive function detects the NLP sequence using the NLP Receive Link Integrity Test function of Figure 28–19. The NLP Receive Link Integrity Test function will not detect link pass based on carrier sense.

The Receive function detects the FLP Burst sequence, decodes the information contained within, and stores the data in rx_link_code_word[16:1]. The Receive function incorporates a receive switch to control connection to the 100BASE-TX or 100BASE-T4 PMAs in addition to the NLP Receive Link Integrity Test function, excluding the 10BASE-T Link Integrity Test function present in a 10BASE-T PMA. If Auto-Negotiation detects link_status=READY from any of the technology-dependent PMAs prior to FLP Burst detection, the autoneg_wait_timer (28.3.2) is started. If any other technology-dependent PMA indicates link_status=READY when the autoneg_wait_timer expires, Auto-Negotiation will not allow any data service to be enabled and may signal this as a remote fault to the Link Partner using the Base Page and will flag this in the Local Device by setting the Parallel Detection Fault bit (6.4) in the Auto-Negotiation expansion register. If a 10BASE-T PMA exists above the Auto-Negotiation function, it is not permitted to receive MDI activity in parallel with the NLP Receive Link Integrity Test function or any other technology-dependent function.

28.2.2.1 FLP Burst ability detection and decoding

In Figure 28–8 to Figure 28–10, the symbol "t_0=0" indicates the event that caused the timers described to start, and all subsequent times given are referenced from that point. All timers referenced shall expire within the range specified in Table 28–9 in 28.3.2.

The Receive function shall identify the Link Partner as Auto-Negotiation able if it receives 6 to 17 (inclusive) consecutive link pulses that are separated by at least flp_test_min_timer time (5 µs to 25 µs) but less than flp_test_max_timer time (165 µs to 185 µs) as shown in Figure 28–8. The information contained in the FLP Burst that identifies the Link Partner as Auto-Negotiation able shall not be passed to the Arbitration function if the FLP Burst is not complete. The Receive function may use the FLP Burst that identifies the Link Partner as Auto-Negotiation able for ability matching if the FLP Burst is complete. However, it is not required to use this FLP Burst for any purpose other than identification of the Link Partner as Auto-Negotiation able. Implementations may ignore multiple FLP Bursts before identifying the Link Partner as Auto-Negotiation able to allow for potential receive equalization time.

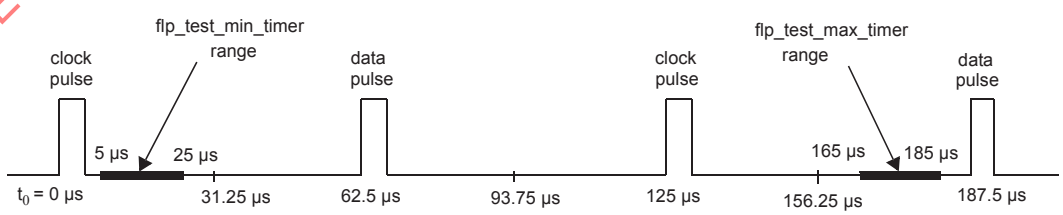

Figure 28–8—FLP detect timers (flp_test_min/max_timers)

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The Receive function captures and decodes link pulses received in FLP Bursts. The first link pulse in an FLP Burst shall be interpreted as a clock link pulse. Detection of a clock link pulse shall restart the data_detect_min_timer and data_detect_max timer. The data_detect_min/max_timers enable the receiver to distinguish data pulses from clock pulses and logic one data from logic zero data, as follows:

a) If, during an FLP Burst, a link pulse is received when the data_detect_min_timer has expired while the data_detect_max_timer has not expired, the data bit shall be interpreted as a logic one (Figure 28–9).
b) If, during an FLP Burst, a link pulse is received after the data_detect_max_timer has expired, the data bit shall be interpreted as a logic zero (Figure 28–9) and that link pulse shall be interpreted as a clock link pulse.

As each data bit is identified it is stored in the appropriate rx_link_code_word[16:1] element.

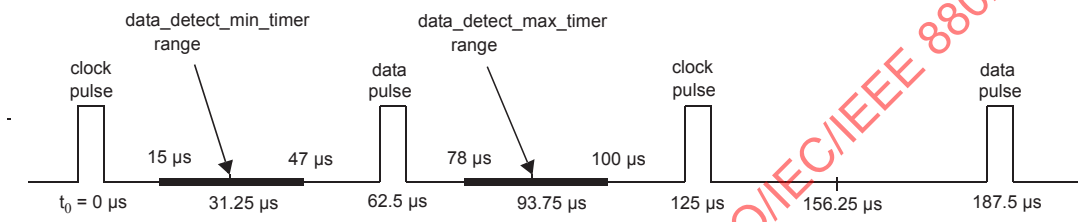
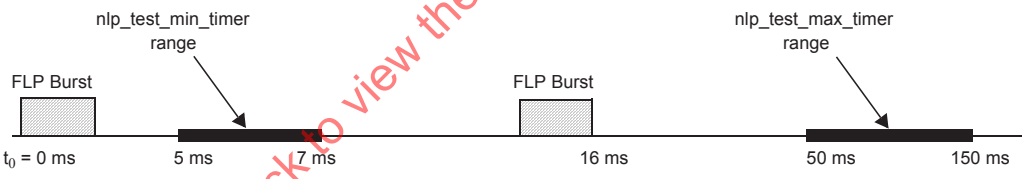


Figure 28–9—FLP data detect timers (data_detect_min/max_timers)

FLP Bursts conforming to the nlp_test_min_timer and nlp_test_max_timer timing as shown in Figure 28–10 shall be considered to have valid separation. The nlp_test_min_timer range for devices that do not support Extended Next Pages is shown in Figure 28–10. The range of nlp_test_min_timer for devices that support Extended Next Pages is specified in 28.3.2.



NOTE—The reference for the starting of the nlp_test_min_timer is from the beginning of the FLP Burst, as shown by t_0, while the reference for the starting of the nlp_test_max_timer is from the expiration of the nlp_test_min_timer.

Figure 28–10—FLP Burst timer (nlp_test_min/max_timers)

28.2.2.2 NLP detection

NLP detection is accomplished via the NLP Receive Link Integrity Test function in Figure 28–19. The NLP Receive Link Integrity Test function is a modification of the original 10BASE-T Link Integrity Test function (Figure 14–6), where the detection of receive activity will not cause a transition to the LINK TEST PASS state during Auto-Negotiation. The NLP Receive Link Integrity Test function also incorporates the Technology-Dependent Interface requirements.

28.2.2.3 Receive Switch function

The Receive Switch function shall enable the receive path from the MDI to a single technology-dependent PMA once a highest common denominator choice has been made and Auto-Negotiation has completed.

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During Auto-Negotiation, the Receive Switch function shall connect both the FLP Burst receiver controlled by the Receive state diagram, Figure 28–17, and the NLP Receive Link Integrity Test state diagram, Figure 28–19, to the MDI. During Auto-Negotiation, the Receive Switch function shall also connect the 100BASE-TX and 100BASE-T4 PMA receivers to the MDI if the 100BASE-TX and/or 100BASE-T4 PMAs are present.

When a PMA is connected to the MDI through the Receive Switch function, the signals at the PMA shall conform to all of the PHY's specifications.

28.2.2.4 Link codeword matching

The Receive function shall generate ability_match, acknowledge_match, and consistency_match variables as defined in 28.3.1.

28.2.3 Arbitration function requirements

The Arbitration function ensures proper sequencing of the Auto-Negotiation function using the Transmit function and Receive function. The Arbitration function enables the Transmit function to advertise and acknowledge abilities. Upon indication of acknowledgment, the Arbitration function determines the highest common denominator using the priority resolution function and enables the appropriate technology-dependent PMA via the Technology-Dependent Interface (28.2.6).

28.2.3.1 Parallel detection function

The Local Device detects a Link Partner that supports Auto-Negotiation by FLP Burst detection. The Parallel Detection function allows detection of Link Partners that support 100BASE-TX, 100BASE-T4, and/or 10BASE-T, but do not support Auto-Negotiation. Prior to detection of FLP Bursts, the Receive Switch shall direct MDI receive activity to the NLP Receive Link Integrity Test state diagram, 100BASE-TX and 100BASE-T4 PMAs, if present, but shall not direct MDI receive activity to the 10BASE-T or any other PMA. If at least one of the 100BASE-TX, 100BASE-T4, or NLP Receive Link Integrity Test functions establishes link_status=READY, the LINK STATUS CHECK state is entered and the autoneg_wait_timer is started. If exactly one link_status=READY indication is present when the autoneg_wait_timer expires, then Auto-Negotiation shall set link_control=ENABLE for the PMA indicating link_status=READY. If a PMA is enabled, the Arbitration function shall set link_control=DISABLE to all other PMAs and indicate that Auto-Negotiation has completed. On transition to the FLP LINK GOOD CHECK state from the LINK STATUS CHECK state the Parallel Detection function shall set the bit in the Link Partner ability register (Register 5) corresponding to the technology detected by the Parallel Detection function.

NOTE 1—Native 10BASE-T devices will be detected by the NLP Receive Link Integrity Test function, an integrated part of the Auto-Negotiation function. Hence, Parallel Detection for the 10BASE-T PMA is not required or allowed.

NOTE 2—When selecting the highest common denominator through the Parallel Detection function, only the half-duplex mode corresponding to the selected PMA may automatically be detected.

28.2.3.2 Renegotiation function

A renegotiation request from any entity, such as a management agent, shall cause the Arbitration function to disable all technology-dependent PMAs and halt any transmit data and link pulse activity until the break_link_timer expires (28.3.2). Consequently, the Link Partner will go into link fail and normal Auto-Negotiation resumes. The Local Device shall resume Auto-Negotiation after the break_link_timer has expired by issuing FLP Bursts with the Base Page valid in tx_link_code_word[16:1].

Once Auto-Negotiation has completed, renegotiation will take place if the Highest Common Denominator technology that receives link_control=ENABLE returns link_status=FAIL. To allow the PMA an

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opportunity to determine link integrity using its own link integrity test function, the link_fail_inhibit_timer qualifies the link_status=FAIL indication such that renegotiation takes place if the link_fail_inhibit_timer has expired and the PMA still indicates link_status=FAIL or link_status=READY.

28.2.3.3 Priority Resolution function

Since a Local Device and a Link Partner may have multiple common abilities, a mechanism to resolve which mode to configure is required. The mechanism used by Auto-Negotiation is a Priority Resolution function that predefines the hierarchy of supported technologies. The single PMA enabled to connect to the MDI by Auto-Negotiation shall be the technology corresponding to the bit in the Technology Ability Field common to the Local Device and Link Partner that has the highest priority as defined in Annex 28B. This technology is referred to as the Highest Common Denominator, or HCD, technology. If the Local Device receives a Technology Ability Field with a bit set that is reserved, the Local Device shall ignore that bit for priority resolution. Determination of the HCD technology occurs on entrance to the FLP LINK GOOD CHECK state. In the event that a technology is chosen through the Parallel Detection function, that technology shall be considered the highest common denominator (HCD) technology. In the event that there is no common technology, HCD shall have a value of "NULL," indicating that no PMA receives link_control=ENABLE, and link_status_[HCD]=FAIL.

28.2.3.4 Next Page function

The Next Page function uses the standard Auto-Negotiation arbitration mechanisms to allow exchange of arbitrary pieces of data. Data is carried by optional Next Pages of information, which follow the transmission and acknowledgment procedures used for the base link codeword. Four types of Next Page encodings are defined: Message Pages, Unformatted Pages, extended Message Pages, and extended Unformatted Pages.

A dual acknowledgment system is used. Acknowledge (Ack) is used to acknowledge receipt of the information; Acknowledge 2 (Ack2) is used to indicate that the receiver is able to act on the information (or perform the task) defined in the message.

Next Page operation is controlled by the use three mandatory control bits, Next Page, Extended Next Page, and Acknowledge, used in the base link codeword. Setting the NP bit in the base link codeword to logic one indicates that the device is Next Page able. Setting the Extended Next Page bit in the Base Page link codeword to logic one indicates that the device is Extended Next Page able. If both a device and its Link Partner are Next Page able, then Next Page exchange may occur. If both a device and its Link Partner are Extended Next Page able, then any Next Page exchange that occurs shall use the Extended Next Page encoding. If one or both devices are not Next Page able, then Next Page exchange will not occur and, after the base link codewords have been exchanged, the FLP LINK GOOD CHECK state will be entered. The Toggle bit is used to ensure proper synchronization between the Local Device and the Link Partner.

Next Page exchange occurs after the base link codewords have been exchanged. Next Page exchange consists of using the normal Auto-Negotiation arbitration process to send Next Page messages. Four message encodings are defined: Message Pages, Unformatted Pages, extended Message Pages, and extended Unformatted Pages. Unformatted Pages can be combined to send extended messages. If the Selector Field values do not match, then each series of Unformatted Pages shall be preceded by a Message Page containing a message code that defines how the following Unformatted Pages will be interpreted. If the Selector Field values match, then the convention governing the use of Message Pages shall be as defined by the Selector Field value definition. Any number of Next Pages may be sent in any order; however, it is recommended that the total number of Next Pages sent be kept small to minimize the link startup time.

Next Page transmission ends when both ends of a link segment set their Next Page bits to logic zero, indicating that neither has anything additional to transmit. It is possible for one device to have more pages to transmit than the other device. Once a device has completed transmission of its Next Page information, it

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shall transmit Message Pages, or extended Message Pages, with Null message codes and the NP bit set to logic zero while its Link Partner continues to transmit valid Next Pages. An Auto-Negotiation able device shall recognize reception of Message Pages, or extended Message Pages, with Null message codes as the end of its Link Partner's Next Page information.

28.2.3.4.1 Next Page encodings

The Next Page shall use the encoding shown in Figure 28–11 and Figure 28–12 for the NP, Ack, MP, Ack2, and T bits. The 11-bit field D10–D0 shall be encoded as a Message Code Field if the MP bit is logic one and an Unformatted Code Field if MP is set to logic zero.

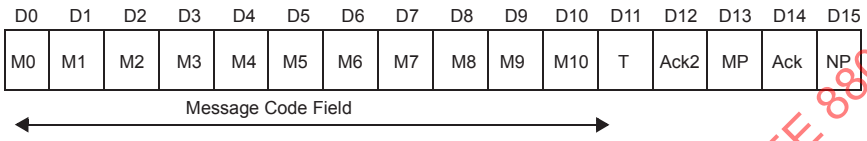

Figure 28–11—Message Page encoding

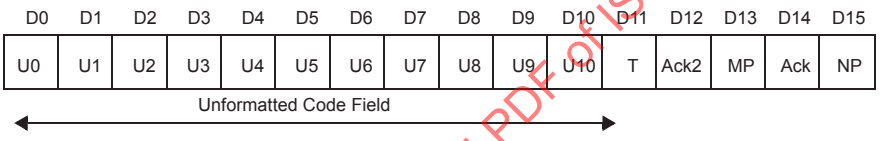

Figure 28–12—Unformatted Page encoding

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28.2.3.4.2 Extended Next Page encodings

Extended Next Pages shall use the encoding shown in Figure 28–13 and Figure 28–14 for the NP, Ack, MP, Ack2, and T bits. The 11-bit field D10:D0 shall be encoded as a Message Code Field if the MP is a logic one and an Unformatted Code Field if the MP bit is set to logic zero.

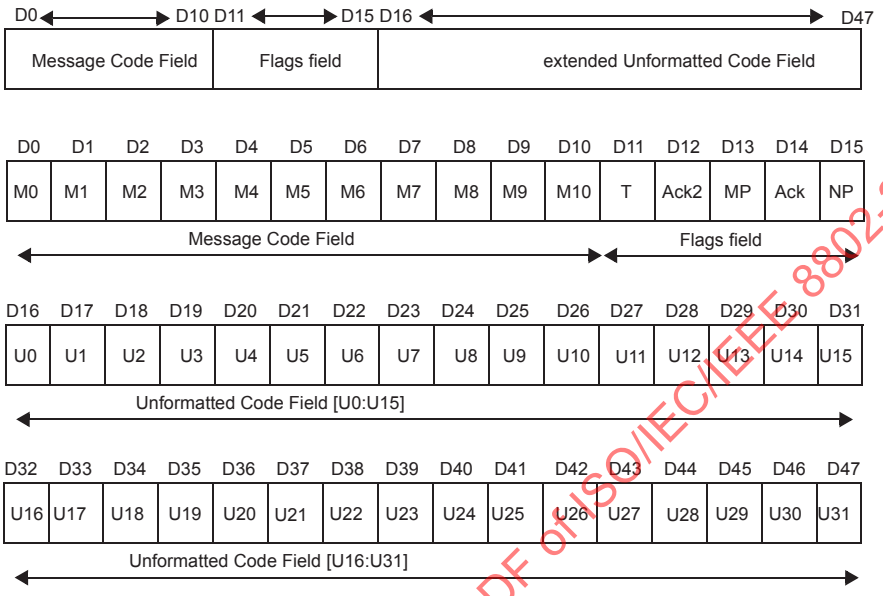

Figure 28–13—Extended Message Page encoding

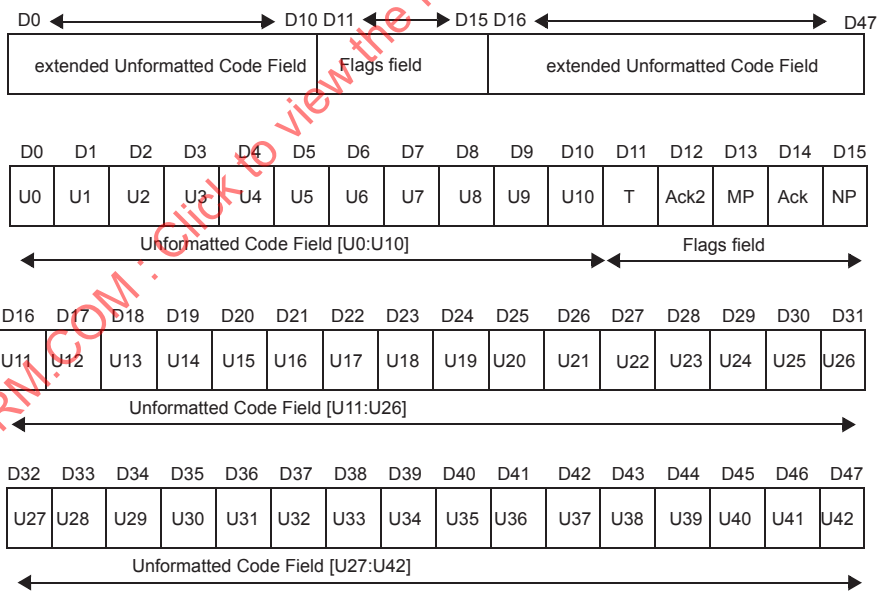

Figure 28–14—Extended Unformatted Page encoding

28.2.3.4.3 Next Page

Next Page (NP) is used by the Next Page function to indicate whether or not this is the last Next Page to be transmitted. NP shall be set as follows:

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logic zero = last page.
logic one = additional Next Page(s) will follow.

28.2.3.4.4 Acknowledge

As defined in 28.2.1.2.5.

28.2.3.4.5 Message Page

Message Page (MP) is used by the Next Page function to differentiate a Message Page from an Unformatted Page. MP shall be set as follows:

logic zero = Unformatted Page.
logic one = Message Page.

28.2.3.4.6 Acknowledge 2

Acknowledge 2 (Ack2) is used by the Next Page function to indicate that a device has the ability to comply with the message. Ack2 shall be set as follows:

logic zero = cannot comply with message.
logic one = will comply with message.

28.2.3.4.7 Toggle

Toggle (T) is used by the Arbitration function to ensure synchronization with the Link Partner during Next Page exchange. This bit shall always take the opposite value of the Toggle bit in the previously exchanged link codeword. The initial value of the Toggle bit in the first Next Page transmitted is the inverse of bit 11 in the base link codeword and, therefore, may assume a value of logic one or zero. The Toggle bit shall be set as follows:

logic zero = previous value of the transmitted link codeword equalled logic one.
logic one = previous value of the transmitted link codeword equalled logic zero.

28.2.3.4.8 Message Page encoding

Message Pages are formatted pages that carry a single predefined message code, which is enumerated in Annex 28C. Two-thousand and forty-eight message codes are available. The allocation of these codes will be controlled by the contents of Annex 28C. If the Message Page bit is set to logic one, then the bit encoding of the link codeword shall be interpreted as a Message Page.

28.2.3.4.9 Message Code Field

Message Code Field (M[10:0]) is an eleven bit wide field, encoding 2048 possible messages. Message Code Field definitions are shown in Annex 28C. Combinations not specified are reserved for future use. Reserved combinations of the Message Code Field shall not be transmitted.

28.2.3.4.10 Unformatted Page encoding

Unformatted Pages carry the messages indicated by Message Pages. Five control bits are predefined, the remaining 11 bits may take on an arbitrary value. If the Message Page bit is set to logic zero, then the bit encoding of the link codeword shall be interpreted as an Unformatted Page.

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28.2.3.4.11 Unformatted Code Field

Unformatted Code Field (U[10:0]) is an eleven bit wide field, which may contain an arbitrary value.

28.2.3.4.12 Extended Unformatted Code Field

The extended Unformatted Code Field is a 32-bit or 43-bit wide field, which may contain an arbitrary value. The field is 32 bits wide in an extended Message Page and 43 bits wide in an extended Unformatted Page.

28.2.3.4.13 Use of Next Pages

a) Both devices must indicate Next Page ability for either to commence exchange of Next Pages.
b) Both devices must indicate Extended Next Page ability for either to commence exchange of Extended Next Pages.
c) If both devices are Next Page able, then both devices shall send at least one Next Page.
d) If both devices are Extended Next Page able, then both devices only transmit Extended Next Pages.
e) Next Page exchange shall continue until neither device on a link has more pages to transmit as indicated by the NP bit. A Message Page with a Null Message Code Field value shall be sent if the device has no other information to transmit.
f) A message code can carry either a specific message or information that defines how following Unformatted Page(s) should be interpreted.
g) If a message code references Unformatted Pages, the Unformatted Pages shall immediately follow the referencing message code in the order specified by the message code.
h) Unformatted Page users are responsible for controlling the format and sequencing for their Unformatted Pages.
i) An Extended Next Page provides a message code and extended Unformatted Code Field. The Message Code Field can carry either a specific message or information that defines how the following extended Unformatted Code Field should be interpreted.

28.2.3.4.14 MII register requirements

The Next Page Transmit register defined in 28.2.4.1.6 shall hold the Next Page to be sent by Auto-Negotiation. Received Next Pages may be stored in the Auto-Negotiation Link Partner ability register.

28.2.3.5 Remote fault sensing function

The Remote Fault function may indicate to the Link Partner that a fault condition has occurred using the Remote Fault bit and, optionally, the Next Page function.

Sensing of faults in a device as well as subsequent association of faults with the Remote Fault bit shall be optional. If the Local Device has no mechanism to detect a fault or associate a fault condition with the received Remote Fault bit indication, then it shall transmit the Remote Fault bit with the value contained in the Auto-Negotiation advertisement register bit (4.13).

A Local Device may indicate it has sensed a fault to its Link Partner by setting the Remote Fault bit in the Auto-Negotiation advertisement register and renegotiating.

If the Local Device sets the Remote Fault bit to logic one, it may also use the Next Page function to specify information about the fault that has occurred. Remote Fault Message Page Codes have been specified for this purpose.

The Remote Fault bit shall remain set until after successful negotiation with the base link codeword, at which time the Remote Fault bit shall be reset to a logic zero. On receipt of a base link codeword with the

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Remote Fault bit set to logic one, the device shall set the Remote Fault bit in the MII status register (1.4) to logic one if the MII management function is present.

28.2.4 Management function requirements

The management interface is used to communicate Auto-Negotiation information to the management entity. If an MII is physically implemented, then management access is via the MII Management interface. Where no physical embodiment of the MII exists, an equivalent to MII Registers 0, 1, 4, 5, 6, and 7 (Clause 22) are recommended to be provided.

28.2.4.1 Media Independent Interface

The Auto-Negotiation function shall have five dedicated registers:

a) MII control register (Register 0).
b) MII status register (Register 1).
c) Auto-Negotiation advertisement register (Register 4).
d) Auto-Negotiation Link Partner ability register (Register 5).
e) Auto-Negotiation expansion register (Register 6).

If the Next Page function is implemented, the Auto-Negotiation Next Page transmit register (Register 7) shall be implemented.

28.2.4.1.1 MII control register

MII control register (Register 0) provides the mechanism to disable/enable and/or restart Auto-Negotiation. The definition for this register is provided in 22.2.4.1.

The Auto-Negotiation function shall be enabled by setting bit 0.12 to a logic one. If bit 0.12 is set to a logic one, then bits 0.13 and 0.8 shall have no effect on the link configuration, and the Auto-Negotiation process will determine the link configuration. If bit 0.12 is cleared to logic zero, then bits 0.13 and 0.8 will determine the link configuration regardless of the prior state of the link configuration and the Auto-Negotiation process.

A PHY shall return a value of one in bit 0.9 until the Auto-Negotiation process has been initiated. The Auto-Negotiation process shall be initiated by setting bit 0.9 to a logic one. If Auto-Negotiation was completed prior to this bit being set, the process shall be reinitiated. If a PHY reports via bit 1.3 that it lacks the ability to perform Auto-Negotiation, then this bit will have no meaning, and should be written as zero. This bit is self-clearing. The Auto-Negotiation process shall not be affected by clearing this bit to logic zero.

28.2.4.1.2 MII status register

The MII status register (Register 1) includes information about all modes of operations supported by the Local Device's PHY, the status of Auto-Negotiation, and whether the Auto-Negotiation function is supported by the PHY or not. The definition for this register is provided in 22.2.4.2.

When read as a logic one, bit 1.5 indicates that the Auto-Negotiation process has been completed, and that the contents of Registers 4, 5, and 6 are valid. When read as a logic zero, bit 1.5 indicates that the Auto-Negotiation process has not been completed, and that the contents of Registers 4, 5, and 6 are meaningless. A PHY shall return a value of zero in bit 1.5 if Auto-Negotiation is disabled by clearing bit 0.12. A PHY shall also return a value of zero in bit 1.5 if it lacks the ability to perform Auto-Negotiation.

When read as logic one, bit 1.4 indicates that a remote fault condition has been detected. The type of fault as well as the criteria and method of fault detection is PHY specific. The Remote Fault bit shall be

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implemented with a latching function, such that the occurrence of a remote fault will cause the Remote Fault bit to become set and remain set until it is cleared. The Remote Fault bit shall be cleared each time Register 1 is read via the management interface, and shall also be cleared by a PHY reset.

When read as a one, bit 1.3 indicates that the PHY has the ability to perform Auto-Negotiation. When read as a logic zero, bit 1.3 indicates that the PHY lacks the ability to perform Auto-Negotiation.

28.2.4.1.3 Auto-Negotiation advertisement register (Register 4) (R/W)

This register contains the Advertised Ability of the PHY. (See Table 28–2). The bit definition for the Base Page is defined in 28.2.1.2. On power-up, before Auto-Negotiation starts, this register shall have the following configuration: The Selector Field (4.4:0) is set to an appropriate code as specified in Annex 28A. The Acknowledge bit (4.14) is set to logic zero. The Technology Ability Field (4.11:5) is set based on the values set in the MII status register (Register 1) (1.15:11) or equivalent. See also 28.2.1.2.3 and Annex 28D.

Table 28–2—Advertisement register bit definitions

Bit(s)	Name	Description	R/W[a]
4.15	Next Page	See 28.2.1.2	R/W
4.14	Reserved	Write as zero, ignore on read	RO
4.13	Remote Fault	See 28.2.1.2	R/W
4.12	Extended Next Page	See 28.2.1.2	R/W
4.11:5	Technology Ability Field	See 28.2.1.2	R/W
4.4:0	Selector Field	See 28.2.1.2	R/W

[a]RO = Read only, R/W = Read/Write.

Only the bits in the Technology Ability Field that represent the technologies supported by the Local Device may be set. Any of the Technology Ability Field bits that may be set can also be cleared by management before a renegotiation. This can be used to enable management to Auto-Negotiate to an alternate common mode.

The management entity may initiate renegotiation with the Link Partner using alternate abilities by setting the Selector Field (4.4:0) and Technology Ability Field (4.11:5) to indicate the preferred mode of operation and setting the Restart Auto-Negotiation bit (0.9) in the control register (Register 0) to logic one.

Any writes to this register prior to completion of Auto-Negotiation as indicated by bit 1.5 should be followed by a renegotiation for the new values to be properly used for Auto-Negotiation. Once Auto-Negotiation has completed, this register value may be examined by software to determine the highest common denominator technology.

28.2.4.1.4 Auto-Negotiation Link Partner ability register (Register 5) (RO)

All of the bits in the Auto-Negotiation Link Partner ability register are read only. A write to the Auto-Negotiation Link Partner ability register shall have no effect.

This register contains the Advertised Ability of the Link Partner's PHY. (See Tables 28–3 and 28–4.) The bit definitions shall be a direct representation of the received link codeword (Figure 28–7). Upon successful completion of Auto-Negotiation, status register (Register 1) Auto-Negotiation Complete bit (1.5) shall be set

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to logic one. If the Next Page function is supported and bit (6.6) in the Auto-Negotiation expansion register (Register 6) is set to logic zero, then the Auto-Negotiation Link Partner ability register may be used to store Link Partner Next Pages. If bit (6.6) in the Auto-Negotiation expansion register (Register 6) is set to logic one, then bit (6.5) determines where the Link Partner Next Pages are stored.

Table 28–3—Link partner ability register bit definitions (Base Page)

Bit(s)	Name	Description	R/W[a]
5.15	Next Page	See 28.2.1.2	RO
5.14	Acknowledge	See 28.2.1.2	RO
5.13	Remote Fault	See 28.2.1.2	RO
5.12	Extended Next Page	See 28.2.1.2	RO
5.11:5	Technology Ability Field	See 28.2.1.2	RO
5.4:0	Selector Field	See 28.2.1.2	RO

[a]RO = Read only.

Table 28–4—Link partner ability register bit definitions (Next Page)

Bit(s)	Name	Description	R/W[a]
5.15	Next Page	See 28.2.3.4	RO
5.14	Acknowledge	See 28.2.3.4	RO
5.13	Message Page	See 28.2.3.4	RO
5.12	Acknowledge 2	See 28.2.3.4	RO
5.11	Toggle	See 28.2.3.4	RO
5.10:0	Message/Unformatted Code Field	See 28.2.3.4	RO

[a]RO = Read only.

The values contained in this register are only guaranteed to be valid once Auto-Negotiation has successfully completed, as indicated by bit 1.5 or, if used with Next Page exchange, after the Page Received bit (6.1) has been set to logic one.

NOTE—If this register is used to store Link Partner Next Pages, the previous value of this register is assumed to be stored by a management entity that needs the information overwritten by subsequent Link Partner Next Pages.

28.2.4.1.5 Auto-Negotiation expansion register (Register 6) (RO)

All of the bits in the Auto-Negotiation expansion register are read only; a write to the Auto-Negotiation expansion register shall have no effect. (See Table 28–5.)

Bits 6.15:7 are reserved for future Auto-Negotiation expansion.

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Table 28–5—Expansion register bit definitions

Bit(s)	Name	Description	R/W[a]	Default
6.15:7	Reserved	Write as zero, ignore on read	RO	0
6.6	Receive Next Page Location Able	1 = Received Next Page storage location is specified by bit (6.5) 0 = Received Next Page storage location is not specified by bit (6.5)	RO	—
6.5	Received Next Page Storage Location	1 = Link Partner Next Pages are stored in Register 8 0 = Link Partner Next Pages are stored in Register 5	RO	—
6.4	Parallel Detection Fault	1 = A fault has been detected via the Parallel Detection function. 0 = A fault has not been detected via the Parallel Detection function.	RO/ LH	0
6.3	Link Partner Next Page Able	1 = Link Partner is Next Page able 0 = Link Partner is not Next Page able	RO	0
6.2	Next Page Able	1 = Local Device is Next Page able 0 = Local Device is not Next Page able	RO	0
6.1	Page Received	1 = A New Page has been received 0 = A New Page has not been received	RO/ LH	0
6.0	Link Partner Auto-Negotiation Able	1 = Link Partner is Auto-Negotiation able 0 = Link Partner is not Auto-Negotiation able	RO	0

[a]RO = Read only, LH = Latching high.

The Receive Next Page Location Able bit (6.6) shall be set to logic one to indicate that the Link Partner Next Page Storage Location bit (6.5) is supported.

The Receive Next Page Storage Location bit (6.5) shall be set to logic one to indicate that the Link Partner's Next Pages are stored in the Auto-Negotiation Link Partner Received Next Page register (Register 8). This bit shall be set to logic zero to indicate that the Link Partner's Next Pages are stored in the Auto-Negotiation Link Partner ability register (Register 5). It is recommended that all new implementations store the Link Partner's Next Pages in the Auto-Negotiation Link Partner Received Next Page ability register (Register 8).

NOTE— It is highly recommended that the Link Partner Next Page Storage Location bit (6.5) is supported. If this bit is not supported there is no indication if the Link Partners Next Page is stored in register 5 or register 8.

The Parallel Detection Fault bit (6.4) shall be set to logic one to indicate that zero or more than one of the NLP Receive Link Integrity Test function, 100BASE-TX, or 100BASE-T4 PMAs have indicated link_status=READY when the autoneg_wait_timer expires. The Parallel Detection Fault bit shall be reset to logic zero on a read of the Auto-Negotiation expansion register (Register 6).

The Link Partner Next Page Able bit (6.3) shall be set to logic one to indicate that the Link Partner supports the Next Page function. This bit shall be reset to logic zero to indicate that the Link Partner does not support the Next Page function.

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The Next Page Able bit (6.2) shall be set to logic one to indicate that the Local Device supports the Next Page function. The Next Page Able bit (6.2) shall be set to logic zero if the Next Page function is not supported.

The Page Received bit (6.1) shall be set to logic one to indicate that a new link codeword has been received and stored in the Auto-Negotiation Link Partner ability register. The Page Received bit shall be reset to logic zero on a read of the Auto-Negotiation expansion register (Register 6).

The Link Partner Auto-Negotiation Able bit (6.0) shall be set to logic one to indicate that the Link Partner is able to participate in the Auto-Negotiation function. This bit shall be reset to logic zero if the Link Partner is not Auto-Negotiation able.

28.2.4.1.6 Auto-Negotiation Next Page transmit register (Register 7) (R/W)

The Auto-Negotiation Next Page Transmit register contains the Next Page link codeword to be transmitted when Next Page ability is supported. (See Table 28–6.) The contents are defined in 28.2.3.4. On power-up, this register shall contain the default value of 2001H, which represents a Message Page with the message code set to Null Message. This value may be replaced by any valid Next Page message code that the device wishes to transmit. Writing to this register shall set mr_next_page_loaded to true.

Table 28–6—Next Page transmit register bit definitions

Bit(s)	Name	Description	R/W[a]
7.15	Next Page	See 28.2.3.4	R/W
7.14	Reserved	Write as 0, ignore on read	RO
7.13	Message Page	See 28.2.3.4	R/W
7.12	Acknowledge 2	See 28.2.3.4	R/W
7.11	Toggle	See 28.2.3.4	RO
7.10:0	Message/Unformatted Code field	See 28.2.3.4	R/W

[a]RO = Read only, R/W = Read/Write.

28.2.4.1.7 Auto-Negotiation Link Partner Received Next Page register (Register 8) (RO)

Support for 100BASE-T2 and 1000BASE-T requires support for Next Page and the provision of an Auto-Negotiation Link Partner Received Next Page register (register 8) to store Link Partner Next Pages as shown in Table 28–7. All of the bits in the Auto-Negotiation Link Partner Received Next Page register are read only. A write to the Auto-Negotiation Link Partner Received Next Page register shall have no effect.

The values contained in this register are only guaranteed to be valid after the Page Received bit (6.1) has been set to logical one or once Auto-Negotiation has successfully completed, as indicated by bit 1.5.

NOTE—If this register is used to store multiple Link Partner Next Pages, the previous value of this register is assumed to be stored by a management entity that needs the information overwritten by subsequent Link Partner Next Pages.

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Table 28–7—Link Partner Received Next Page register bit definitions

Bit(s)	Name	Description	R/W[a]
8.15	Next Page	see 28.2.3.4	RO
8.14	Acknowledge	see 28.2.3.4	RO
8.13	Message Page	see 28.2.3.4	RO
8.12	Acknowledge 2	see 28.2.3.4	RO
8.11	Toggle	see 28.2.3.4	RO
8.10:0	Message/Unformatted Code Field	see 28.2.3.4	RO

[a]RO = Read only.

28.2.4.1.8 State diagram variable to MII register mapping

The state diagrams of Figures 28–16 to 28–19 generate and accept variables of the form "mr_x," where x is an individual signal name. These variables comprise a management interface that may be connected to the MII management function or other equivalent function. Table 28–8 describes how the MII registers map to the management function interface signals.

Table 28–8—State diagram variable to MII register mapping

State diagram variable	MII register	MDIO register
mr_adv_ability[16:1]	4.15:0 Auto-Negotiation advertisement register	7.16.15:0 AN advertisement register
mr_autoneg_complete	1.5 Auto-Negotiation Complete	7.1.5 Auto-Negotiation Complete
mr_autoneg_enable	0.12 Auto-Negotiation Enable	7.0.12 Auto-Negotiation Enable
mr_lp_adv_ability[16:1]	For Base Page: 5.15:0 Auto-Negotiation link partner ability register For Next Page(s): If 6.6=1 and 6.5=1 then 8.15:0 is Auto-Negotiation link partner Received Next Page register If 6.6=1 and 6.5= 0 then 5.15:0 is Auto-Negotiation link partner ability register If 6.6=0 then 8.15:0 or 5.15:0 is Auto-Negotiation link partner Next Page ability register	7.19.15:0 AN LP Base Page ability register
mr_lp_autoneg_able	6.0 Link Partner Auto-Negotiation able	
mr_lp_np_able	6.3 Link Partner Next Page able	
mr_main_reset	0.15 Reset	7.0.15 Reset
mr_next_page_loaded	Set on write to Auto-Negotiation Next Page Transmit register; cleared by Arbitration state diagram	
mr_np_able	6.2 Next Page able	

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Table 28–8—State diagram variable to MII register mapping *(continued)*

State diagram variable	MII register	MDIO register
mr_np_tx[16:1]	7.15:0 Auto-Negotiation Next Page Transmit Register	7.22.15:0 AN XNP transmit register
mr_np_tx[32:17]	Extended Next Pages not supported by MII register interface	7.23.15:0 Unformatted Code Field 1
mr_np_tx[48:33]	Extended Next Pages not supported by MII register interface	7.24.15:0 Unformatted Code Field 2
mr_page_rx	6.1 Page Received	7.1.6 Page Received
mr_parallel_detection_fault	6.4 Parallel Detection Fault	
mr_restart_negotiation	0.9 Auto-Negotiation Restart	7.0.9 Auto-Negotiation Restart
set if Auto-Negotiation is available	1.3 Auto-Negotiation Ability	7.1.3 Auto-Negotiation Ability

28.2.4.2 Auto-Negotiation managed object class

The Auto-Negotiation Managed Object Class is defined in Clause 30.

28.2.5 Absence of management function

In the absence of any management function, the advertised abilities shall be provided through a logical equivalent of mr_adv_ability[16:1]. A device shall comply with all Next Page function requirements, including the provision of the mr_np_able, mr_lp_np_able, and mr_next_page_loaded variables (or their logical equivalents), in order to permit the NP bit to be set to logic one in the transmitted link codeword.

NOTE—Storage of a valid base link codeword is required to prevent a deadlock situation where negotiation must start again while Next Pages are being transmitted. If a shared transmit register were used, then renegotiation could not occur when Next Pages were being transmitted because the base link codeword would not be available. This requirement can be met using a number of different implementations, including use of temporary registers or register stacks.

28.2.6 Technology-Dependent Interface

The Technology-Dependent Interface is the communication mechanism between each technology's PMA and the Auto-Negotiation function. Auto-Negotiation can support multiple technologies, all of which need not be implemented in a given device. Each of these technologies may utilize its own technology-dependent link integrity test function.

28.2.6.1 PMA_LINK.indication

This primitive is generated by the PMA to indicate the status of the underlying medium. The purpose of this primitive is to give the PCS, repeater client, or Auto-Negotiation function a means of determining the validity of received code elements.

28.2.6.1.1 Semantics of the service primitive

PMA_LINK.indication(link_status)

The link_status parameter shall assume one of three values: READY, OK, or FAIL, indicating whether the underlying receive channel is intact and ready to be enabled (READY), intact and enabled (OK), or not

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intact (FAIL). When link_status=FAIL or link_status=READY, the PMA_CARRIER.indication and PMA_UNITDATA.indication primitives are undefined.

28.2.6.1.2 When generated

A technology-dependent PMA and the NLP Receive Link Integrity Test state diagram (Figure 28–19) shall generate this primitive to indicate the value of link_status.

28.2.6.1.3 Effect of receipt

The effect of receipt of this primitive shall be governed by the state diagrams of Figure 28–18.

28.2.6.2 PMA_LINK.request

This primitive is generated by Auto-Negotiation to allow it to enable and disable operation of the PMA.

28.2.6.2.1 Semantics of the service primitive

PMA_LINK.request(link_control)

The link_control parameter shall assume one of three values: SCAN_FOR_CARRIER, DISABLE, or ENABLE.

The link_control=SCAN_FOR_CARRIER mode is used by the Auto-Negotiation function prior to receiving any FLP Bursts or link_status=READY indications. During this mode, the PMA shall search for carrier and report link_status=READY when carrier is received, but no other actions shall be enabled.

The link_control=DISABLE mode shall be used by the Auto-Negotiation function to disable PMA processing.

The link_control=ENABLE mode shall be used by Auto-Negotiation to turn control over to a single PMA for all normal processing functions.

28.2.6.2.2 When generated

The Auto-Negotiation function shall generate this primitive to indicate to the PHY how to respond, in accordance with the state diagrams of Figure 28–17 and Figure 28–18.

Upon power-on or reset, if the Auto-Negotiation function is enabled (mr_autoneg_enable=true) the PMA_LINK.request(DISABLE) message shall be issued to all technology-dependent PMAs. If Auto-Negotiation is disabled at any time including at power-on or reset, the state of PMA_LINK.request(link_control) is implementation dependent.

28.2.6.2.3 Effect of receipt

The effect of receipt of this primitive shall be governed by the NLP Receive Link Integrity Test state diagram (Figure 28–19) and the receiving technology-dependent link integrity test function, based on the intent specified in the primitive semantics.

28.2.6.3 PMA_LINKPULSE.request

This primitive is generated by Auto-Negotiation to indicate that a valid Link Pulse, as transmitted in compliance with Figure 14–13, has been received.

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28.2.6.3.1 Semantics of the service primitive

PMA_LINKPULSE.request (linkpulse)

The linkpulse parameter shall assume one of two values: TRUE or FALSE.

The linkpulse=FALSE mode shall be used by the Auto-Negotiation function to indicate that the Receive state diagram has performed a state transition.

The linkpulse=TRUE mode shall be used by the Auto-Negotiation function to indicate that a valid Link Pulse has been received.

28.2.6.3.2 When generated

The Auto-Negotiation function shall generate this primitive to indicate to the PHY how to respond, in accordance with the state diagram of Figure 28–17.

Upon power-on or reset, if the Auto-Negotiation function is enabled (mr_autoneg_enable=true) the PMA_LINKPULSE.request (FALSE) message shall be issued to all technology-dependent PMAs. If Auto-Negotiation is disabled at any time including at power-on or reset, the state of PMA_LINKPULSE.request (linkpulse) is implementation dependent.

28.2.6.3.3 Effect of receipt

The effect of receipt of this primitive shall be governed by the receiving technology-dependent PMA function, based on the intent specified in the primitive semantics.

28.3 State diagrams and variable definitions

The notation used in the state diagrams (Figure 28–16 to Figure 28–19) follows the conventions in 21.5. State diagram variables follow the conventions of 21.5.2 except when the variable has a default value. Variables in a state diagram with default values evaluate to the variable default in each state where the variable value is not explicitly set. Variables using the “mr_x” notation do not have state diagram defaults; however, their appropriate initialization conditions when mapped to the MII interface are covered in 28.2.4 and 22.2.4, and Clause 45 MDIO management interface. The variables, timers, and counters used in the state diagrams are defined in 28.3, 14.2.3, and 28.2.6.

Auto-Negotiation shall implement the Transmit state diagram, Receive state diagram, Arbitration state diagram, and NLP Receive Link Integrity Test state diagram as depicted in 28.3. Additional requirements to these state diagrams are made in the respective functional requirements sections. Options to these state diagrams clearly stated as such in the functional requirements sections or state diagrams shall be allowed. In the case of any ambiguity between stated requirements and the state diagrams, the state diagrams shall take precedence.

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The functional reference diagram (Figure 28–15) provides a generic example, illustrated with initial PMA implementations and showing the mechanism for expansion. New PMAs are documented in Annex 28D.

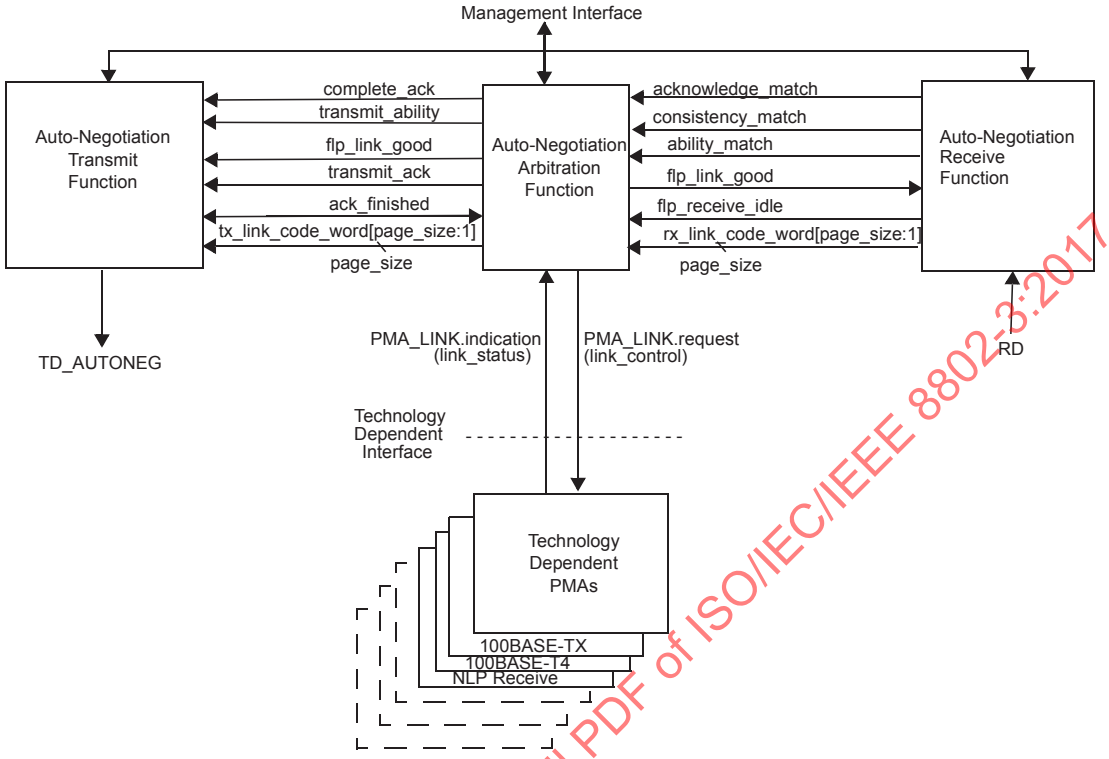

Figure 28–15—Functional reference diagram

28.3.1 State diagram variables

A variable with "_[x]" appended to the end of the variable name indicates a variable or set of variables as defined by "x". "x" may be as follows:

all;	represents all specific technology-dependent PMAs supported in the Local Device and the NLP Receive Link Integrity Test state diagram.
1GigT;	represents that the 1000BASE-T PMA is the signal source.
10GigT;	represents that the 10GBASE-T PMA is the signal source.
HCD;	represents the single technology-dependent PMA chosen by Auto-Negotiation as the highest common denominator technology through the Priority Resolution or Parallel Detection function. To select 10BASE-T, LIT is used instead of NLP to enable the full 10BASE-T Link Integrity Test function state diagram.
notHCD;	represents all technology-dependent PMAs not chosen by Auto-Negotiation as the highest common denominator technology through the Priority Resolution or Parallel Detection function.
TX;	represents that the 100BASE-TX PMA is the signal source.
T4;	represents that the 100BASE-T4 PMA is the signal source.
NLP;	represents that the NLP Receive Link Integrity Test function is the signal source.
PD;	represents all of the following that are present: 100BASE-TX PMA, 100BASE-T4 PMA, and the NLP Receive Link Integrity Test state diagram.
LIT;	represents the 10BASE-T Link Integrity Test function state diagram is the signal source or

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destination.

Variables with [16:1] appended to the end of the variable name indicate arrays that can be directly mapped to 16-bit registers. For these variables, "[x]" indexes an element or set of elements in the array, where "[x]" may be as follows:

— Any integer.
— Any variable that takes on integer values.
— NP; represents the index of the Next Page bit.
— ACK; represents the index of the Acknowledge bit.
— RF; represents the index of the Remote Fault bit.

Variables of the form "mr_x", where x is a label, comprise a management interface that is intended to be connected to the MII Management function. However, an implementation-specific management interface may provide the control and status function of these bits.

ability_match

Indicates that three consecutive link codewords match, ignoring the Acknowledge bit. Three consecutive words are any three words received one after the other, regardless of whether the word has already been used in a word-match comparison or not.

Values: false; three matching consecutive link codewords have not been received, ignoring the Acknowledge bit (default).
true; three matching consecutive link codewords have been received, ignoring the Acknowledge bit.

NOTE—This variable is set by this variable definition; it is not set explicitly in the state diagrams.

ability_match_word [16:1]

A 16-bit array that contains the last link codeword that caused ability_match = true. For each element in the array:

Values: zero; data bit is logical zero.
one; data bit is logical one.

ack_finished

Status indicating that the final remaining_ack_cnt link codewords with the Ack bit set have been transmitted.

Values: false; more link codewords with the Ack bit set to logic one must be transmitted.
true; all remaining link codewords with the Ack bit set to logic one have been transmitted.

acknowledge_match

Indicates that three consecutive link codewords match and have the Acknowledge bit set. Three consecutive words are any three words received one after the other, regardless of whether the word has already been used in a word match comparison or not.

Values: false; three matching and consecutive link codewords have not been received with the Acknowledge bit set (default).
true; three matching and consecutive link codewords have been received with the Acknowledge bit set.

NOTE—This variable is set by this variable definition; it is not set explicitly in the state diagrams.

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base_page

Status indicating that the page currently being transmitted by Auto-Negotiation is the initial link codeword encoding used to communicate the device's abilities.

Values: false; a page other than base link codeword is being transmitted.
true; the base link codeword is being transmitted.

complete_ack

Controls the counting of transmitted link codewords that have their Acknowledge bit set.

Values: false; transmitted link codewords with the Acknowledge bit set are not counted (default).
true; transmitted link codewords with the Acknowledge bit set are counted.

consistency_match

Indicates that the link codeword that caused ability_match to be set is the same as the link codeword that caused acknowledge_match to be set.

Values: false; the link codeword that caused ability_match to be set is not the same as the link codeword that caused acknowledge_match to be set, ignoring the Acknowledge bit value.
true; the link codeword that caused ability_match to be set is the same as the link codeword that caused acknowledge_match to be set, independent of the Acknowledge bit value.

NOTE—This variable is set by this variable definition; it is not set explicitly in the state diagrams.

desire_np

Status indicating that the Local Device desires to engage in Next Page exchange. This information comes from the setting of the NP bit in the base link codeword stored in the Auto-Negotiation advertisement register (Register 4).

Values: false; Next page exchange is not desired.
true; Next page exchange is desired.

flp_link_good

Indicates that Auto-Negotiation has completed.

Values: false; negotiation is in progress (default).
true; negotiation is complete, forcing the Transmit and Receive functions to IDLE.

flp_receive_idle

Indicates that the Receive state diagram is in the IDLE, LINK PULSE DETECT, or LINK PULSE COUNT state.

Values: false; the Receive state diagram is not in the IDLE, LINK PULSE DETECT, or LINK PULSE COUNT state (default).
true; the Receive state diagram is in the IDLE, LINK PULSE DETECT, or LINK PULSE COUNT state.

incompatible_link

Parameter used following Priority Resolution to indicate the resolved link is incompatible with the Local Device settings. A device's ability to set this variable to true is optional.

Values: false; A compatible link exists between the Local Device and Link Partner (default).
true; Optional indication that Priority Resolution has determined no highest common denominator exists following the most recent negotiation.

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NOTE—This variable is set by this variable definition; it is not set explicitly in the state diagrams.

link_control
This variable is defined in 28.2.6.2.1.

link_status
This variable is defined in 28.2.6.1.1.

linkpulse
This variable is defined in 28.2.6.3.1.

Values: false; linkpulse is set to false after any Receive State Diagram state transition (default).
true; linkpulse is set to true when a valid Link Pulse is received.

mr_autoneg_complete
Status indicating whether Auto-Negotiation has completed or not.

Values: false; Auto-Negotiation has not completed.
true; Auto-Negotiation has completed.

mr_autoneg_enable
Controls the enabling and disabling of the Auto-Negotiation function.

Values: false; Auto-Negotiation is disabled.
true; Auto-Negotiation is enabled.

mr_adv_ability[16:1]
A 16-bit array that contains the Advertised Abilities link codeword.
For each element within the array:

Values: zero; data bit is logical zero.
one; data bit is logical one.

mr_lp_adv_ability[16:1]
A 16-bit array that contains the Link Partner's Advertised Abilities link codeword.
For each element within the array:

Values: zero; data bit is logical zero.
one; data bit is logical one.

mr_lp_np_able
Status indicating whether the Link Partner supports Next Page exchange.

Values: false; the Link Partner does not support Next Page exchange.
true; the Link Partner supports Next Page exchange.

mr_np_able
Status indicating whether the Local Device supports Next Page exchange.

Values: false; the Local Device does not support Next Page exchange.
true; the Local Device supports Next Page exchange.

mr_lp_autoneg_able
Status indicating whether the Link Partner supports Auto-Negotiation.

Values: false; the Link Partner does not support Auto-Negotiation.
true; the Link Partner supports Auto-Negotiation.

mr_main_reset
Controls the resetting of the Auto-Negotiation state diagrams.

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Values: false; do not reset the Auto-Negotiation state diagrams.
true; reset the Auto-Negotiation state diagrams.

mr_next_page_loaded

Status indicating whether a new page has been loaded into the Auto-Negotiation Next Page Transmit register (Register 7).

Values: false; a New Page has not been loaded.
true; a New Page has been loaded.

mr_np_tx[page_size:1]

A 16-bit or 48-bit array that contains the new Next Page to transmit.
For each element within the array:

Values: zero; data bit is logical zero.
one; data bit is logical one.

mr_page_rx

Status indicating whether a New Page has been received. A New Page has been successfully received when acknowledge_match=true and consistency_match=true and the link codeword has been written to mr_lp_adv_ability[16:1].

Values: false; a New Page has not been received.
true; a New Page has been received.

mr_parallel_detection_fault

Error condition indicating that while performing Parallel Detection, either flp_receive_idle = false, or zero or more than one of the following indications were present when the autoneg_wait_timer expired. This signal is cleared on read of the Auto-Negotiation expansion register.

1) link_status_ [NLP] = READY
2) link_status_[TX] = READY
3) link_status_[T4] = READY

Values: false; exactly one of the above three indications was true when the autoneg_wait_timer expired, and flp_receive_idle = true.
true; either zero or more than one of the above three indications was true when the autoneg_wait_timer expired, or flp_receive_idle = false.

mr_restart_negotiation

Controls the entrance to the TRANSMIT DISABLE state to break the link before Auto-Negotiation is allowed to renegotiate via management control.

Values: false; renegotiation is not taking place.
true; renegotiation is started.

np_rx

Flag to hold the value of rx_link_code_word[NP] upon entry to the COMPLETE ACKNOWLEDGE state. This value is associated with the value of rx_link_code_word[NP] when acknowledge_match was last set.

Values zero; local device np_rx bit equals a logical zero.
one; local device np_rx bit equals a logical one.

page_size

Status indicating the size of Next Page that the device is prepared to transmit and receive.

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Values: 16; the device does not support Extended Next Pages or Extended Next Page ability has not been enabled.
48; Extended Next Page ability is supported and has been enabled.

NOTE— This variable is set by this variable definition; it is not set explicitly in the state diagrams. The variable takes on the value of 16 upon entry into the TRANSMIT DISABLE state and is updated upon entry into the NEXT PAGE WAIT state.

power_on

Condition that is true until such time as the power supply for the device that contains the Auto-Negotiation state diagrams has reached the operating region or the device has low power mode set via MII control register bit 0.11.

Values: false; the device is completely powered (default).
true; the device has not been completely powered.

rx_link_code_word[page_size:1]

A 16-bit or 48-bit array that contains the data bits to be received from an FLP Burst. For each element within the array:

Values: zero; data bit is a logical zero.
one; data bit is a logical one.

single_link_ready

Status indicating that flp_receive_idle = true and only one the of the following indications is being received:

1) link_status_[NLP] = READY
2) link_status_[TX] = READY
3) link_status_[T4] = READY

Values: false; either zero or more than one of the above three indications are true or flp_receive_idle = false.
true; Exactly one of the above three indications is true and flp_receive_idle = true.

NOTE—This variable is set by this variable definition; it is not set explicitly in the state diagrams.

TD_AUTONEG

Controls the signal sent by Auto-Negotiation on the TD_AUTONEG circuit.

Values: idle; Auto-Negotiation prevents transmission of all link pulses on the MDI.
link_test_pulse; Auto-Negotiation causes a single link pulse as defined by Figure 14–13 to be transmitted on the MDI.

toggle_rx

Flag to keep track of the state of the Link Partner's Toggle bit.

Values: 0; Link Partner's Toggle bit equals logic zero.
1; Link Partner's Toggle bit equals logic one.

toggle_tx

Flag to keep track of the state of the Local Device's Toggle bit.

Values: 0; Local Device's Toggle bit equals logic zero.
1; Local Device's Toggle bit equals logic one.

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transmit_ability
: Controls the transmission of the link codeword containing tx_link_code_word[page_size:1].

  Values: false; any transmission of tx_link_code_word[page_size:1] is halted (default).
  true; the transmit state diagram begins sending tx_link_code_word[page_size:1].

transmit_ack
: Controls the setting of the Acknowledge bit in the tx_link_code_word[page_size:1] to be transmitted.

  Values: false; sets the Acknowledge bit in the transmitted tx_link_code_word[page_size:1] to a logic zero (default).
  true; sets the Acknowledge bit in the transmitted tx_link_code_word[page_size:1] to a logic one.

transmit_disable
: Controls the transmission of tx_link_code_word[page_size:1].

  Values: false; tx_link_code_word[page_size:1] transmission is allowed (default).
  true; tx_link_code_word[page_size:1] transmission is halted.

tx_link_code_word[page_size:1]
: A 16-bit or 48-bit array that contains the data bits to be transmitted in an FLP Burst. This array may be loaded from mr_adv_ability or mr_np_tx.
  For each element within the array:

  Values: Zero; data bit is logical zero.
  One; data bit is logical one.

28.3.2 State diagram timers

All timers operate in the manner described in 14.2.3.2.

autoneg_wait_timer
: Timer for the amount of time to wait before evaluating the number of link integrity test functions with link_status=READY asserted. The autoneg_wait_timer shall expire 500 ms to 1000 ms from the assertion of link_status=READY from the 100BASE-TX PMA, 100BASE-T4 PMA, or the NLP Receive State diagram.

break_link_timer
: Timer for the amount of time to wait in order to assure that the Link Partner enters a Link Fail state. The timer shall expire 1200 ms to1500 ms after being started.

data_detect_max_timer
: Timer for the maximum time between a clock pulse and the next link pulse. This timer is used in conjunction with the data_detect_min_timer to detect whether the data bit between two clock pulses is a logic zero or a logic one. The data_detect_max_timer shall expire 78 µs to 100 µs from the last clock pulse.

data_detect_min_timer
: Timer for the minimum time between a clock pulse and the next link pulse. This timer is used in conjunction with the data_detect_max_timer to detect whether the data bit between two clock pulses is a logic zero or a logic one. The data_detect_min_timer shall expire 15 µs to 47 µs from the last clock pulse.

flp_test_max_timer
: Timer for the maximum time between two link pulses within an FLP Burst. This timer is used in conjunction with the flp_test_min_timer to detect whether the Link Partner is transmitting FLP

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Bursts. The flp_test_max_timer shall expire 165 µs to 185 µs from the last link pulse.

flp_test_min_timer
: Timer for the minimum time between two link pulses within an FLP Burst. This timer is used in conjunction with the flp_test_max_timer to detect whether the Link Partner is transmitting FLP Bursts. The flp_test_min_timer shall expire 5 µs to 25 µs from the last link pulse.

interval_timer
: Timer for the separation of a transmitted clock pulse from a data bit. The interval_timer shall expire 55.5 µs to 69.5 µs from each clock pulse and data bit.

link_fail_inhibit_timer
: Timer for qualifying a link_status=FAIL indication or a link_status=READY indication when a specific technology link is first being established. A link will only be considered "failed" if the link_fail_inhibit_timer has expired and the link has still not gone into the link_status=OK state. The link_fail_inhibit_timer shall expire 750 ms to 1000 ms after entering the FLP LINK GOOD CHECK state for devices operating at 10/100/1000 Mb/s. The link_fail_inhibit_timer shall expire 2000 ms to 2250 ms after entering the FLP LINK GOOD CHECK state for devices operating at 10 Gb/s.

  NOTE—The link_fail_inhibit_timer expiration value must be greater than the time required for the Link Partner to complete Auto-Negotiation after the Local Device has completed Auto-Negotiation plus the time required for the specific technology to enter the link_status=OK state. The maximum time difference between a Local Device and its Link Partner completing Auto-Negotiation is

  (Maximum FLP Burst to FLP Burst separation) × (Maximum number of FLP Bursts needed to complete acknowledgment) = (24 ms) × (8 bursts) = 192 ms.

  For example, 100BASE-T4 requires approximately 460 ms to enter link_status=OK for a total minimum link_fail_inhibit_timer time of 652 ms. The lower bound for the link_fail_inhibit_timer was chosen to provide adequate margin for the current technologies and any future PMAs.

nlp_test_max_timer
: Timer for the maximum time that no FLP Burst may be seen before forcing the receive state diagram to the IDLE state. The nlp_test_max_timer shall expire 50 ms to 150 ms after being started or restarted.

nlp_test_min_timer
: Timer for the minimum time between two consecutive FLP Bursts. The nlp_test_min_timer shall expire 5 ms to 7 ms after being started or restarted for devices that do not support Extended Next Pages, and shall expire 6.75 ms to 7.25 ms after being started or restarted for devices that do support Extended Next Pages.

transmit_link_burst_timer
: Timer for the separation of a transmitted FLP Burst from the next FLP Burst. The transmit_link_burst_timer shall expire 5.7 ms to 22.3 ms after the last transmitted link pulse in an FLP Burst when Extended Next Pages are not supported. When Extended Next Pages are supported, the timer shall expire 5.7 ms to 6.8 ms after the last transmitted link pulse when transmitting 16-bit pages, and shall expire 1.3 ms to 3.1 ms after the last transmitted pulse when transmitting 48-bit pages.

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Table 28–9—Timer min./max. value summary

Parameter	Min.	Typ.	Max.	Units
autoneg_wait_timer	500		1000	ms
break_link_timer	1200		1500	ms
data_detect_min_timer	15		47	µs
data_detect_max_timer	78		100	µs
flp_test_min_timer	5		25	µs
flp_test_max_timer	165		185	µs
interval_timer	55.5	62.5	69.5	µs
link_fail_inhibit_timer (10/100/1000 Mb/s devices)	750		1000	ms
link_fail_inhibit_timer (10 Gb/s devices)	2000		2250	ms
nlp_test_max_timer	50		150	ms
nlp_test_min_timer (no support of Extended Next Pages)	5		7	ms
nlp_test_min_timer (support of Extended Next Pages)	6.75		7.25	ms
transmit_link_burst_timer (no support of Extended Next Pages)	5.7	14	22.3	ms
transmit_link_burst_timer (support of Extended Next Pages when page_size is 16)	5.7	6.25	6.8	ms
transmit_link_burst_timer (support of Extended Next Pages when page_size is 48)	1.3	2.25	3.2	ms

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28.3.3 State diagram counters

flp_cnt

A counter that may take on integer values from 0 to 17. This counter is used to keep a count of the number of FLPs detected to enable the determination of whether the Link Partner supports Auto-Negotiation.

Values: not_done; 0 to 5 inclusive.
done; 6 to 17 inclusive.
init; counter is reset to zero.

remaining_ack_cnt

A counter that may take on integer values from 0 to 8. The number of additional link codewords with the Acknowledge Bit set to logic one to be sent to ensure that the Link Partner receives the acknowledgment.

Values: not_done; positive integers between 0 and 5 inclusive.
done; positive integers 6 to 8 inclusive (default).
init; counter is reset to zero.

rx_bit_cnt

A counter that may take on integer values from 0 to (page_size+1). This counter is used to keep a count of data bits received from an FLP Burst and to ensure that when erroneous extra pulses are received, the first page_size bits are kept while the rest are ignored. When this variable reaches page_size or (page_size+1), enough data bits have been received. This counter does not increment beyond (page_size+1) and does not return to 0 until it is reinitialized.

Values: not_done; 1 to (page_size–1) inclusive.
done; page_size or (page_size+1).
init; counter is reset to zero.
rx_bit_cnt_check; 10 to 17 inclusive.

tx_bit_cnt

A counter that may take on integer values from 1 to (page_size+1). This counter is used to keep a count of data bits sent within an FLP Burst. When this variable reaches (page_size+1), all data bits have been sent.

Values: not_done; 1 to page_size inclusive.
done; (page_size+1).
init; counter is initialized to 1.

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28.3.4 State diagrams

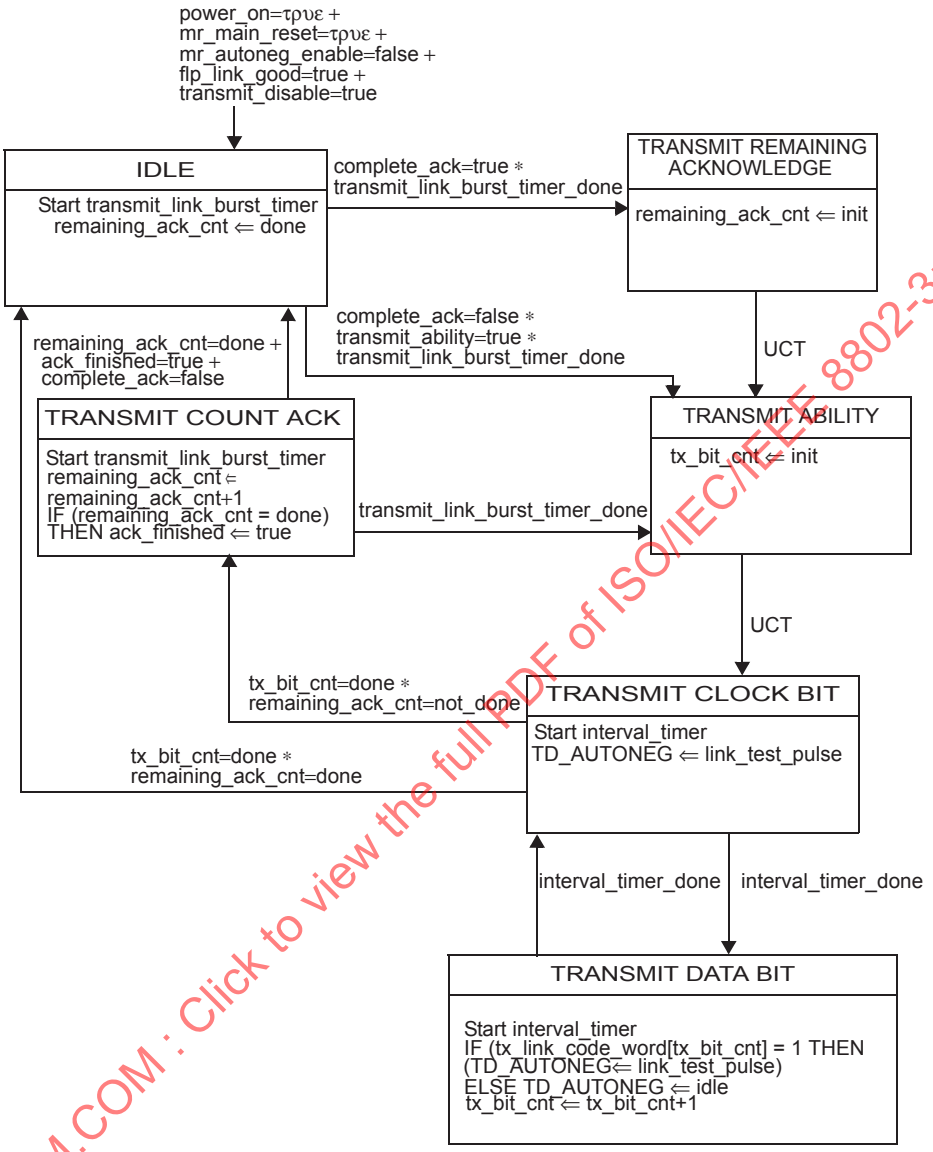

Figure 28–16—Transmit state diagram

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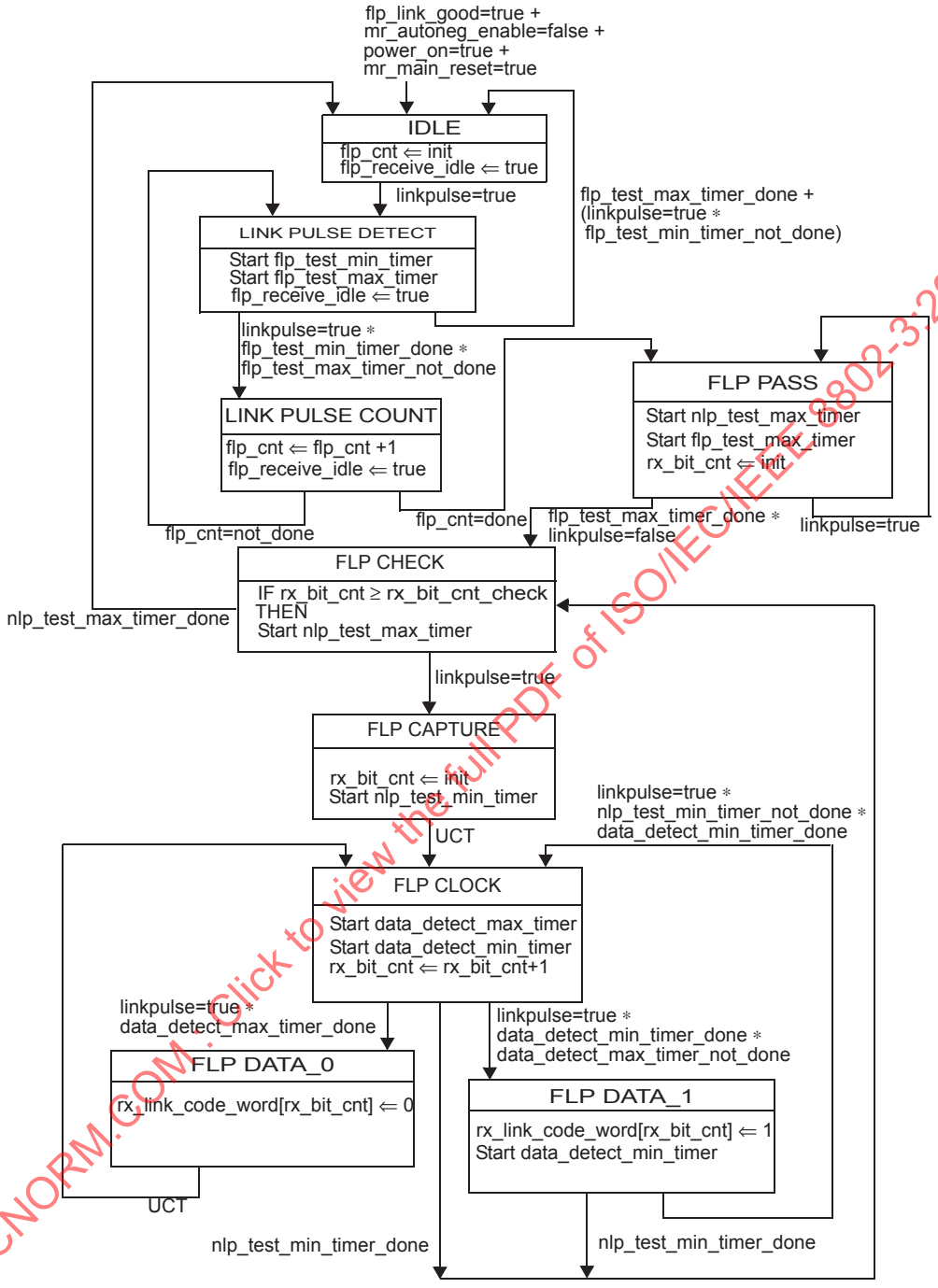

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Figure 28–17—Receive state diagram

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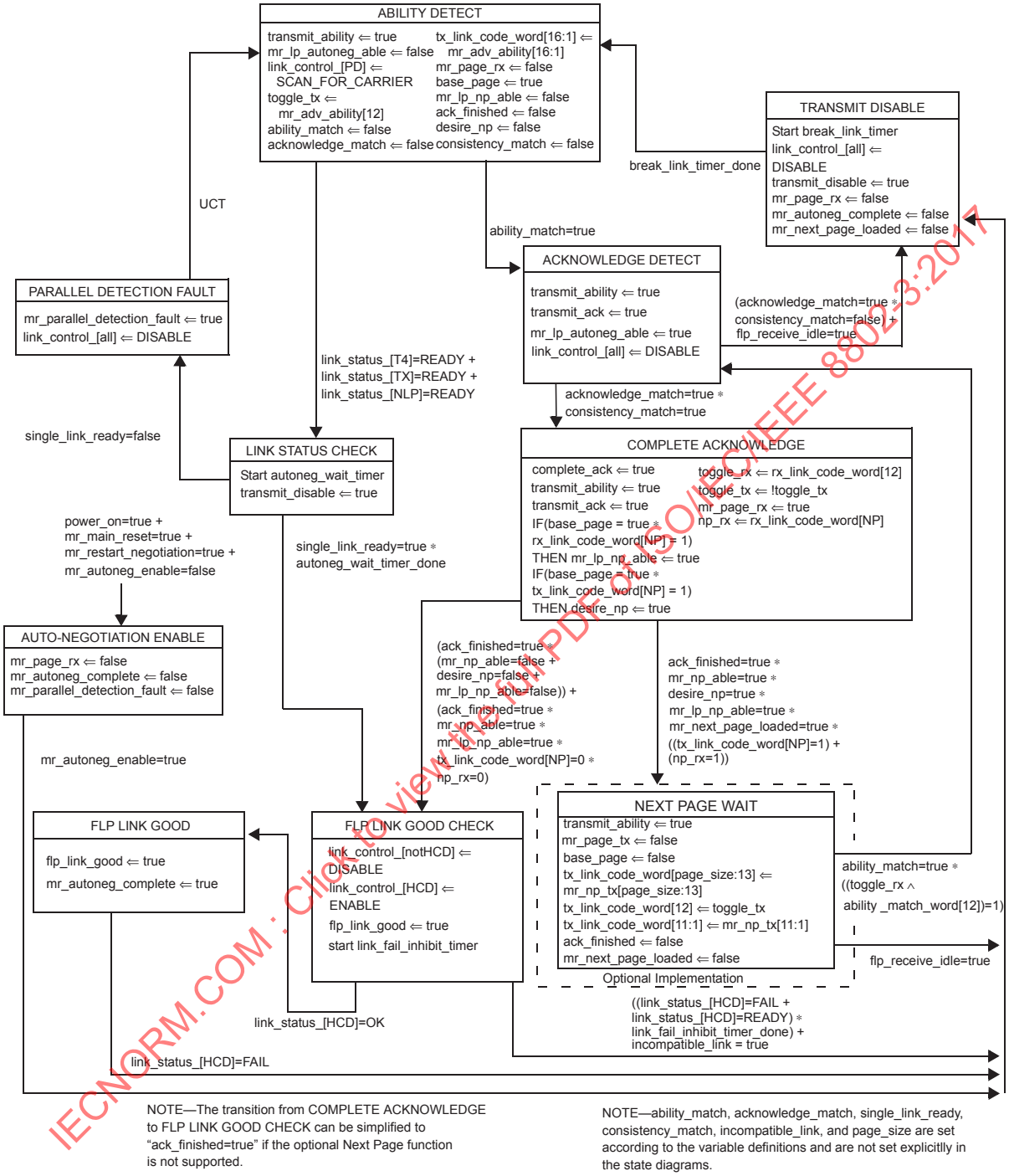

NOTE—The transition from COMPLETE ACKNOWLEDGE to FLP LINK GOOD CHECK can be simplified to "ack_finished=true" if the optional Next Page function is not supported.

NOTE—ability_match, acknowledge_match, single_link_ready, consistency_match, incompatible_link, and page_size are set according to the variable definitions and are not set explicitly in the state diagrams.

Figure 28–18—Arbitration state diagram

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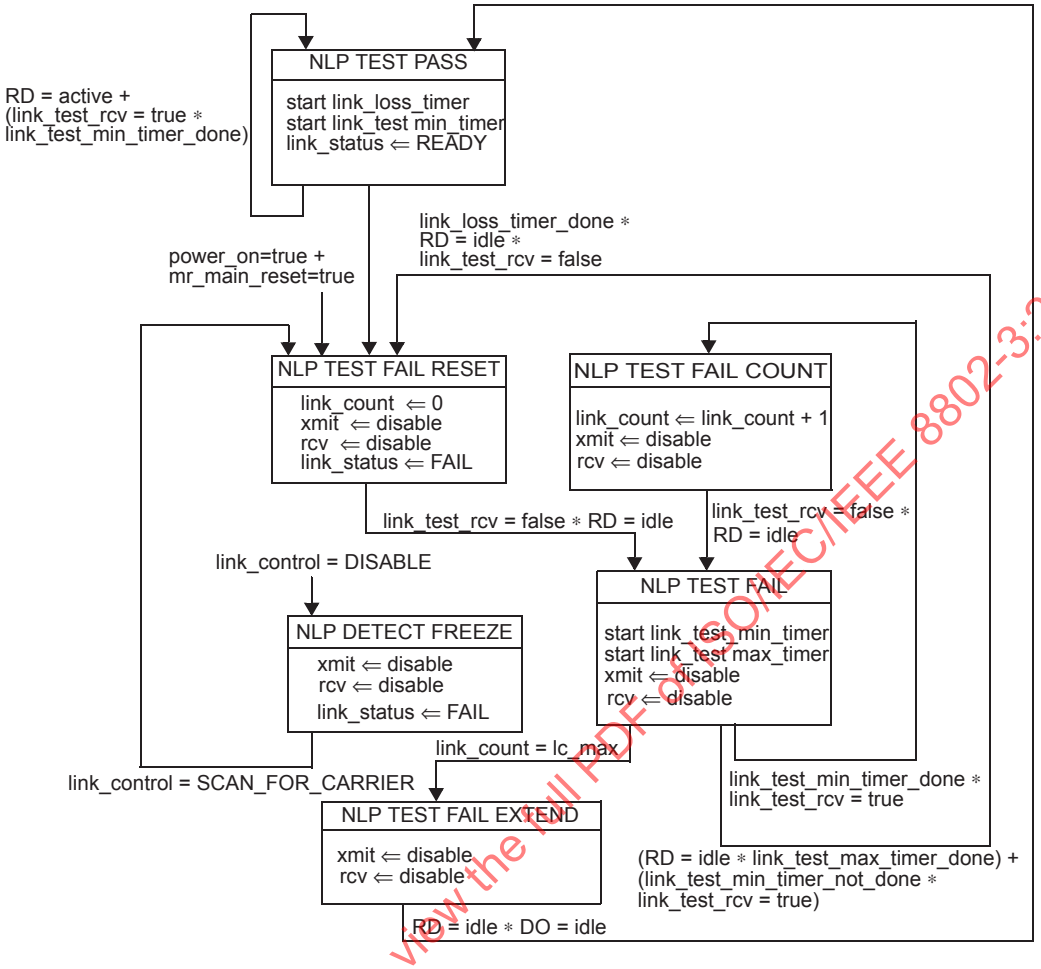

NOTE—The variables link_control and link_status are viewed as dedicated signals by the NLP Receive Link integrity Test state diagram, but are viewed as link_control_[NLP] and link_status_[NLP] by the Auto-Negotiation Arbitration state diagram, Figure 28–18.

Figure 28–19—NLP Receive Link Integrity Test state diagram

28.4 Electrical specifications

The electrical characteristics of pulses within FLP Bursts shall be identical to the characteristics of NLPs and shall meet the requirements of Figure 14–13.

It is the responsibility of the technology-specific Transmit and Receive functions to interface to the MDI correctly.

NOTE—The requirements relative to the interface to the MDI are specified via the Transmit Switch and Receive Switch functions.

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28.5 Protocol implementation conformance statement (PICS) proforma for Clause 28, Physical Layer link signaling for Auto-Negotiation on twisted pair[11]

28.5.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 28, Physical Layer link signaling for Auto-Negotiation on twisted pair, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

28.5.2 Identification

28.5.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

28.5.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 28, Physical Layer link signaling for 10 Mb/s, 100 Mb/s, and 1000 Mb/s Auto-Negotiation on twisted pair
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	No [ ] Yes [ ]

Date of Statement	

[11] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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28.5.3 Major capabilities/options

Item	Feature	Subclause	Status	Support	Value/Comment
10BT	Implementation supports a 10BASE-T data service	28.1.2	O		N/A
*NP	Implementation supports Next Page function	28.1.2	O		N/A
*MII	Implementation supports the MII Management Interface	28.1.2	O/1		N/A
MGMT	Implementation supports a non-MII Management Interface	28.1.2	O/1		N/A
*NOM	Implementation does not support management	28.1.2	O/1		N/A
*RF	Implementation supports Remote Fault Sensing	28.2.3.5	O		N/A
*NPSL	Link Partner Next Page Storage Location bit	28.2.4.1.5	O		N/A
*ENP	Implementation supports Extended Next Pages	28.2.3.4.2	O		N/A
*OPT	Implementation supports optimized FLP burst to FLP burst timing	28.2.1.1.2	ENP:M !ENP:O		N/A
*10G	Implementation supports a 10GBASE-T PHY	55	O		N/A

28.5.4 PICS proforma tables for Physical Layer link signaling for Auto-Negotiation on twisted pair

28.5.4.1 Scope

Item	Feature	Subclause	Status	Support	Value/Comment
SC1	MII Management Interface control and status registers	28.1.3	MII:M		Implemented in accordance with the definitions in Clause 22 and 28.2.4
SC2	CSMA/CD compatible devices using an eight-pin modular connector and using a signaling method to automatically configure the preferred mode of operation	28.1.4	M		Auto-Negotiation function implemented in compliance with Clause 28
SC3	Device uses 10BASE-T compatible link signaling to advertise non-CSMA/CD abilities	28.1.4	M		Auto-Negotiation function implemented in compliance with Clause 28
SC4	Future CSMA/CD implementations that use an eight-pin modular connector	28.1.4	M		Interoperable with devices compliant with Clause 28

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28.5.4.2 Auto-Negotiation functions

Item	Feature	Subclause	Status	Support	Value/Comment
AN1	Transmit	28.2	M		Complies with Figure 28–16
AN2	Receive	28.2	M		Complies with Figure 28–17
AN3	Arbitration	28.2	M		Complies with Figure 28–18
AN4	NLP Receive Link Integrity Test	28.2	10BT:M		Complies with Figure 28–19
AN5	Technology-Dependent Interface	28.2	M		Complies with 28.2.6
AN6	Technology-dependent link integrity test	28.2	M		Implemented and interfaced to for those technologies supported by device
AN7	Management	28.2	O		MII based or alternate management

28.5.4.3 Transmit function requirements

Item	Feature	Subclause	Status	Support	Value/Comment
TF1	FLP Burst transmission	28.2.1.1	M		Not transmitted once Auto-Negotiation is complete and highest common denominator PMA has been enabled. Prohibited other than for link start-up
TF2	FLP Burst composition	28.2.1.1.1	M		Pulses in FLP Bursts meet the requirements of Figure 14–13
TF3	FLP Burst pulse definition	28.2.1.1.1	M		Odd-numbered pulse positions represent clock information; even-numbered pulse positions represent data information
TF4	The first pulse in an FLP Burst	28.2.1.1.2	M		Defined as a clock pulse for timing purposes
TF5	FLP Burst clock pulse spacing	28.2.1.1.2	M		Within an FLP Burst, spacing is 125 µs ± 14 µs
TF6	Logic one data bit representation	28.2.1.1.2	M		Pulse transmitted 62.5 µs ± 7 µs after the preceding clock pulse
TF7	Logic zero data bit representation	28.2.1.1.2	M		No link integrity test pulses within 111 µs of the preceding clock pulse
TF8	Consecutive FLP Bursts	28.2.1.1.2	M		The first link pulse in each FLP Burst is separated by 16 ms ± 8 ms
TF9	Consecutive FLP Bursts	28.2.1.1.2	OPT:M		The first link pulse in each FLP Burst is separated by 8.25 ms ± 0.25 ms

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28.5.4.3 Transmit function requirements *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
TF10	FLP Burst Base Page	28.2.1.2	M		Conforms to Figure 28–7
TF11	FLP Burst bit transmission order	28.2.1.2	M		Transmission is D0 first to D15 last
TF12	Selector Field values	28.2.1.2.1	M		Only defined values transmitted
TF13	Technology Ability Field values	28.2.1.2.2	M		Implementation supports a data service for each ability set in the Technology Ability Field
TF14	Remote Fault bit	28.2.1.2.4	M		Used in accordance with the Remote Fault function specifications
TF15	Acknowledge bit set, no Next Page to be sent	28.2.1.2.5	M		Set to logic one in the link codeword after the reception of at least three consecutive and consistent FLP Bursts
TF16	Acknowledge bit set, Next Page to be sent	28.2.1.2.5	NP:M		Set to logic one in the transmitted link codeword after the reception of at least three consecutive and consistent FLP Bursts and the current receive link codeword is saved
TF17	Number of link codewords sent with Acknowledge bit set	28.2.1.2.5	M		6 to 8 inclusive after COMPLETE ACKNOWLEDGE state entered
TF18	Device does not implement optional Next Page ability	28.2.1.2.6	M		NP=0 in base link codeword
TF19	Device implements optional Next Page ability and wishes to engage in Next Page exchange	28.2.1.2.6	NP:M		NP=1 in base link codeword
TF20	Transmit Switch function on completion of Auto-Negotiation	28.2.1.3	M		Enables the transmit path from a single technology-dependent PMA to the MDI once the highest common denominator has been selected
TF21	Transmit Switch function during Auto-Negotiation	28.2.1.3	M		Connects FLP Burst generator governed by Figure 28–16 to the MDI
TF22	Signals presented at MDI after connection through Transmit Switch from PMA	28.2.1.3	M		Conform to appropriate PHY specifications

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28.5.4.4 Receive function requirements

Item	Feature	Subclause	Status	Support	Value/Comment
RF1	Timer expiration	28.2.2.1	M		Timer definition in 28.3.2, values shown in Table 28–9
RF2	Identification of Link Partner as Auto-Negotiation able	28.2.2.1	M		Reception of 6 to 17 (inclusive) consecutive link pulses separated by at least flp_test_min_timer time but less than flp_test_max_timer time
RF3	First FLP Burst identifying Link Partner as Auto-Negotiation able	28.2.2.1	M		Data recovered is discarded if FLP Burst is incomplete
RF4	First link pulse in an FLP Burst	28.2.2.1	M		Interpreted as a clock link pulse
RF5	Restart of the data_detect_min_timer and data_detect_max_timer	28.2.2.1	M		Detection of a clock link pulse (Figure 28–9)
RF6	Reception of logic one	28.2.2.1	M		Link pulse received between greater than data_detect_min_timer time and less than data_detect_max_timer time after a clock pulse (Figure 28–9)
RF7	Reception of logic zero	28.2.2.1	M		Link pulse received after greater than data_detect_max_timer time after clock pulse, is treated as clock pulse (Figure 28–9)
RF8	FLP Bursts separation	28.2.2.1	M		Conforms to the nlp_test_min_timer and nlp_test_max_timer timing (Figure 28–10)
RF9	Receive Switch function on completion of Auto-Negotiation	28.2.2.3	M		Enables the receive path from the MDI to a single technology-dependent PMA once the highest common denominator has been selected
RF10	Receive Switch function during Auto-Negotiation	28.2.2.3	M		Connects the MDI to the FLP and NLP receivers governed by Figures 28–17 and 28–19, and to the 100BASE-TX and 100BASE-T4 receivers if present
RF11	Signals presented to PMA after connection through Receive Switch from MDI	28.2.2.3	M		Conform to appropriate PHY specifications
RF12	Generation of ability_match, acknowledge_match, and consistency_match	28.2.2.4	M		Responsibility of Receive function in accordance with 28.3.1

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28.5.4.5 Arbitration functions

Item	Feature	Subclause	Status	Support	Value/Comment
AF1	MDI receive connection during Auto-Negotiation, prior to FLP detection	28.2.3.1	M		Connected to the NLP Receive Link Integrity Test state diagram, and the link integrity test functions of 100BASE-TX and/or 100BASE-T4. Not connected to the 10BASE-T or any other PMA
AF2	Parallel detection operational mode selection	28.2.3.1	M		Set link_control=ENABLE for the single PMA indicating link_status=READY when the autoneg_wait_timer expires
AF3	Parallel detection PMA control	28.2.3.1	M		Set link_control=DISABLE to all PMAs except the selected operational PMA and indicate Auto-Negotiation has completed
AF4	Parallel detection setting of Link Partner ability register	28.2.3.1	M		On transition to the FLP LINK GOOD CHECK state from the LINK STATUS CHECK state the Parallel Detection function shall set the bit in the Link Partner ability register (Register 5) corresponding to the technology detected by the Parallel Detection function
AF5	Response to renegotiation request	28.2.3.2	M		Disable all technology-dependent link integrity test functions and halt transmit activity until break_link_timer expires
AF6	Auto-Negotiation resumption	28.2.3.2	M		Issue FLP Bursts with Base Page valid in tx_link_code_word[16:1] after break_link_timer expires
AF7	Priority resolution	28.2.3.3	M		Single PMA connected to MDI is enabled corresponding to Technology Ability Field bit common to both Local/Link Partner Device and that has highest priority as defined by Annex 28B
AF8	Effect of receipt of reserved Technology Ability Field bit on priority resolution	28.2.3.3	M		Local Device ignores during priority resolution
AF9	Effect of parallel detection on priority resolution	28.2.3.3	M		Local Device considers technology identified by parallel detection as HCD
AF10	Values for HCD and link_status_[HCD] in the event there is no common technology	28.2.3.3	M		HCD=NULL link_status_[HCD]=FAIL

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28.5.4.5 Arbitration functions *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
AF11	Message Page to Unformatted Page relationship for non-matching Selector Fields	28.2.3.4	NP:M		Each series of Unformatted Pages is preceded by an Message Page containing a message code that defines how the following Unformatted Page(s) will be interpreted
AF12	Message Page to Unformatted Page relationship for matching Selector Fields	28.2.3.4	NP:M		Use of Message Pages is specified by the Selector Field value
AF13	Transmission of Null message codes	28.2.3.4	NP:M		Sent with NP=0 on completion of all Next Pages while Link Partner continues to transmit valid Next Page information
AF14	Reception of Null message codes	28.2.3.4	NP:M		Recognized as indicating end of Link Partner's Next Page information
AF15	Next Page encoding	28.2.3.4.1	NP:M		Comply with Figures 28–11 and 28–12 for the NP, Ack, MP, Ack2, and T bits
AF16	Message/Unformatted Code Field	28.2.3.4.1	NP:M		D10-D0 encoded as Message Code Field if MP=1 or Unformatted Code Field if MP=0
AF17	NP bit encoding	28.2.3.4.3	NP:M		Logic 0=last page, logic 1=additional Next Page(s) follow
AF18	Message Page bit encoding	28.2.3.4.5	NP:M		Logic 0=Unformatted Page, logic 1=Message Page
AF19	Ack2 bit encoding	28.2.3.4.6	NP:M		Logic 0=cannot comply with message; logic 1= will comply with message
AF20	Toggle	28.2.3.4.7	NP:M		Takes the opposite value of the Toggle bit in the previously exchanged link codeword
AF21	Toggle encoding	28.2.3.4.7	NP:M		Logic zero = previous value of the transmitted link codeword equalled logic one Logic one = previous value of the transmitted link codeword equalled logic zero
AF22	Message Page encoding	28.2.3.4.8	NP:M		If MP=1, link codeword interpreted as Message Page
AF23	Message Code Field	28.2.3.4.9	NP:M		Combinations not shown in Annex 28C are reserved and may not be transmitted
AF24	Unformatted Page encoding	28.2.3.4.10	NP:M		If MP=0, link codeword interpreted as Unformatted Page

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28.5.4.5 Arbitration functions *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
AF25	Minimum Next Page exchange	28.2.3.4.13	NP:M		If both devices indicate Next Page able, both send a minimum of one Next Page
AF26	Multiple Next Page exchange	28.2.3.4.13	NP:M		If both devices indicate Next Page able, exchange continues until neither Local/Remote Device has additional information; device sends Next Page with Null message code if it has no information to transmit
AF27	Unformatted Page ordering	28.2.3.4.13	NP:M		Unformatted Pages immediately follow the referencing message code in the order specified by the message code
AF28	Next Page Transmit register	28.2.3.4.14	NP:M		Defined in 28.2.4.1.6
AF29	Next Page receive data	28.2.3.4.14	NP:O		May be stored in Auto-Negotiation Link Partner ability register
AF30	Remote Fault sensing	28.2.3.5	RF:M		Optional
AF31	Transmission of RF bit by Local Device	28.2.3.5	M		If Local Device has no method to set RF bit, it must transmit RF bit with value of RF bit in Auto-Negotiation advertisement register (4.13)
AF32	RF bit reset	28.2.3.5	M		Once set, the RF bit remains set until successful renegotiation with the base link codeword
AF33	Receipt of Remote Fault indication in base link codeword	28.2.3.5	MII:M		Device sets the Remote Fault bit in the MII status register (1.4) to logic one if MII is present
AF34	Extended Next Page exchange	28.2.3.4	ENP:M		If both device and link partner are ENP able, any NP exchange uses Extended Next Pages

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28.5.4.6 Management function requirements

Item	Feature	Subclause	Status	Support	Value/Comment
MF1	Mandatory MII registers for Auto-Negotiation	28.2.4.1	MII:M		Registers 0, 1, 4, 5, 6
MF2	Optional MII register for Auto-Negotiation	28.2.4.1	MII* NP:M		Register 7
MF3	Auto-Negotiation enable	28.2.4.1.1	MII:M		Set control register Auto-Negotiation Enable bit (0.12)
MF4	Manual Speed/Duplex settings	28.2.4.1.1	MII:M		When bit 0.12 set, control register Speed Detection (0.13) and Duplex Mode (0.8) are ignored, and the Auto-Negotiation function determines link configuration
MF5	Control register (Register 0) Restart Auto-Negotiation (0.9) default	28.2.4.1.1	MII:M		PHY returns value of one in 0.9 until Auto-Negotiation has been initiated
MF6	Control register (Register 0) Restart Auto-Negotiation (0.9) set	28.2.4.1.1	MII:M		When 0.9 set, Auto-Negotiation will (re)initiate. On completion, 0.9 will be reset by the PHY device. Writing a zero to 0.9 at any time has no effect
MF7	Control register (Register 0) Restart Auto-Negotiation (0.9) reset	28.2.4.1.1	MII:M		0.9 is self-clearing; writing a zero to 0.9 at any time has no effect
MF8	Status register (Register 1) Auto-Negotiation Complete (1.5) reset	28.2.4.1.2	MII:M		If bit 0.12 reset, or a PHY lacks the ability to perform Auto-Negotiation, (1.5) is reset
MF9	Status register (Register 1) Remote Fault (1.4)	28.2.4.1.2	MII:M		Set by the PHY and remains set until either the status register is read or the PHY is reset
MF10	Advertisement register power on default	28.2.4.1.3	MII:M		Selector field as defined in Annex 28A; Ack=0; Technology Ability Field based on MII status register (1.15:11) or logical equivalent
MF11	Link partner ability register read/write	28.2.4.1.4	MII:M		Read only; write has no effect
MF12	Link partner ability register bit definitions	28.2.4.1.4	MII:M		Direct representation of the received link codeword (Figure 28–7)
MF13	Status register (Register 1) Auto-Negotiation Complete (1.5) set	28.2.4.1.4	MII:M		Set to logic one upon successful completion of Auto-Negotiation
MF14	Auto-Negotiation expansion register (Register 6)	28.2.4.1.5	MII:M		Read only; write has no effect

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28.5.4.6 Management function requirements *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
MF15	Link Partner Auto-Negotiation Able bit (6.0)	28.2.4.1.5	MII:M		Set to indicate that the Link Partner is able to participate in the Auto-Negotiation function
MF16	Page Received bit (6.1) set	28.2.4.1.5	MII:M		Set to indicate that a new link codeword has been received and stored in the Auto-Negotiation Link Partner ability register
MF17	Page Received bit (6.1) reset	28.2.4.1.5	MII:M		Reset on a read of the Auto-Negotiation expansion register (Register 6)
MF18	The Next Page Able bit (6.2) set	28.2.4.1.5	NP* MII:M		Set to indicate that the Local Device supports the Next Page function
MF19	The Link Partner Next Page Able bit (6.3) set	28.2.4.1.5	MII:M		Set to indicate that the Link Partner supports the Next Page function
MF20	Parallel Detection Fault bit (6.4) set	28.2.4.1.5	MII:M		Set to indicate that zero or more than one of the NLP Receive Link Integrity Test function, 100BASE-TX, or 100BASE-T4 PMAs have indicated link_status=READY when the autoneg_wait_timer expires
MF21	Parallel Detection Fault bit (6.4) reset	28.2.4.1.5	MII:M		Reset on a read of the Auto-Negotiation expansion register (Register 6)
MF22	Link Partner Next Page Storage Location bit	28.2.4.1.5	NPSL * MII:M		Indicates location of Link Partner Next Page
MF23	Receive Next Page Location Able bit	28.2.4.1.5	MII:M		Indicates if Link Partner Next Page Storage Location bit is supported.
MF24	Next Page Transmit register default	28.2.4.1.6	NP* MII:M		On power-up, contains value of 2001 H
MF25	Write to Next Page Transmit register	28.2.4.1.6	NP* MII:M		mr_next_page_loaded set to true
MF26	Absence of management function	28.2.5	NOM:M		Advertised abilities provided through a logical equivalent of mr_adv_ability[16:1]
MF27	Next Page support in absence of MII management	28.2.5	NOM:M		Device must provide logical equivalent of mr_np_able, mr_lp_np_able, or mr_next_page_loaded variables in order to set NP bit in transmitted link codeword

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28.5.4.7 Technology-dependent interface

Item	Feature	Subclause	Status	Support	Value/Comment
TD1	PMA_LINK.indication (link_status) values	28.2.6.1.1	M		link_status set to READY, OK or FAIL
TD2	PMA_LINK.indication (link_status) generation	28.2.6.1.2	M		Technology-dependent PMA and NLP Receive Link Integrity Test state diagram (Figure 28–19) responsibility
TD3	PMA_LINK.indication (link_status), effect of receipt	28.2.6.1.3	M		Governed by the state diagram of Figure 28–18
TD4	PMA_LINK.request (link_control) values	28.2.6.1.3	M		link_control set to SCAN_FOR_CARRIER, DISABLE, or ENABLE
TD5	Effect of link_control=SCAN_FOR_CARRIER	28.2.6.2.1	M		PMA to search for carrier and report link_status=READY when carrier is received, but no other actions are enabled
TD6	Effect of link_control=DISABLE	28.2.6.2.1	M		Disables PMA processing
TD7	Effect of link_control=ENABLE	28.2.6.2.1	M		Control passed to a single PMA for normal processing functions
TD8	PMA_LINK.request(link_control) generation	28.2.6.2.2	M		Auto-Negotiation function responsibility in accordance with Figures 28–17 and 28–18
TD9	PMA_LINK.request(link_control) default upon power-on, reset, or release from power-down	28.2.6.2.2	M		link_control = DISABLE state to all technology-dependent PMAs
TD10	PMA_LINK.request(link_control) effect of receipt	28.2.6.2.3	M		Governed by Figure 28–19 and the receiving technology-dependent link integrity test function
TD11	The linkpulse parameter shall	28.2.6.3.1	M		TRUE or FALSE.
TD12	The linkpulse=FALSE shall be used	28.2.6.3.1	M		By the Auto-Negotiation function to indicate that the Receive State Diagram has performed a state transition
TD13	The linkpulse=TRUE shall be used	28.2.6.3.1	M		By the Auto-Negotiation function to indicate that a valid Link Pulse has been received

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28.5.4.7 Technology-dependent interface *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
TD14	The Auto-Negotiation function shall generate linkpulse	28.2.6.3.2	M		To indicate to the PHY how to respond, in accordance with the state diagram of Figure 28–17.
TD15	Upon power-on or reset, if Auto-Negotiation is enabled (mr_autoneg_enable=true) the PMA_LINKPULSE.request(FALSE) message shall be	28.2.6.3.2	M		Issued to all technology-dependent PMAs.
TD16	The effect of the receipt of linkpulse shall be governed	28.2.6.3.3	M		By the receiving technology-dependent PMA function, based on the intent specified in the primitive semantics.

28.5.4.8 State diagrams

Item	Feature	Subclause	Status	Support	Value/Comment
SD1	Adherence to state diagrams	28.3	M		Implement all features of Figures 28–16 to 28–19. Identified options to Figures 28–16 to 28–19 are permitted
SD2	Ambiguous requirements	28.3	M		State diagrams take precedence in defining functional operation
SD3	autoneg_wait_timer	28.3.2	M		Expires 500 ms to 1000 ms after being started
SD4	break_link_timer	28.3.2	M		Expires 1200 ms to 1500 ms after being started
SD5	data_detect_min_timer	28.3.2	M		Expires 15 µs to 47 µs from the last clock pulse
SD6	data_detect_max_timer	28.3.2	M		Expire 78 µs to 100 µs from the last clock pulse
SD7	flp_test_max_timer	28.3.2	M		Expires 165 µs to 185 µs from the last link pulse
SD8	flp_test_min_timer	28.3.2	M		Expires 5 µs to 25 µs from the last link pulse
SD9	interval_timer	28.3.2	M		Expires 55.5 µs to 69.5 µs from each clock pulse and data bit
SD10	link_fail_inhibit_timer (10/100/1000 Mb/s)	28.3.2	!10G:M		Expires 750 ms to 1000 ms after entering the FLP LINK GOOD CHECK state
SD11	link_fail_inhibit_timer (10 Gb/s)	28.3.2	10G:M		Expires 2000 ms to 2250 ms after entering the FLP LINK GOOD CHECK state upon successful master/slave resolution

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28.5.4.8 State diagrams *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
SD12	nlp_test_max_timer	28.3.2	M		Expires 50 ms to 150 ms after being started if not restarted
SD13	nlp_test_min_timer	28.3.2	!ENP:M		Expires 5 ms to 7 ms after being started if not restarted
SD14	nlp_test_min_timer (with Extended Next Page)	28.3.2	ENP:M		Expires 6.75 ms to 7.25 ms after being started if not restarted
SD15	transmit_link_burst_timer (with no optimized timing)	28.3.1	!OPT:M		Expires 5.7 ms to 22.3 ms after the last transmitted link pulse in an FLP Burst
SD16	transmit_link_burst_timer (with optimized timing and 16-bit pages)	28.3.1	OPT:M		Expires 5.7 ms to 6.8 ms after the last transmitted link pulse in an FLP Burst
SD17	transmit_link_burst_timer (with optimized timing and 48-bit pages)	28.3.1	OPT:M		Expires 1.3 ms to 3.2 ms after the last transmitted link pulse in an FLP Burst containing Extended Next Pages

28.5.4.9 Electrical characteristics

Item	Feature	Subclause	Status	Support	Value/Comment
EC1	Pulses within FLP Bursts	28.4	M		Identical to the characteristics of NLPs and meet the requirements of Figure 14–13

28.5.4.10 Auto-Negotiation annexes

Item	Feature	Annex	Status	Support	Value/Comment
AA1	Selector field: S[4:0] values in the link codeword	Annex 28A	M		Identifies base message type as defined by Table 28A–1
AA2	Selector field reserved combinations	Annex 28A	M		Transmission not permitted
AA3	Relative priorities of the technologies supported by the IEEE 802.3 Selector Field value	28B.3	M		Defined in Annex 28B.3
AA4	Relative order of the technologies supported by IEEE 802.3 Selector Field	28B.3	M		Remain unchanged
AA5	Addition of new technology	28B.3	M		Inserted into its appropriate place in the priority resolution hierarchy, shifting technologies of lesser priority lower in priority

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28.5.4.10 Auto-Negotiation annexes *(continued)*

Item	Feature	Annex	Status	Support	Value/Comment
AA6	Addition of vendor-specific technology	28B.3	M		Priority of IEEE 802.3 standard topologies maintained, vendor-specific technologies to be inserted into an appropriate location
AA7	Message Code Field	Annex 28C	NP:M		Defines how following Unformatted Pages (if applicable) are interpreted
AA8	Order of Unformatted Code Fields within extended Pages	Annex 28C	NP:M		Pages to be in order specified by message code
AA9	Message Code Field reserved combinations	Annex 28C	NP:M		Transmission not permitted
AA10	Auto-Negotiation reserved code 1	28C.1	NP:M		Transmission of M10 to M0 equals 0, not permitted
AA11	Null message code	28C.2	NP:M		Transmitted during Next Page exchange when the Local Device has no information to transmit and Link Partner has additional pages to transmit
AA12	Remote Fault Identifier message code	28C.5	NP:M		Followed by single Unformatted Page to identify fault type with types defined in 28C.5
AA13	Organizationally Unique Identifier message code	28C.6	NP:M		Followed by 4 Unformatted Pages. First Unformatted Page contains most significant 11 bits of OUI or CID (bits 23:13) with MSB in U10; Second Unformatted Page contains next most significant 11 bits of OUI or CID (bits 12:2), with MSB in U10; Third Unformatted Page contains the least significant 2 bits of OUI or CID (bits 1:0) with MSB in U10, bits U8:0 contains user-defined code specific to OUI or CID; Fourth Unformatted Page contains user-defined code specific to OUI or CID

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28.5.4.10 Auto-Negotiation annexes *(continued)*

Item	Feature	Annex	Status	Support	Value/Comment
AA14	PHY Identifier message code	28C.7	NP:M		Followed by 4 Unformatted Pages. First Unformatted Page contains most significant 11 bits of PHY ID (2.15:5) with MSB in U10; Second Unformatted Page contains PHY ID bits 2.4:0 to 3.15:10, with MSB in U10; Third Unformatted Page contains PHY ID bits 3.9:0, with MSB in U10, and U0 contains user-defined code specific to PHY ID; Fourth Unformatted Page contains user-defined code specific to PHY ID
AA15	Auto-Negotiation reserved code 2	28C.8	NP:M		Transmission of M10 to M0 equals 1, not permitted

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28.6 Auto-Negotiation expansion

Auto-Negotiation is designed in a way that allows it to be easily expanded as new technologies are developed. When a new technology is developed, the following things must be done to allow Auto-Negotiation to support it:

a) The appropriate Selector Field value to contain the new technology must be selected and allocated.
b) A Technology bit must be allocated for the new technology within the chosen Selector Field value.
c) The new technology's relative priority within the technologies supported within a Selector Field value must be established.

Code space allocations are enumerated in Annex 28A, Annex 28B, and Annex 28C. Additions and insertions to the annexes are allowed. No changes to existing bits already defined are allowed.

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29. System considerations for multisegment 100BASE-T networks

NOTE—This clause relates to clauses that are not recommended for new installations. This clause is not recommended for new installations. Since March 2012, maintenance changes are no longer being considered for this clause.

29.1 Overview

This clause provides information on building 100BASE-T networks. The 100BASE-T technology is designed to be deployed in both homogenous 100 Mb/s networks and heterogeneous 10/100 Mb/s mixed CSMA/CD networks. Network topologies can be developed within a single 100BASE-T collision domain, but maximum flexibility is achieved by designing multiple collision domain networks that are joined by bridges and/or routers configured to provide a range of service levels to DTEs. For example, a combined 100BASE-T/10BASE-T system built with repeaters and bridges can deliver dedicated 100 Mb/s, shared 100 Mb/s, dedicated 10 Mb/s, and shared 10 Mb/s service to DTEs. The effective bandwidth of shared services is controlled by the number of DTEs that share the service.

Linking multiple 100BASE-T collision domains with bridges maximizes flexibility. Bridged topology designs can provide single bandwidth (Figure 29–1) or multiple bandwidth (Figure 29–2) services.

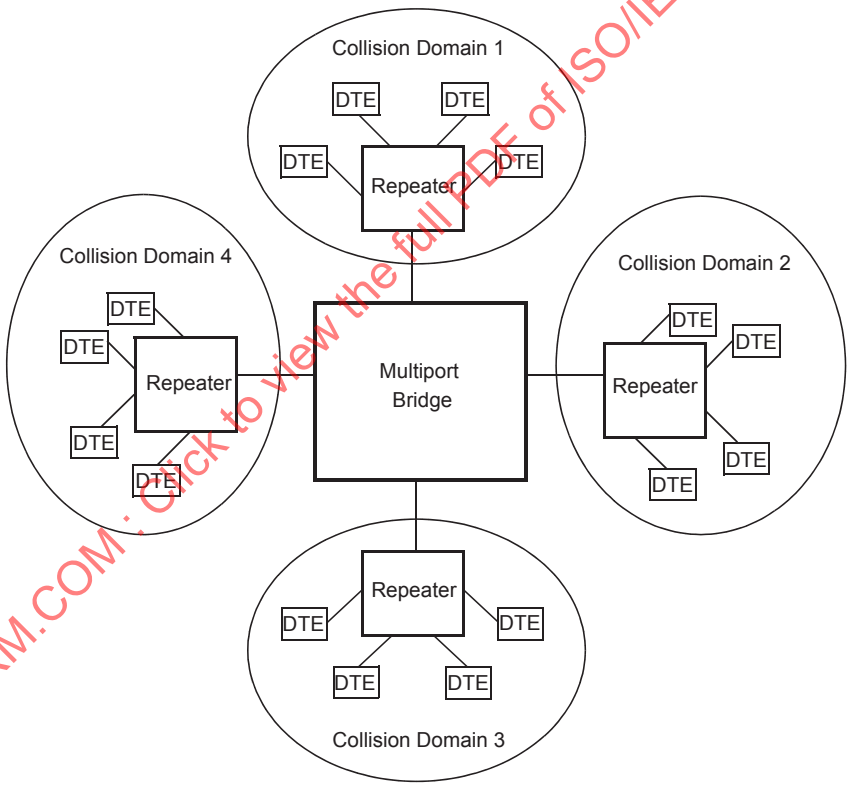

Figure 29–1—100 Mb/s multiple collision domain topology using multiport bridge

Individual collision domains can be linked by single devices (as shown in Figure 29–1 and Figure 29–2) or by multiple devices from any of several transmission systems. The design of multiple-collision-domain networks is governed by the rules defining each of the transmission systems incorporated into the design.

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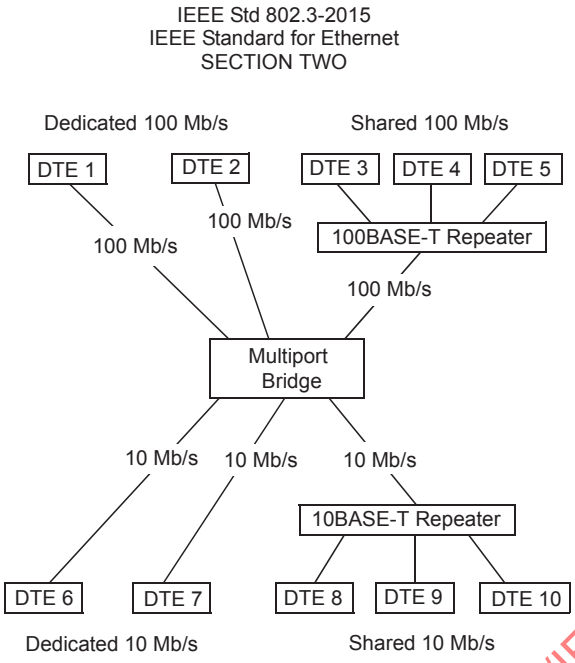

Figure 29–2—Multiple bandwidth, multiple collision domain topology using multiport bridge

The design of shared bandwidth 10 Mb/s collision domains is defined in 13.1 through 13.4; the design of shared bandwidth 100 Mb/s CSMA/CD collision domains is defined in 29.1.1 through 29.3.1.2. The design of 10BASE full duplex LANs is defined in 13.5; the design of full duplex 100BASE-X LANs is defined in 29.4.

29.1.1 Single collision domain multisegment networks

This clause provides information on building 100 Mb/s CSMA/CD multisegment networks within a single collision domain. The proper operation of a CSMA/CD network requires the physical size and number of repeaters to be limited in order to meet the round-trip propagation delay requirements of 4.2.3.2.3 and 4.4.2 and IPG requirements specified in 4.4.2.

This clause provides two network models. Transmission System Model 1 is a set of configurations that have been validated under conservative rules and have been qualified as meeting the requirements set forth above. Transmission System Model 2 is a set of calculation aids that allow those configuring a network to test a proposed configuration against a simple set of criteria that allows it to be qualified. Transmission System Model 2 validates an additional broad set of topologies that are fully functional and do not fit within the simpler, but more restrictive rules of Model 1.

The physical size of a CSMA/CD network is limited by the characteristics of individual network components. These characteristics include the following:

a) Media lengths and their associated propagation time delay
b) Delay of repeater units (start-up, steady-state, and end of event)
c) Delay of MAUs and PHYs (start-up, steady-state, and end of event)
d) Interpacket gap shrinkage due to repeater units
e) Delays within the DTE associated with the CSMA/CD access method
f) Collision detect and deassertion times associated with the MAUs and PHYs

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Table 29–1 summarizes the delays for 100BASE-T media segments. For more detailed information on the delays associated with individual 100BASE-T components, see

MII: Annex 22A
100BASE-T2:32.12
100BASE-T4:23.11
100BASE-TX:24.6
100BASE-FX: ISO/IEC 9314-3:1990
Repeater:27.3

Table 29–1—Delays for network media segments Model 1

Media type	Maximum number of PHYs per segment	Maximum segment length (m)	Maximum medium round-trip delay per segment (BT)
Balanced cable link segment 100BASE-T	2	100	114
Fiber link segment	2	412	412

29.1.2 Repeater usage

Repeaters are the means used to connect segments of a network medium together into a single collision domain. Different signaling systems (i.e., 100BASE-T2, 100BASE-T4, 100BASE-TX, 100BASE-FX) can be joined into a common collision domain using repeaters. Bridges can also be used to connect different signaling systems; however, if a bridge is so used, each system connected to the bridge will be a separate collision domain.

Two types of repeaters are defined for 100BASE-T (see Clause 27). Class I repeaters are principally used to connect unlike physical signaling systems and have internal delays such that only one Class I repeater can reside within a single collision domain when maximum cable lengths are used (see Figure 29–4). Class II repeaters typically provide ports for only one physical signaling system type (e.g., 100BASE-TX but not 100BASE-T4) and have smaller internal delays so that two such repeaters may reside within a given collision domain when maximum cable lengths are used (see Figure 29–6). Cable length can be sacrificed to add additional repeaters in a collision domain (see 29.3).

29.2 Transmission System Model 1

The following network topology constraints apply to networks using Transmission System Model 1.

a) All balanced cable (copper) segments less than or equal to 100 m each.
b) Fiber segments less than or equal to 412 m each.
c) MII cables for 100BASE-T shall not exceed 0.5 m each. When evaluating system topology, MII cable delays need not be accounted for separately. Delays attributable to the MII are incorporated into DTE and repeater component delays.

29.3 Transmission System Model 2

The physical size and number of topological elements in a 100BASE-T network is limited primarily by round-trip collision delay. A network configuration must be validated against collision delay using a net-

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work model. Since there are a limited number of topology models for any 100BASE-T collision domain, the modeling process is quite straightforward and can easily be done either manually or with a spreadsheet.

The model proposed here is derived from the one presented in 13.4. Modifications have been made to accommodate adjustments for DTE, repeater, and cable speeds.

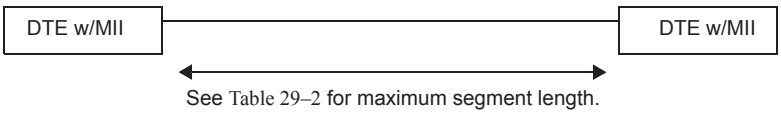

Figure 29–3—Model 1: Two DTEs, no repeater

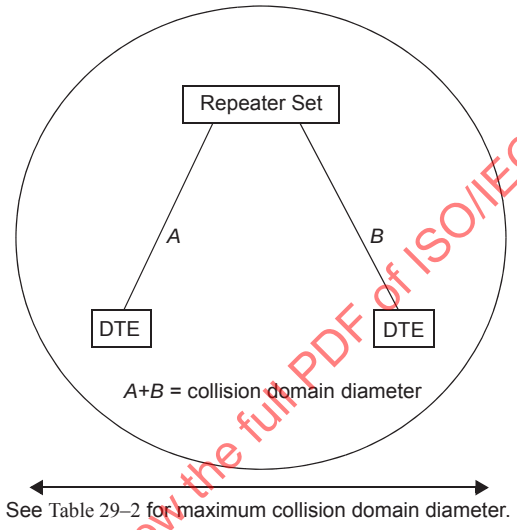

Figure 29–4—Model 1: Single repeater

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Table 29–2—Maximum Model 1 collision domain diameter[a]

Model	Balanced cabling (copper)	Fiber	Balanced cabling & fiber (T2 or T4 and FX)	Balanced cabling & fiber (TX and FX)
DTE-DTE (see Figure 29–3)	100	412	NA	NA
One Class I repeater (see Figure 29–4)	200	272	231[a]	260.8[a]
One Class II repeater (see Figure 29–4)	200	320	304[b]	308.8[b]
Two Class II repeaters (see Figure 29–5)	205	228	236.3[c]	216.2[c]

[a]Assumes 100 m of balanced cabling and one fiber link.
[b]This entry included for completeness. It may be impractical to construct a T4 to FX class II repeater.
[c] Assumes 105 m of balanced cabling and one fiber link.

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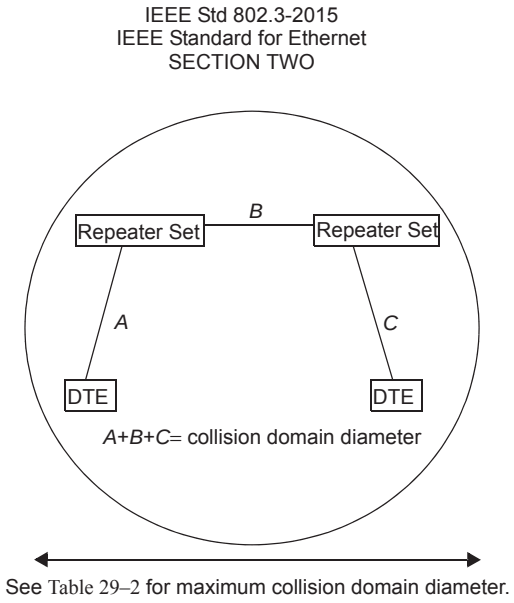

Figure 29–5—System Model 1: Two Class II repeaters

29.3.1 Round-trip collision delay

For a network to be valid, it must be possible for any two DTEs on the network to contend for the network at the same time. Each station attempting to transmit must be notified of the contention by the returned "collision" signal within the "collision window" (see 4.1.2.2 and 5.2.2.1.2). Additionally, the maximum length fragment created must contain less than 512 bits after the start-of-frame delimiter (SFD). These requirements limit the physical diameter (maximum distance between DTEs) of a network. The maximum round-trip delay must be qualified between all pairs of DTEs in the network. In practice this means that the qualification must be done between those that, by inspection of the topology, are candidates for the longest delay. The following network modeling methodology is provided to assist that calculation.

29.3.1.1 Worst-case path delay value (PDV) selection

The worst-case path through a network to be validated shall be identified by examination of aggregate DTE delays, cable delays, and repeater delays. The worst case consists of the path between the two DTEs at opposite ends of the network that have the longest round-trip time. Figure 29–6 and Figure 29–7 show schematic representations of one-repeater and two-repeater paths.

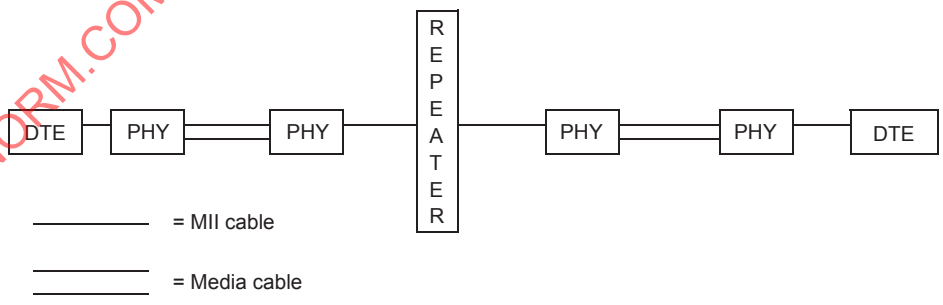

Figure 29–6—System Model 2: Single repeater

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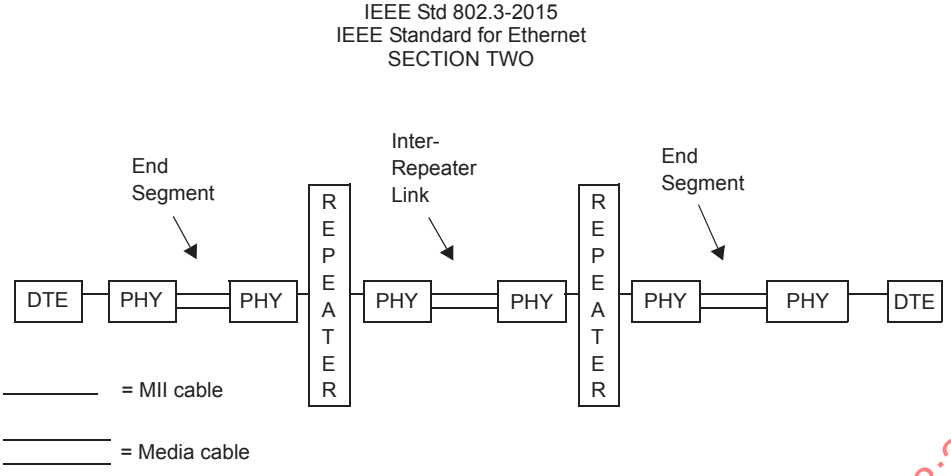

Figure 29–7—System Model 2-2: Two repeaters

29.3.1.2 Worst-case PDV calculation

Once a set of paths is chosen for calculation, each shall be checked for validity against the following formula:

PDV = ∑link delays (LSDV) + ∑repeater delays + DTE delays + safety margin

Values for the formula variables are determined by the following method:

a) Determine the delay for each link segment (Link Segment Delay Value, or LSDV), including inter-repeater links, using the formula

LSDV=2 (for round-trip delay) × segment length × cable delay for this segment

NOTE 1—Length is the sum of the cable lengths between the PHY interfaces at the repeater and the farthest DTE for End Segments plus the sum of the cable lengths between the repeater PHY interfaces for Inter-Repeater Links. All measurements are in meters.

NOTE 2—Cable delay is the delay specified by the manufacturer or the maximum value for the type of cable used as shown in Table 29–3. For this calculation, cable delay must be specified in bit times per meter (BT/m). Table 29–4 can be used to convert values specified relative to the speed of light (%c) or nanoseconds per meter (ns/m).

NOTE 3—When actual cable lengths or propagation delays are not known, use the Max delay in bit times as specified in Table 29–3 for copper cables. Delays for fiber should be calculated, as the value found in Table 29–3 will be too large for most applications.

b) Sum together the LSDVs for all segments in the path.

c) Determine the delay for each repeater in the path. If model-specific data are not available from the manufacturer, determine the class of each repeater (I or II) and enter the appropriate default value from Table 29–3.

d) MII cables for 100BASE-T shall not exceed 0.5 m each. When evaluating system topology, MII cable delays need not be accounted for separately. Delays attributable to the MII are incorporated into DTE and repeater component delays.

e) Use the DTE delay value shown in Table 29–3 unless your equipment manufacturer defines a different value.

f) Decide on appropriate safety margin—0 to 5 bit times—for the PDV calculation. Safety margin is used to provide additional margin to accommodate unanticipated delay elements, such as extra-long connecting cable runs between wall jacks and DTEs. (A safety margin of 4 BT is recommended.)

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g) Insert the values obtained through the calculations above into the following formula to calculate the PDV. (Some configurations may not use all the elements of the formula.)

PDV = ∑link delays (LSDV) + ∑repeater delays + DTE delay + safety margin

h) If the PDV is less than 512, the path is qualified in terms of worst-case delay.

i) Late collisions and/or CRC errors are indicators that path delays exceed 512 BT.

Table 29–3—Network component delays, Transmission System Model 2

Component	Round trip delay in bit times per meter	Maximum round trip delay in bit times
Two TX/FX DTEs		100
Two T4 DTEs		138
Two T2 DTEs		96
One T2 or T4 and one TX/FX DTE[a]		127
Cat 3 cabling segment	1.14	114 (100 m)
Cat 4 cabling segment	1.14	114 (100 m)
Cat 5 cabling segment	1.112	111.2 (100 m)
STP cabling segment	1.112	111.2 (100 m)
Fiber optic cabling segment	1.0	412 (412 m)
Class I repeater		140
Class II repeater with all ports TX/FX		92
Class II repeater with any port T4		67
Class II repeater with any port T2		90

[a] Worst-case values are used (TX/FX values for MAC transmit start and MDI input to collision detect; T4 value for MDI input to MDI output).

29.4 Full duplex 100 Mb/s topology limitations

Unlike half duplex CSMA/CD networks, the physical size of full duplex 100 Mb/s CSMA/CD networks is not limited by the round-trip collision propagation delay. Instead, the maximum link length between DTEs is limited only by the signal transmission characteristics of the specific cable, as specified in Table 29–5.

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Table 29–4—Conversion table for cable delays

Speed relative to *c*	ns/m	BT/m
0.4	8.34	0.834
0.5	6.67	0.667
0.51	6.54	0.654
0.52	6.41	0.641
0.53	6.29	0.629
0.54	6.18	0.618
0.55	6.06	0.606
0.56	5.96	0.596
0.57	5.85	0.585
0.58	5.75	0.575
0.5852	5.70	0.570
0.59	5.65	0.565
0.6	5.56	0.556
0.61	5.47	0.547
0.62	5.38	0.538
0.63	5.29	0.529
0.64	5.21	0.521
0.65	5.13	0.513
0.654	5.10	0.510
0.66	5.05	0.505
0.666	5.01	0.501
0.67	4.98	0.498
0.68	4.91	0.491
0.69	4.83	0.483
0.7	4.77	0.477
0.8	4.17	0.417
0.9	3.71	0.371

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Table 29–5—Link segment length limits; 100 Mb/s full duplex segments

Cable type	Maximum link segment length
100BASE-TX (UTP, STP per Clause 25)	100 m
100BASE-FX (multimode fiber per Clause 26)	2000 m
100BASE-T2 (UTP per Clause 32)	100 m

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30. Management

30.1 Overview

This clause provides the Layer Management specification for DTEs, repeaters, MAUs, and Midspans based on the CSMA/CD access method. The clause is produced from the ISO framework additions to Clause 5, Layer Management; Clause 19, Repeater Management; and Clause 20, MAU Management. It incorporates additions to the objects, attributes, and behaviours to support 100 Mb/s, 1000 Mb/s and 10 Gb/s, full duplex operation, MAC Control, Link Aggregation, DTE Power via MDI, subscriber access networks, and the Link Layer Discovery Protocol (LLDP) IEEE 802.3 Organizationally Specific TLVs. The objects, attributes, and behaviours to support Link Aggregation are deprecated by IEEE Std 802.1AX-2008.

The layout of this clause takes the same form as 5.1, 5.2, and Clause 19, and Clause 20, although with equivalent subclauses grouped together. It identifies a common management model and framework applicable to IEEE 802.3 managed elements, identifies those elements and defines their managed objects, attributes, and behaviours in a protocol-independent language.

This clause provides the Layer Management specification for DTEs, repeaters, and MAUs based on the CSMA/CD access method. It defines facilities comprised of a set of statistics and actions needed to provide IEEE 802.3 Management services. The information in this clause should be used in conjunction with the Procedural Model defined in 4.2.7 through 4.2.10. The Procedural Model provides a formal description of the relationship between the CSMA/CD Layer Entities and the Layer Management facilities.

This management specification has been developed in accordance with the OSI management architecture as specified in the ISO Management Framework document, ISO/IEC 7498-4:1989. It is independent of any particular management application or management protocol.

The management facilities defined in this standard may be accessed both locally and remotely. Thus, the Layer Management specification provides facilities that can be accessed from within a station or can be accessed remotely by means of a peer-management protocol operating between application entities.

In CSMA/CD no peer management facilities are necessary for initiating or terminating normal protocol operations or for handling abnormal protocol conditions. Since these activities are subsumed by the normal operation of the protocol, they are not considered to be a function of Layer Management and are, therefore, not discussed in this clause.

Implementation of part or all of Layer Management is not a requirement for conformance to any other clause of this standard.

The intent of this standard is to furnish a management specification that can be used by the wide variety of different devices that may be attached to an Ethernet network. Thus, a comprehensive list of management facilities is provided.

The improper use of some of the facilities described in this clause may cause serious disruption of the network. In accordance with ISO management architecture, any necessary security provisions should be provided by the Agent in the Local System Environment. This can be in the form of specific security features or in the form of security features provided by the peer communication facilities.

The device that connects directly to the media is called MAU for 10 Mb/s operation and its equivalent is the combined PMA and PMD sublayers at higher operating speeds. Because this clause defines management for use at many speeds, it needs to be able to refer to MAUs and the PMA and PMD sublayer combination as a group. Therefore, in this clause, the term MAU will include PMA and PMD sublayers as well as MAUs, except in those instances where it is explicitly restricted to 10 Mb/s.

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30.1.1 Scope

This clause includes selections from Clause 5, Clause 19, and Clause 20. It is intended to be an entirely equivalent specification for the management of 10 Mb/s DTEs, 10 Mb/s baseband repeater units, and 10 Mb/s integrated MAUs. It incorporates additions to the objects, attributes, and behaviours to support subsequent additions to this standard.Implementations of management for DTEs, repeater units, and embedded MAUs should follow the requirements of this clause (e.g., a 10 Mb/s implementation should incorporate the attributes to indicate that it is not capable of 100 Mb/s or 1000 Mb/s operation; half duplex DTE should incorporate the attributes to indicate that it is not capable of full duplex operation, etc.).

For 10 Mb/s ports without integral MAUs, attributes are provided for characteristics observable from the AUI of the connected DTE or repeater. Direct management of AUI MAUs that are external to their respective DTEs or repeaters is beyond the scope of this standard.

The managed objects within this standard are defined in terms of their behaviour, attributes, actions, notifications, and packages in accordance with IEEE 802.1 and ISO standards for network management. Managed objects are grouped into mandatory and optional packages.

This specification is defined to be independent of any particular management application or management protocol. The means by which the managed objects defined in this standard are accessed is beyond the scope of this standard.

30.1.2 Relationship to objects in IEEE 802.1F

The following managed object classes, if supported by an implementation, shall be as specified in IEEE Std 802.1F-1993 (withdrawn): ResourceTypeID, EWMAMetricMonitor.

oResourceTypeID

This object class is mandatory and shall be implemented as defined in IEEE 802.1F. This object is bound to oMAC-Entity, oRepeater, oMidSpan, and oMAU as defined by the NAMEBINDINGs. Note that the binding to oMAU is mandatory only when MII is present. The Entity Relationship Diagrams, Figure 30–3, Figure 30–4, and Figure 30–5 show these bindings pictorially.

oEWMAMetricMonitor

This object class is optional. When implemented, it shall be implemented as defined in IEEE 802.1F, subject to the specific requirements described below. This object is bound to system as defined by the NAMEBINDINGs.

Implementations of IEEE 802.3 Management that support the oEWMAMetricMonitor managed object class are required to support values of granularity period as small as one second. Implementations are required to support at least one sequence of low and high thresholds. The granularity period may be set to equal to the moving time period as a minimal conformant implementation.

30.1.3 Systems management overview

Within the ISO Open Systems Interconnection (OSI) architecture, the need to handle the special problems of initializing, terminating, and monitoring ongoing activities and assisting in their operations, as well as handling abnormal conditions, is recognized. These needs are collectively addressed by the systems management component of the OSI architecture.

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A management protocol is required for the exchange of information between systems on a network. This management standard is independent of any particular management protocol.

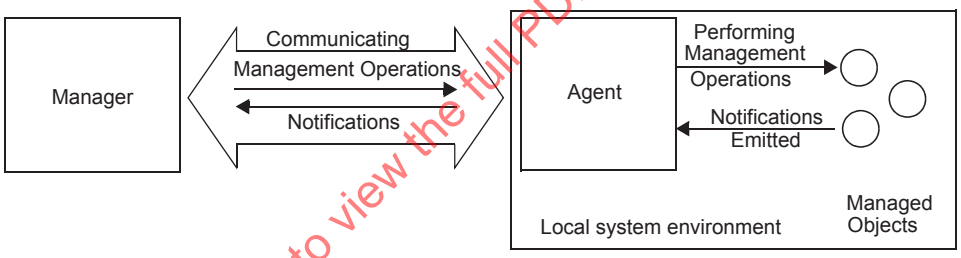
This management standard, in conjunction with the management standards of other layers, provides the means to perform various management functions. IEEE 802.3 Management collects information needed from the MAC and Physical Layers and the devices defined in IEEE 802.3. It also provides a means to exercise control over those elements.

The relationship between the various management entities and the layer entities according to the ISO model is shown in Figure 30–1.

30.1.4 Management model

This standard describes management of DTEs, repeaters, and integrated MAUs in terms of a general model of management of resources within the open systems environment. The model, which is described in ISO/IEC 10040:1992, is briefly summarized here.

Management is viewed as a distributed application modeled as a set of interacting management processes. These processes are executed by systems within the open environment. A managing system executes a managing process that invokes management operations. A managed system executes a process that is receptive to these management operations and provides an interface to the resources to be managed. A managed object is the abstraction of a resource that represents its properties as seen by (and for the purpose of) management. Managed objects respond to a defined set of management operations. Managed objects are also capable of emitting a defined set of notifications. This interaction of processes is shown in Figure 30–1.



NOTE—This figure is drawn from Figure 1 of ISO/IEC 10040:1992, Information technology—Open Systems Interconnection—Systems management overview. In the event of any conflict, the depiction in ISO/IEC 10040:1992 takes precedence.

Figure 30–1—Interaction between manager, agent, and objects

A managed object is a management view of a resource. The resource may be a logical construct, function, physical device, or anything subject to management. Managed objects are defined in terms of four types of elements:

a) *Attributes.* Data-like properties (as seen by management) of a managed object.
b) *Actions.* Operations that a managing process may perform on an object or its attributes.
c) *Notifications.* Unsolicited reports of events that may be generated by an object.
d) *Behaviour.* The way in which managed objects, attributes, and actions interact with the actual resources they model and with each other.

The above items are defined in 30.3 through 30.3.7 of this clause in terms of the template requirements of ISO/IEC 10165-4:1991.

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Some of the functions and resources within IEEE 802.3 devices are appropriate targets for management. They have been identified by specifying managed objects that provide a management view of the functions or resources. Within this general model, the IEEE 802.3 device is viewed as a managed device. It performs functions as defined by the applicable standard for such a device. Managed objects providing a view of those functions and resources appropriate to the management of the device are specified. The purpose of this standard is to define the object classes associated with the devices in terms of their attributes, operations, notifications, and behaviour.

30.2 Managed objects

30.2.1 Introduction

This clause identifies the Managed Object classes for IEEE 802.3 components within a managed system. It also identifies which managed objects and packages are applicable to which components.

All counters defined in this specification are assumed to be wrap-around counters. Wrap-around counters are those that automatically go from their maximum value (or final value) to zero and continue to operate. These unsigned counters do not provide for any explicit means to return them to their minimum (zero), i.e., reset. Because of their nature, wrap-around counters should be read frequently enough to avoid loss of information. When a counter has a maximum increment rate specified at one speed of operation, and that counter is appropriate to a higher speed of operation, then the maximum increment rate at that higher speed of operation is

$$\text{maximum increment rate specified} \times \left(\frac{\text{higher speed of operation in Mb/s}}{\text{specified speed of operation in Mb/s}} \right) \quad (30\text{–}1)$$

unless otherwise indicated.

30.2.2 Overview of managed objects

Managed objects provide a means to

— Identify a resource
— Control a resource
— Monitor a resource

30.2.2.1 Text description of managed objects

In case of conflict, the formal behaviour definitions in 30.3, 30.4, 30.5, 30.6, and 30.7 take precedence over the text descriptions in this subclause.

oAggPortDebugInformation

If oAggregator is implemented, a single instance of oAggPortDebugInformation may be contained within oAggregationPort. This managed object class provides optional additional information that can assist with debugging and fault finding in Systems that support Link Aggregation.

NOTE—This object is deprecated by IEEE Std 802.1AX-2008.

oAggPortStats

If oAggregator is implemented, a single instance of oAggPortStats may be contained within oAggregationPort. This managed object class

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provides optional additional statistics related to LACP and Marker protocol activity on an instance of an Aggregation Port that is involved in Link Aggregation.

NOTE—This object is deprecated by IEEE Std 802.1AX-2008.

oAggregationPort If oAggregator is implemented, oAggregationPort is contained within oAggregator. An instance of this managed object class is present for each Aggregation Port that is part of the aggregation represented by the oAggregator instance. This managed object class provides the basic management controls necessary to allow an instance of an Aggregation Port to be managed, for the purposes of Link Aggregation.

NOTE—This object is deprecated by IEEE Std 802.1AX-2008.

oAggregator If implemented, oAggregator is the top-most managed object class of the DTE containment tree shown in Figure 30–4. Note that this managed object class may be contained within another superior managed object class. Such containment is expected, but is outside the scope of this International Standard. The oAggregator managed object class provides the management controls necessary to allow an instance of an Aggregator to be managed.

NOTE—This object is deprecated by IEEE Std 802.1AX-2008.

oAutoNegotiation The managed object of that portion of the containment trees shown in Figure 30–4 and Figure 30–5. The attributes, notifications, and actions defined in 30.6 are contained within the MAU managed object.

oGroup The group managed object class is a view of a collection of repeater ports.

oEXTENSION If implemented, oEXTENSION is contained within oMACControlEntity. The oEXTENSION managed object class provides the management controls necessary to allow an instance of the MAC Control EXTENSION function to be managed.

oLldpXdot3Config The top-most managed object class of the Link Layer Discovery Protocol (LLDP) containment tree shown in Figure 30–6. Note that this managed object class may be contained within another superior managed object class. Such containment is expected, but is outside the scope of this standard.

oLldpXdot3LocSystemsGroup
If oLldpXdot3Config is implemented, a single instance of oLldpXdot3LocSystemsGroup may be contained within oLldpXdot3Config. This managed object class provides the LLDP local system information.

oLldpXdot3RemSystemsGroup
If oLldpXdot3Config is implemented, a single instance of oLldpXdot3RemSystemsGroup may be contained within oLldpXdot3Config. This managed object class provides the LLDP remote system information.

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oMACControlEntity If implemented, and if oOAM is implemented, a single instance of oMACControlEntity is contained within oOAM. Otherwise, if implemented, and if oAggregator is implemented, oMACControlEntity is contained within oAggregator. Otherwise, if implemented, oMACControlEntity becomes the top-most managed object class of the DTE containment tree shown in Figure 30–4. Note that this managed object class may be contained within another superior managed object class. Such containment is expected, but is outside the scope of this International Standard.

oMACControlFunctionEntity
If implemented, oMACControlFunctionEntity is contained within oMACControlEntity. The oMACControlFunctionEntity managed object class provides the management controls necessary to allow an instance of the MAC Control PAUSE function to be managed.

oMACEntity If oMACControlEntity is implemented, oMACEntity is contained within oMACControlEntity. Otherwise, if oOAM is implemented, oMACEntity is contained within oOAM. Otherwise, if oAggregator is implemented, oMACEntity is contained within oAggregator. Otherwise, oMACEntity becomes the top-most managed object class of the DTE containment tree shown in Figure 30–3. Note that this managed object class may be contained within another superior managed object class. Such containment is expected, but is outside the scope of this International Standard.

oMAU The managed object of that portion of the containment trees shown in Figure 30–3 and Figure 30–4. The attributes, notifications, and actions defined in 30.5 are contained within the MAU managed object. Neither counter values nor the value of MAUAdminState is required to be preserved across events involving the loss of power.

oMidSpan The top-most managed object class of the Midspan containment tree shown in Figure 30–5. Note that this managed object class may be contained within another superior managed object class. Such containment is expected, but is outside the scope of this standard.

oMPCP If implemented, oMPCP is contained within oMACControlEntity. The oMPCP managed object class provides the management controls necessary to allow an instance of the Multipoint MAC Control function to be managed.

oOAM If implemented, and if oAggregator is implemented, oOAM is contained within oAggregator. An instance of this managed object class is present for each Aggregation Port that is part of the aggregation represented by the oAggregator instance. Otherwise, if implemented, oOAM becomes the top-most managed object class of the DTE containment tree shown in Figure 30–3. Note that this managed object class may be contained within another superior managed object class. Such containment is expected, but is outside the scope of this International Standard.

oOMPEmulation If implemented, oOMPEmulation is contained within oMACEntity. The oOMPEmulation managed object class provides the management controls necessary to allow an instance of an OMPEmulation sublayer to be managed.

oPHYEntity If oOMPEmulation is implemented, oPHYEntity is contained within

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oOMPEmulation. Otherwise oPHYEntity is contained within oMACEntity. Many instances of oPHYEntity may coexist within one instance of oMACEntity; however, only one PHY may be active for data transfer to and from the MAC at any one time. oPHYEntity is the managed object that contains the MAU, PAF, and PSE managed objects in a DTE.

oPAF The oPAF managed object class provides the management controls necessary to allow an instance of a PME aggregation function (PAF) to be managed. The PAF managed object class also provides a view of a collection of PMEs.

oPD The managed object of that portion of the containment trees shown in Figure 30–3, Figure 30–4, and Figure 30–5. This managed object class provides the attributes, actions, and notifications required for management by a PSE system.

oPME The oPME managed object class provides the management controls necessary to allow an instance of a PME to be managed. The oPAF managed object contains the PME managed object in a DTE.

oPSE The managed object of that portion of the containment trees shown in Figure 30–3, Figure 30–4, and Figure 30–5. This managed object class provides the attributes, actions, and notifications required for management of a PD system.

oPSEGroup The PSE Group managed object class is a view of a collection of PSEs.

oRepeater The top-most managed object class of the repeater containment tree shown in Figure 30–4. Note that this managed object class may be contained within another superior managed object class. Such containment is expected, but is outside the scope of this standard.

oRepeaterMonitor A managed object class called out by IEEE Std 802.1F-1993. See 30.1.2, oEWMAMetricMonitor.

oRepeaterPort The repeater port managed object class provides a view of the functional link between the data transfer service and a single PMA. The attributes associated with repeater port deal with the monitoring of traffic being handled by the repeater from the port and control of the operation of the port. The Port Enable/Disable function as reported by portAdminState is preserved across events involving loss of power. The oRepeaterPort managed object contains the MAU managed object in a repeater set.

NOTE—Attachment to nonstandard PMAs is outside the scope of this standard.

oResourceTypeID A managed object class called out by IEEE Std 802.1F-1993. It is used within this clause to identify manufacturer, product, and revision of managed components that implement functions and interfaces defined within IEEE 802.3. The Clause 22 MII or Clause 35 GMII specifies two registers to carry PHY Identifier (22.2.4.3.1), which provides succinct information sufficient to support oResourceTypeID.

oTimeSync If implemented, oTimeSync is contained within oPHYEntity. The oTimeSync managed object class provides the controls neccessary to manage the instance of the TimeSync function.

oWIS The managed object of that portion of the containment tree shown in

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Figure 30–3. The attributes defined in 30.8 are contained within the oMAU managed object.

30.2.2.2 Functions to support management

Functions are defined in other clauses that facilitate managed operation. The functions in other clauses that facilitate managed operation are referenced from the text of this management clause.

30.2.2.2.1 DTE MAC sublayer functions

For DTE MACs, with regard to reception-related error statistics a hierarchical order has been established such that when multiple error statuses can be associated with one frame, only one status is returned to the LLC. This hierarchy in descending order is as follows:

— frameTooLong
— alignmentError
— frameCheckError
— lengthError

The counters are primarily incremented based on the status returned to the MAC client; therefore, the hierarchical order of the counters is determined by the order of the status. Frame fragments are not included in any of the statistics unless otherwise stated. In implementing any of the specified actions, receptions and transmissions that are in progress are completed before the action takes effect.

30.2.2.2.2 Repeater functions

The Repeater Port Object class contains seven functions which are defined in this clause and are used to collect statistics on the activity received by the port. The relationship of the functions to the repeater port and to the port attributes is shown in Figure 30–2.

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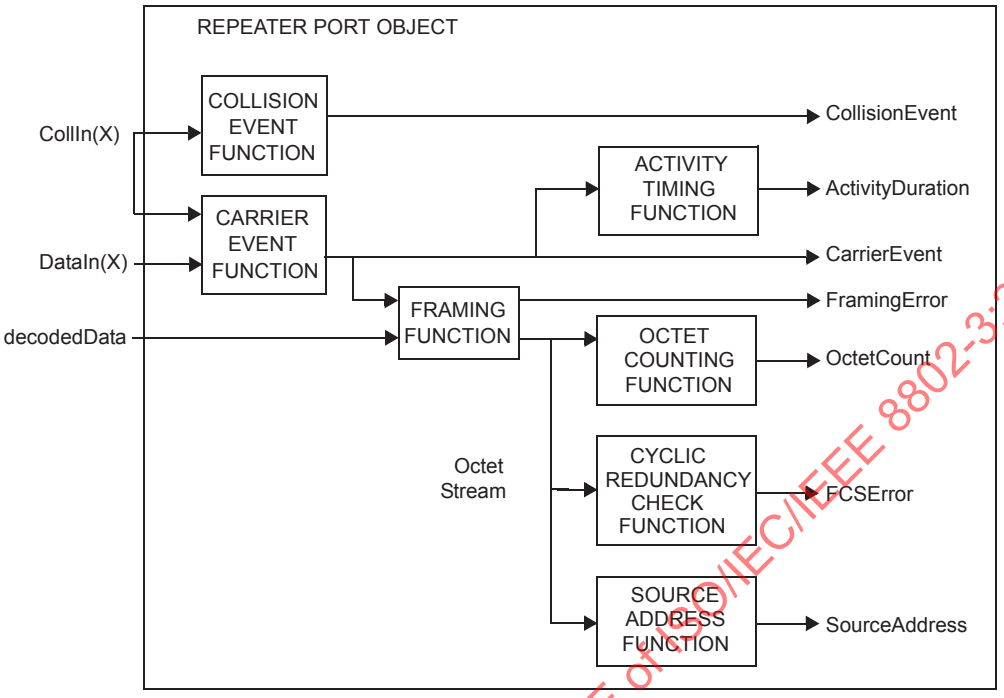

Figure 30–2—Functions relationship

Activity Timing function

The Activity Timing function measures the duration of the assertion of the CarrierEvent signal. For 10 Mb/s repeaters, this duration value must be adjusted by removing the value of Carrier Recovery Time (see 9.5.6.5) to obtain the true duration of activity on the network. The output of the Activity Timing function is the ActivityDuration value, which represents the duration of the CarrierEvent signal as expressed in units of bit times.

Carrier Event function

For 10 Mb/s repeaters the Carrier Event function for port N asserts the CarrierEvent signal when the repeater exits the IDLE state (see Figure 9–2) and the port has been determined to be port N. It deasserts the CarrierEvent signal when, for a duration of at least Carrier Recovery Time (see 9.5.6.5), both the DataIn(N) variable has the value II and the CollIn(N) variable has the value –SQE. The value N is the port assigned at the time of transition from the IDLE state. For 100 and 1000 Mb/s repeaters the Carrier Event function for port N asserts the CarrierEvent signal when the repeater exits the IDLE state of the repeater state diagram (Figure 27–2 and Figure 41–2) and the port has been determined to be port N. The Carrier Event function for Port N deasserts the CarrierEvent signal when the repeater enters the IDLE state of the repeater state diagram (Figure 27–2 and Figure 41–2).

Collision Event function

The Collision Event function asserts the CollisionEvent signal when a

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collision is detected at a repeater port. For a 10 Mb/s repeater port this is indicated by the CollIn(X) variable having the value SQE. For a 100 and 1000 Mb/s repeater port this is indicated by entering the COLLISION COUNT INCREMENT state of the partition state diagram (Figure 27–8 and Figure 41–4). The CollisionEvent signal remains asserted until the assertion of any CarrierEvent signal due to the reception of the following event.

Cyclic Redundancy Check function

The Cyclic Redundancy Check function verifies that the sequence of octets output by the Framing function contains a valid Frame Check Sequence Field. The Frame Check Sequence Field is the last four octets received from the output of the Framing function. The algorithm for generating an FCS from the octet stream is specified in 3.2.9. If the FCS generated according to this algorithm is not the same as the last four octets received from the Framing function, then the FCSError signal is asserted. The FCSError signal is cleared and the Cyclic Redundancy Check function is reinitialized upon the assertion of the CarrierEvent signal due to the reception of the following event and, additionally in the case of a frame burst on a 1000 Mb/s network, upon the recognition of a valid Start of Packet delimiter (see 35.2.3.6), once the duration of the CarrierEvent is greater than or equal to slotTime.

Framing function

The Framing function recognizes the boundaries of an incoming frame by monitoring the CarrierEvent signal and the decoded data stream. Data bits are accepted while the CarrierEvent signal is asserted. The framing function delineates frames by stripping the Start of Packet delimiter (see 35.2.3.6), preamble, Start of frame delimiter, End of Packet delimiter (see 35.2.3.6), and any Carrier Extend from the received data stream. The remaining bits of each frame are aligned along octet boundaries. If there is not an integral number of octets, then FramingError shall be asserted. The FramingError signal is cleared upon the assertion of the CarrierEvent signal due to the reception of the following event. For 1000 Mb/s repeaters, the data stream shall continue until the end of the CarrierEvent signal or upon the recognition of a valid Start of Packet delimiter once the duration of the CarrierEvent is greater than or equal to slotTime. Such a Start of Packet delimiter will begin a new data stream.

Octet Counting function

The Octet Counting function counts the number of complete octets received from the output of the framing function. The output of the octet counting function is the OctetCount value. The OctetCount value is reset to zero upon the assertion of the CarrierEvent signal due to the reception of the following event and, additionally in the case of a frame burst on a 1000 Mb/s network, upon the recognition of a valid Start of Packet delimiter (see 35.2.3.6), once the duration of the CarrierEvent is greater than or equal to slotTime.

Source Address function

The Source Address function extracts octets from the stream output by the framing function. The seventh through twelfth octets shall be extracted from the octet stream and output as the SourceAddress variable. The SourceAddress variable is set to an invalid state upon the

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assertion of the CarrierEvent signal due to the reception of the following event and, additionally in the case of a frame burst on a 1000 Mb/s network, upon the recognition of a valid Start of Packet delimiter (see 35.2.3.6), once the duration of the CarrierEvent is greater than or equal to slotTime.

30.2.3 Containment

A containment relationship is a structuring relationship for managed objects in which the existence of a managed object is dependent on the existence of a containing managed object. The contained managed object is said to be the subordinate managed object, and the containing managed object the superior managed object. The containment relationship is used for naming managed objects. The local containment relationships among object classes are depicted in the entity relationship diagrams, Figure 30–3 through Figure 30–6. These figures show the names of the object classes and whether a particular containment relationship is one-to-one, one-to-many or many-to-one. For further requirements on this topic, see IEEE Std 802.1F-1993. PSE management is only valid in a system that provides management at the next higher containment level, that is, either a DTE, repeater or Midspan with management.

MAU management is only valid in a system that provides management at the next higher containment level, that is, either a DTE or repeater with management.

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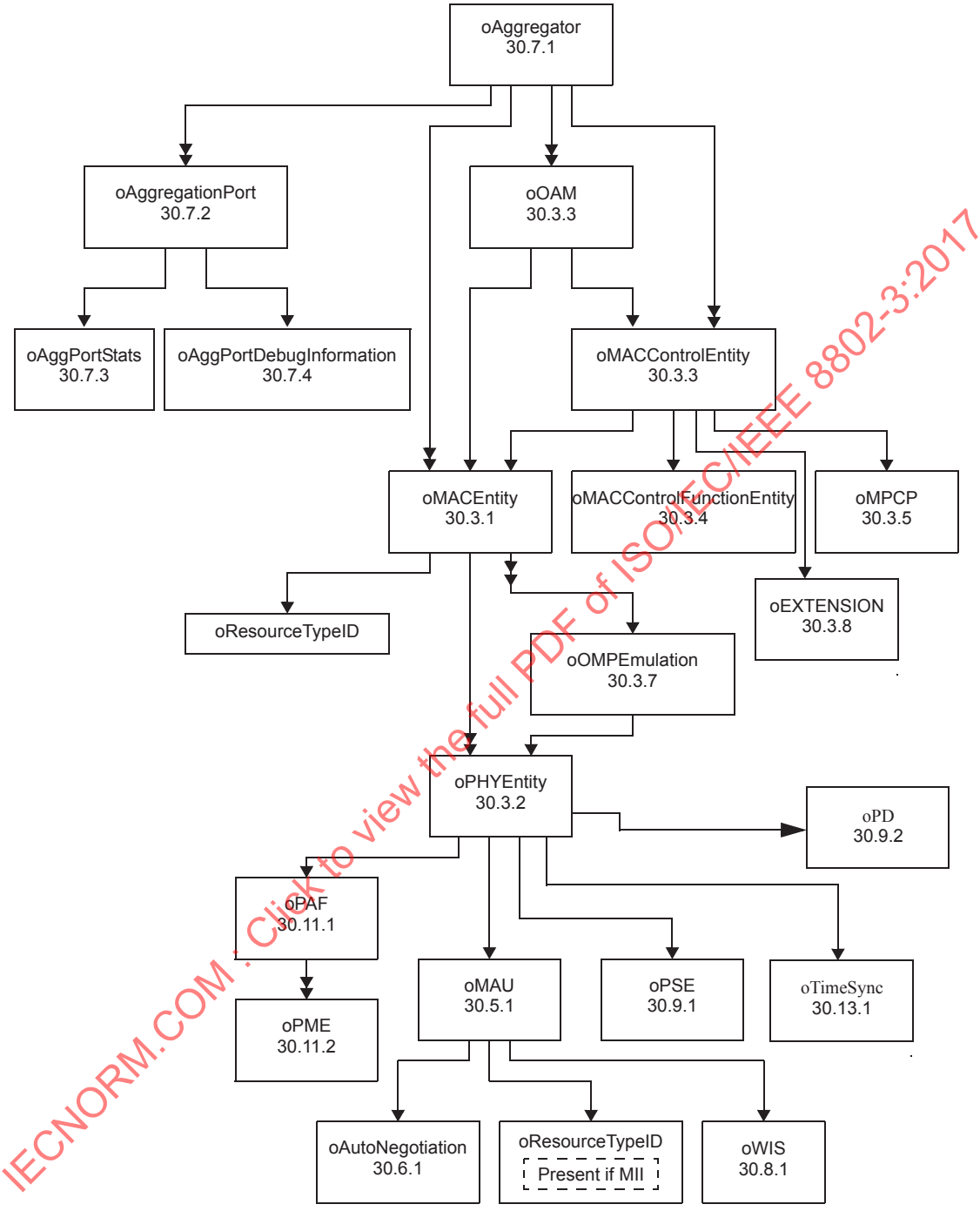

Note—The objects oAggregator, oAggregationPort, oAggPortStats and oAggPortDebugInformation are deprecated by IEEE Std 802.1AX-2008.

Figure 30–3— DTE System entity relationship diagram

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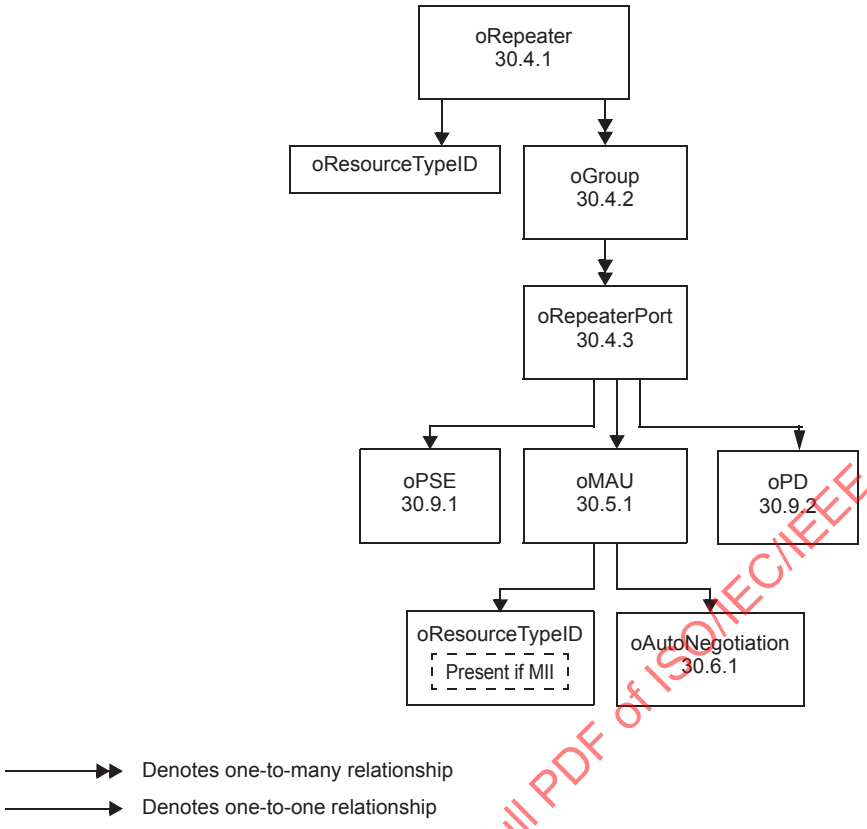

Figure 30–4—Repeater entity relationship diagram

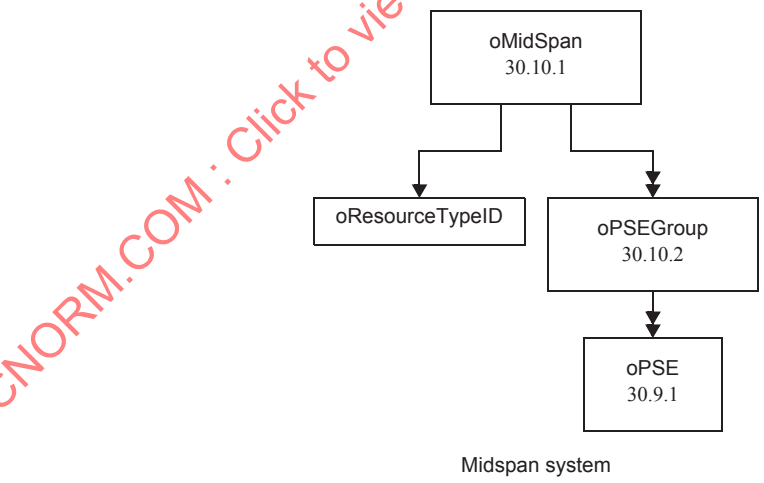

Figure 30–5—Midspan entity relationship diagram

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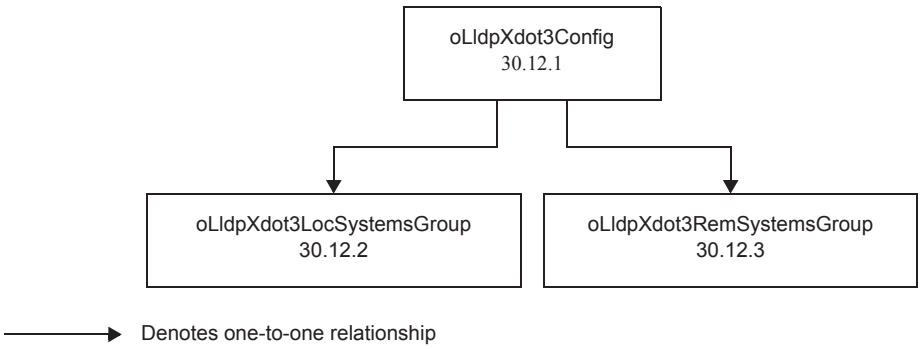

Figure 30–6—Link Layer Discovery Protocol entity relationship diagram

30.2.4 Naming

The name of an individual managed object is hierarchically defined within a managed system. For example, in the context of repeater management, a repeater port might be identified as "repeater 3, group 01, port 13," that is, port 13 of group 01 of a repeater with repeaterID 3 within the managed system.

In the case of MAU management, this will present itself in one of the two forms that are appropriate for a MAU's use, that is, as associated with a CSMA/CD interface of a DTE or with a particular port of a managed repeater. For example, a MAU could be identified as "repeater 3, group 01, port 13, MAU 1" or, that is, the MAU associated with port 13 of group 01 of a repeater with repeaterID 3 within the managed system. Examples of this are represented in the relationship of the naming attributes in the entity relationship diagram, Figure 30–3.

30.2.5 Capabilities

This standard makes use of the concept of *packages* as defined in ISO/IEC 10165-4:1992 as a means of grouping behaviour, attributes, actions, and notifications within a managed object class definition. Packages may either be mandatory, or be conditional, that is to say, present if a given condition is true. Within this standard *capabilities* are defined, each of which corresponds to a set of packages, which are components of a number of managed object class definitions and which share the same condition for presence. Implementation of the appropriate Basic and Mandatory packages is the minimum requirement for claiming conformance to IEEE 802.3 Management. Implementation of an entire optional capability is required in order to claim conformance to that capability. The capabilities and packages for IEEE 802.3 Management are specified in Table 30–1a through Table 30–7.

DTE Management has two packages that are required for management at the minimum conformance configuration—the Basic Package and the Mandatory Package. Systems that implement the optional MAC Control sublayer shall also implement the Basic and Mandatory Packages for the MAC Control Entity managed object class to claim DTE minimum conformance. For systems that include multiple PHY entities per MAC entity and implement the Multiple PHY Package to manage the selection of the active PHY, the optional Recommended Package shall be implemented. Systems that implement the optional Link Aggregation sublayer shall also implement the Basic and Mandatory Packages for the Aggregator and Aggregation Port managed object class to claim minimum DTE conformance.

For managed MAUs, the Basic Package is mandatory; all other packages are optional. For a managed MAU to be conformant to this standard, it shall fully implement the Basic Package. For a MAU to be conformant to an optional package it shall implement that entire package. While nonconformant (reference aMAUType

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= “other”) MAUs may utilize some or all of this clause to specify their management, conformance to this clause requires both a conformant MAU and conformant management. MAU Management is optional with respect to all other CSMA/CD Management. If an MII is present then the conditional MII Capability must be implemented. This provides the means to identify the vendor and type of the externally connected device.

There are two distinct aspects of Repeater Management.

The first aspect provides the means to monitor and control the functions of a repeater. These functions include, but are not limited to: identifying a repeater, testing and initializing a repeater, and enabling/disabling a port. This is encompassed by the mandatory Basic Control Capability.

The second aspect provides the means to monitor traffic from attached segments, and to measure traffic sourced by DTEs connected to these segments. This is done by gathering statistics on packets that enter a repeater and maintaining those statistics on a per port basis. This is encompassed by the optional Performance Monitor Capability. The optional Address Tracking Capability provides the means to identify existence and movement of attached DTEs by their MAC addresses. While nonconformant (reference aRepeaterType = “other”) repeaters may utilize some or all of this clause to specify their management, conformance to this clause requires both a conformant repeater and conformant management.

If link Auto-Negotiation is present and managed, the Auto-Negotiation managed object class shall be implemented in its entirety. All attributes and actions are mandatory.

The 1000 Mb/s Burst Monitor Capability provides additional attributes that relate only to 1000 Mb/s operation, while the 100 Mb/s Monitor Capability has attributes that apply to a mixed 100 and 1000 Mb/s operation. These attributes are provided to complement the counter attributes of the optional packages and capabilities that apply to 10 Mb/s and mixed 10, 100, and 1000 Mb/s implementations. It is recommended that when the 100/1000 Mb/s Monitor Capability or 1000 Mb/s Burst Monitor Capability is implemented, the appropriate complementary counter packages and capabilities are also implemented.

For managed PSEs, the PSE Basic Package is mandatory and the PSE Recommended Package is optional. For managed PDs, the PD Basic Package is mandatory. For a managed PSE to be conformant to this standard, it shall fully implement the PSE Basic Package. For a managed PD to be conformant to this standard, it shall fully implement the PD Basic Package. For a managed PSE to be conformant to the optional Recommended Package it shall implement that entire package. PSE and PD management is optional with respect to all other CSMA/CD management.

For managed Midspans, the Midspan managed object class shall be implemented in its entirety. All attributes and notifications are mandatory. Midspan management is optional with respect to all other CSMA/CD management.

For LLDP management, the LLDP Basic Package is mandatory. All other LLDP packages are conditional on the IEEE 802.3 Organizationally Specific TLVs supported and the LLDP operating mode (see IEEE Std 802.1AB, Clause 10).

LLDP MAC/PHY Configuration/Status Local Package is mandatory for managed entities that support IEEE 802.3 Organizationally Specific TLV named “MAC/PHY Configuration/Status” and are either in LLDP transmit only mode or in LLDP transmit and receive mode. LLDP MAC/PHY Config/Status Remote Package is mandatory for managed entities that support IEEE 802.3 Organizationally Specific TLV named “MAC/PHY Configuration/Status” and are either in LLDP receive only mode or in LLDP transmit and receive mode.

LLDP Power via MDI Local Package is mandatory for managed entities that support IEEE 802.3 Organizationally Specific TLV named “Power via MDI” and are either in LLDP transmit only mode or in LLDP transmit and receive mode. LLDP Power via MDI Remote Package is mandatory for managed

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entities that support IEEE 802.3 Organizationally Specific TLV named “Power via MDI” and are either in LLDP receive only mode or in LLDP transmit and receive mode.

LLDP Link Aggregation Local Package is mandatory for managed entities that support IEEE 802.3 Organizationally Specific TLV named “Link Aggregation” and are either in LLDP transmit only mode or in LLDP transmit and receive mode. LLDP Link Aggregation Remote Package is mandatory for managed entities that support IEEE 802.3 Organizationally Specific TLV named “Link Aggregation” and are either in LLDP receive only mode or in LLDP transmit and receive mode.

LLDP Max Frame Size Local Package is mandatory for managed entities that support IEEE 802.3 Organizationally Specific TLV named “Max Frame Size” and are either in LLDP transmit only mode or in LLDP transmit and receive mode. LLDP Max Frame Size Remote Package is mandatory for managed entities that IEEE 802.3 Organizationally Specific TLV named “Max Frame Size” and are either in LLDP receive only mode or in LLDP transmit and receive mode. (See Table 30–7.)

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Table 30–1a—Capabilities

				DTE								Repeater					MAU						
				Basic Package (mandatory)	Mandatory Package (mandatory)	Recommended Package (optional)	Optional Package (optional)	Array Package (optional)	Excessive Deferral Package (optional)	Multiple PHY Package (optional)	PHY Error Monitor Capability (optional)	Basic Control Capability (mandatory)	Performance Monitor Capability (optional)	Address Tracking Capability (optional)	100/1000 Mb/s Monitor Capability (optional)	1000 Mb/s Burst Monitor Capability (optional)	Basic Package (mandatory)	MAU Control Package (optional)	Media Loss Tracking Package (conditional)	Broadband DTE MAU Package (conditional)	MII Capability (conditional)	PHY Error Monitor Capability (optional)	Auto-Negotiation Package (mandatory)
oResourceTypeID managed object																							
	aResourceTypeIDName	ATTRIBUTE	GET	X								X									X		
	aResourceInfo	ATTRIBUTE	GET	X								X									X		
oMACEntity managed object class (30.3.1)																							
	aMACID	ATTRIBUTE	GET	X																			
	aFramesTransmittedOK	ATTRIBUTE	GET		X																		
	aSingleCollisionFrames	ATTRIBUTE	GET		X																		
	aMultipleCollisionFrames	ATTRIBUTE	GET		X																		
	aFramesReceivedOK	ATTRIBUTE	GET		X																		
	aFrameCheckSequenceErrors	ATTRIBUTE	GET		X																		
	aAlignmentErrors	ATTRIBUTE	GET		X																		
	aOctetsTransmittedOK	ATTRIBUTE	GET			X																	
	aFramesWithDeferredXmissions	ATTRIBUTE	GET			X																	
	aLateCollisions	ATTRIBUTE	GET			X																	
	aFramesAbortedDueToXSColls	ATTRIBUTE	GET			X																	
	aFramesLostDueToIntMACXmitError	ATTRIBUTE	GET			X																	
	aCarrierSenseErrors	ATTRIBUTE	GET			X																	
	aOctetsReceivedOK	ATTRIBUTE	GET			X																	
	aFramesLostDueToIntMACRcvError	ATTRIBUTE	GET			X																	
	aPromiscuousStatus	ATTRIBUTE	GET-SET			X																	
	aReadMulticastAddressList	ATTRIBUTE	GET			X																	
	aMaxFrameLength	ATTRIBUTE	GET				X																
	aSlowProtocolFrameLimit	ATTRIBUTE	GET				X																
	aMulticastFramesXmittedOK	ATTRIBUTE	GET				X																
	aBroadcastFramesXmittedOK	ATTRIBUTE	GET				X																
	aFramesWithExcessiveDeferral	ATTRIBUTE	GET						X														
	aMulticastFramesReceivedOK	ATTRIBUTE	GET				X																
	aBroadcastFramesReceivedOK	ATTRIBUTE	GET				X																
	aInRangeLengthErrors	ATTRIBUTE	GET				X																
	aOutOfRangeLengthField	ATTRIBUTE	GET				X																
	aFrameTooLongErrors	ATTRIBUTE	GET				X																
	aMACEnableStatus	ATTRIBUTE	GET-SET				X																

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Table 30–1b—Capabilities

				DTE									Repeater					MAU					
				Basic Package (mandatory)	Mandatory Package (mandatory)	Recommended Package (optional)	Optional Package (optional)	Array Package (optional)	Excessive Deferral Package (optional)	Multiple PHY Package (optional)	PHY Error Monitor Capability (optional)	Energy-Efficient Ethernet (optional)	Basic Control Capability (mandatory)	Performance Monitor Capability (optional)	Address Tracking Capability (optional)	100/1000 Mb/s Monitor Capability (optional)	1000 Mb/s Burst Monitor Capability (optional)	Basic Package (mandatory)	MAU Control Package (optional)	Media Loss Tracking Package (conditional)	Broadband DTE MAU Package (conditional)	MII Capability (conditional)	PHY Error Monitor Capability (optional)	Auto-Negotiation Package (mandatory)
oMACEntity managed object class (con'd.)																							
	aTransmitEnableStatus	ATTRIBUTE	GET-SET				X																
	aMulticastReceiveStatus	ATTRIBUTE	GET-SET				X																
	aReadWriteMACAddress	ATTRIBUTE	GET-SET				X																
	aCollisionFrames	ATTRIBUTE	GET					X															
	aMACCapabilities	ATTRIBUTE	GET		X[1]	X																	
	aDuplexStatus	ATTRIBUTE	GET-SET		X[1]	X																	
	aRateControlAbility	ATTRIBUTE	GET		X																		
	aRateControlStatus	ATTRIBUTE	GET-SET		X																		
	aDeferControlAbility	ATTRIBUTE	GET		X																		
	aDeferControlStatus	ATTRIBUTE	GET-SET		X																		
	acInitializeMAC	ACTION		X																			
	acAddGroupAddress	ACTION				X																	
	acDeleteGroupAddress	ACTION				X																	
	acExecuteSelfTest	ACTION					X																
oPHYEntity managed object class (30.3.2)																							
	aPHYID	ATTRIBUTE	GET	X																			
	aPHYType	ATTRIBUTE	GET	X																			
	aPHYTypeList	ATTRIBUTE	GET	X																			
	aSQETestErrors	ATTRIBUTE	GET			X																	
	aSymbolErrorDuringCarrier	ATTRIBUTE	GET								X												
	aMIIDetect	ATTRIBUTE	GET	X																			
	aPHYAdminState	ATTRIBUTE	GET	X																			
	acPHYAdminControl	ACTION								X													
	aTransmitLPIMicroseconds	ATTRIBUTE	GET									X											
	aReceiveLPIMicroseconds	ATTRIBUTE	GET									X											
	aTransmitLPITransitions	ATTRIBUTE	GET									X											
	aReceiveLPITransitions	ATTRIBUTE	GET									X											

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Table 30–1b—Capabilities *(continued)*

				DTE										Repeater						MAU					
				Basic Package (mandatory)	Mandatory Package (mandatory)	Recommended Package (optional)	Optional Package (optional)	Array Package (optional)	Excessive Deferral Package (optional)	Multiple PHY Package (optional)	PHY Error Monitor Capability (optional)	Energy-Efficient Ethernet (optional)	Auto-Negotiation Package (mandatory)	Basic Control Capability (mandatory)	Performance Monitor Capability (optional)	Address Tracking Capability (optional)	100/1000 Mb/s Monitor Capability (optional)	1000 Mb/s Burst Monitor Capability (optional)	Auto-Negotiation Package (mandatory)	Basic Package (mandatory)	MAU Control Package (optional)	Media Loss Tracking Package (conditional)	Broadband DTE MAU Package (conditional)	MII Capability (conditional)	PHY Error Monitor Capability (optional)	Auto-Negotiation Package (mandatory)
oMACControlEntity managed object class (30.3.3)																									
	aMACControlID	ATTRIBUTE	GET		X																				
	aMACControlFunctionsSupported	ATTRIBUTE	GET-SET		X																				
	aMACControlFramesTransmitted	ATTRIBUTE	GET			X																			
	aMACControlFramesReceived	ATTRIBUTE	GET			X																			
	aUnsupportedOpcodesReceived	ATTRIBUTE	GET			X																			
	aPFCEnableStatus	ATTRIBUTE	GET	X[2]																					

NOTE 1: The aMACCapabilities and aDuplexStatus attributes are mandatory in systems that can operate in full duplex mode. They are recommended in systems that can operate only in half duplex mode.

NOTE 2: The aPFCenableStatus attribute is mandatory in systems that support the PFC MAC Control Function. It is optional in systems that do not support the PFC MAC Control Function.

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Table 30–1c—Capabilities

			DTE								Repeater					MAU					
			Basic Package (mandatory)	Mandatory Package (mandatory)	Recommended Package (optional)	Optional Package (optional)	Array Package (optional)	Excessive Deferral Package (optional)	Multiple PHY Package (optional)	PHY Error Monitor Capability (optional)	Basic Control Capability (mandatory)	Performance Monitor Capability (optional)	Address Tracking Capability (optional)	100/1000 Mb/s Monitor Capability (optional)	1000 Mb/s Burst Monitor Capability (optional)	Basic Package (mandatory)	MAU Control Package (optional)	Media Loss Tracking Package (conditional)	Broadband DTE MAU Package (conditional)	MII Capability (conditional)	PHY Error Monitor Capability (optional)	Auto-Negotiation Package (mandatory)
oMACControlFunctionEntity managed object class (30.3.4)																					
aPAUSELinkDelayAllowance	ATTRIBUTE	GET-SET		X																	
aPAUSEMACCtrlFramesTransmitted	ATTRIBUTE	GET			X																
aPAUSEMACCtrlFramesReceived	ATTRIBUTE	GET			X																
oEXTENSION managed object class (30.3.8)																					
aEXTENSIONMACCtrlFramesTrans-	ATTRIBUTE	GET			X																
aEXTENSIONMACCtrlFramesRe-	ATTRIBUTE	GET			X																
oRepeater managed object class (30.4.1)																					
aRepeaterID	ATTRIBUTE	GET									X										
aRepeaterType	ATTRIBUTE	GET									X										
aRepeaterGroupCapacity	ATTRIBUTE	GET									X										
aGroupMap	ATTRIBUTE	GET									X										
aRepeaterHealthState	ATTRIBUTE	GET									X										
aRepeaterHealthText	ATTRIBUTE	GET									X										
aRepeaterHealthData	ATTRIBUTE	GET									X										
aTransmitCollisions	ATTRIBUTE	GET										X									
acResetRepeater	ACTION										X										
acExecuteNonDisruptiveSelfTest	ACTION										X										
nRepeaterHealth	NOTIFICATION										X										
nRepeaterReset	NOTIFICATION										X										
nGroupMapChange	NOTIFICATION										X										
oGroup managed object class (30.4.2)																					
aGroupID	ATTRIBUTE	GET									X										
aGroupPortCapacity	ATTRIBUTE	GET									X										
aPortMap	ATTRIBUTE	GET									X										
nPortMapChange	NOTIFICATION										X										

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Table 30–1d—Capabilities

				DTE								Repeater					MAU						
				Basic Package (mandatory)	Mandatory Package (mandatory)	Recommended Package (optional)	Optional Package (optional)	Array Package (optional)	Excessive Deferral Package (optional)	Multiple PHY Package (optional)	PHY Error Monitor Capability (optional)	Basic Control Capability (mandatory)	Performance Monitor Capability (optional)	Address Tracking Capability (optional)	100/1000 Mb/s Monitor Capability (optional)	1000 Mb/s Burst Monitor Capability (optional)	Basic Package (mandatory)	MAU Control Package (optional)	Media Loss Tracking Package (conditional)	Broadband DTE MAU Package (conditional)	MII Capability (conditional)	PHY Error Monitor Capability (optional)	Auto-Negotiation Package (mandatory)
oRepeaterPort managed object class (30.4.3)																							
	aPortID	ATTRIBUTE	GET									X											
	aPortAdminState	ATTRIBUTE	GET									X											
	aAutoPartitionState	ATTRIBUTE	GET									X											
	aReadableFrames	ATTRIBUTE	GET										X										
	aReadableOctets	ATTRIBUTE	GET										X										
	aFrameCheckSequenceErrors	ATTRIBUTE	GET										X										
	aAlignmentErrors	ATTRIBUTE	GET										X										
	aFramesTooLong	ATTRIBUTE	GET										X										
	aShortEvents	ATTRIBUTE	GET										X										
	aRunts	ATTRIBUTE	GET										X										
	aCollisions	ATTRIBUTE	GET										X										
	aLateEvents	ATTRIBUTE	GET										X										
	aVeryLongEvents	ATTRIBUTE	GET										X										
	aDataRateMismatches	ATTRIBUTE	GET										X										
	aAutoPartitions	ATTRIBUTE	GET										X										
	aIsolates	ATTRIBUTE	GET												X								
	aSymbolErrorDuringPacket	ATTRIBUTE	GET												X								
	aLastSourceAddress	ATTRIBUTE	GET											X									
	aSourceAddressChanges	ATTRIBUTE	GET											X									
	aBursts	ATTRIBUTE	GET													X							
	acPortAdminControl	ACTION										X											

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Table 30–1e—Capabilities

			DTE								Repeater					MAU									
			Basic Package (mandatory)	Mandatory Package (mandatory)	Recommended Package (optional)	Optional Package (optional)	Array Package (optional)	Excessive Deferral Package (optional)	Multiple PHY Package (optional)	PHY Error Monitor Capability (optional)	Basic Control Capability (mandatory)	Performance Monitor Capability (optional)	Address Tracking Capability (optional)	100/1000 Mb/s Monitor Capability (optional)	1000 Mb/s Burst Monitor Capability (optional)	Basic Package (mandatory)	MAU Control Package (optional)	Media Loss Tracking Package (conditional)	Broadband DTE MAU Package (conditional)	MII Capability (conditional)	PHY Error Monitor Capability (optional)	10GBASE-T Operating Margin Package (conditional)	Forward Error Correction Package (conditional)	Energy-Efficient Ethernet (optional)	Auto-Negotiation Package (mandatory)
oMAU managed object class (30.5.1)																									
aMAUID	ATTRIBUTE	GET														X									
aMAUType	ATTRIBUTE	GET-SET														X									
aMAUTypeList	ATTRIBUTE	GET														X									
aMediaAvailable	ATTRIBUTE	GET														X									
aLoseMediaCounter	ATTRIBUTE	GET																X							
aJabber	ATTRIBUTE	GET														X									
aMAUAdminState	ATTRIBUTE	GET														X									
aBbMAUXmitRcvSplitType	ATTRIBUTE	GET																	X						
aBroadbandFrequencies	ATTRIBUTE	GET																	X						
aFalseCarriers	ATTRIBUTE	GET																			X				
aBIPErrorCount	ATTRIBUTE	GET																			X				
aLaneMapping	ATTRIBUTE	GET																			X				
aRSFECBIPErrorCount	ATTRIBUTE	GET																			X				
aRSFECLaneMapping	ATTRIBUTE	GET																			X				
aIdleErrorCount	ATTRIBUTE	GET																			X				
aFECAbility	ATTRIBUTE	GET																				X			
aFECmode	ATTRIBUTE	GET-SET																				X			
aFECCorrectedBlocks	ATTRIBUTE	GET																				X			
aFECUncorrectableBlocks	ATTRIBUTE	GET																				X			
aRSFECBypassAbility	ATTRIBUTE	GET																				X			
aRSFECIndicationAbility	ATTRIBUTE	GET																				X			
aRSFECBypassEnable	ATTRIBUTE	GET-SET																				X			
aRSFECIndicationEnable	ATTRIBUTE	GET-SET																				X			
aSNROpMarginChnlA	ATTRIBUTE	GET																					X		
aSNROpMarginChnlB	ATTRIBUTE	GET																					X		
aSNROpMarginChnlC	ATTRIBUTE	GET																					X		
aSNROpMarginChnlD	ATTRIBUTE	GET																					X		
acResetMAU	ACTION																X								
acMAUAdminControl	ACTION																X								
nJabber	NOTIFICATION															X									
aLDFastRetrainCount	ATTRIBUTE	GET																						X	
aLPFastRetrainCount	ATTRIBUTE	GET																						X	

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Table 30–1e—Capabilities *(continued)*

			DTE								Repeater					MAU									
			Basic Package (mandatory)	Mandatory Package (mandatory)	Recommended Package (optional)	Optional Package (optional)	Array Package (optional)	Excessive Deferral Package (optional)	Multiple PHY Package (optional)	PHY Error Monitor Capability (optional)	Basic Control Capability (mandatory)	Performance Monitor Capability (optional)	Address Tracking Capability (optional)	100/1000 Mb/s Monitor Capability (optional)	1000 Mb/s Burst Monitor Capability (optional)	Basic Package (mandatory)	MAU Control Package (optional)	Media Loss Tracking Package (conditional)	Broadband DTE MAU Package (conditional)	MII Capability (conditional)	PHY Error Monitor Capability (optional)	10GBASE-T Operating Margin Package (conditional)	Forward Error Correction Package (conditional)	Energy-Efficient Ethernet (optional)	Auto-Negotiation Package (mandatory)
oAuto-Negotiation managed object class (30.6.1)																									
aAutoNegID	ATTRIBUTE	GET																							X
aAutoNegAdminState	ATTRIBUTE	GET																							X
aAutoNegRemoteSignaling	ATTRIBUTE	GET																							X
aAutoNegAutoConfig	ATTRIBUTE	GET-SET																							X
aAutoNegLocalTechnologyAbility	ATTRIBUTE	GET																							X
aAutoNegAdvertisedTechnologyAbil-	ATTRIBUTE	GET-SET																							X
aAutoNegReceivedTechnologyAbility	ATTRIBUTE	GET																							X
aAutoNegLocalSelectorAbility	ATTRIBUTE	GET																							X
aAutoNegAdvertisedSelectorAbility	ATTRIBUTE	GET-SET																							X
aAutoNegReceivedSelectorAbility	ATTRIBUTE	GET																							X
acAutoNegRestartAutoConfig	ACTION																								X
acAutoNegAdminControl	ACTION																								X
Common Attributes Template																									
aCMCounter	ATTRIBUTE	GET		X	X	X		X		X		X	X	X			X	X			X				

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Table 30–2—Link Aggregation capabilities

				DTE					
	Object name	Object type	Operations supported	Basic Package (mandatory)	Mandatory Package (mandatory)	Recommended Package (optional)	Optional Package (optional)	Aggregation Port Statistics (optional)	Aggregation Port Debug Information (optional)
oAggregator (30.7.1) NOTE—This object is deprecated by IEEE Std 802.1AX-2008									
	aAggID	ATTRIBUTE	GET	X					
	aAggDescription	ATTRIBUTE	GET		X				
	aAggName	ATTRIBUTE	GET-SET		X				
	aAggActorSystemID	ATTRIBUTE	GET-SET		X				
	aAggActorSystemPriority	ATTRIBUTE	GET-SET		X				
	aAggAggregateOrIndividual	ATTRIBUTE	GET		X				
	aAggActorAdminKey	ATTRIBUTE	GET-SET		X				
	aAggActorOperKey	ATTRIBUTE	GET		X				
	aAggMACAddress	ATTRIBUTE	GET		X				
	aAggPartnerSystemID	ATTRIBUTE	GET		X				
	aAggPartnerSystemPriority	ATTRIBUTE	GET		X				
	aAggPartnerOperKey	ATTRIBUTE	GET		X				
	aAggAdminState	ATTRIBUTE	GET-SET		X				
	aAggOperState	ATTRIBUTE	GET		X				
	aAggTimeOfLastOperChange	ATTRIBUTE	GET		X				
	aAggDataRate	ATTRIBUTE	GET		X				
	aAggOctetsTxOK	ATTRIBUTE	GET			X			
	aAggOctetsRxOK	ATTRIBUTE	GET			X			
	aAggFramesTxOK	ATTRIBUTE	GET		X				
	aAggFramesRxOK	ATTRIBUTE	GET		X				
	aAggMulticastFramesTxOK	ATTRIBUTE	GET				X		
	aAggMulticastFramesRxOK	ATTRIBUTE	GET				X		
	aAggBroadcastFramesTxOK	ATTRIBUTE	GET				X		
	aAggBroadcastFramesRxOK	ATTRIBUTE	GET				X		
	aAggFramesDiscardedOnTx	ATTRIBUTE	GET			X			
	aAggFramesDiscardedOnRx	ATTRIBUTE	GET			X			
	aAggFramesWithTxErrors	ATTRIBUTE	GET			X			

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Table 30–2—Link Aggregation capabilities *(continued)*

				DTE					
	Object name	Object type	Operations supported	Basic Package (mandatory)	Mandatory Package (mandatory)	Recommended Package (optional)	Optional Package (optional)	Aggregation Port Statistics (optional)	Aggregation Port Debug Information (optional)
	aAggFramesWithRxErrors	ATTRIBUTE	GET			X			
	aAggUnknownProtocolFrames	ATTRIBUTE	GET			X			
	aAggLinkUpDownNotificationEnable	ATTRIBUTE	GET-SET		X				
	nAggLinkUpNotification	NOTIFICATION			X				
	nAggLinkDownNotification	NOTIFICATION			X				
	aAggPortList	ATTRIBUTE	GET			X			
	aAggCollectorMaxDelay	ATTRIBUTE	GET-SET		X				
oAggregationPort (30.7.2) NOTE—This object is deprecated by IEEE Std 802.1AX-2008									
	aAggPortID	ATTRIBUTE	GET	X					
	aAggPortActorSystemPriority	ATTRIBUTE	GET-SET		X				
	aAggPortActorSystemID	ATTRIBUTE	GET		X				
	aAggPortActorAdminKey	ATTRIBUTE	GET-SET		X				
	aAggPortActorOperKey	ATTRIBUTE	GET		X				
	aAggPortPartnerAdminSystemPriority	ATTRIBUTE	GET-SET		X				
	aAggPortPartnerOperSystemPriority	ATTRIBUTE	GET		X				
	aAggPortPartnerAdminSystemID	ATTRIBUTE	GET-SET		X				
	aAggPortPartnerOperSystemID	ATTRIBUTE	GET		X				
	aAggPortPartnerAdminKey	ATTRIBUTE	GET-SET		X				
	aAggPortPartnerOperKey	ATTRIBUTE	GET		X				
	aAggPortSelectedAggID	ATTRIBUTE	GET		X				
	aAggPortAttachedAggID	ATTRIBUTE	GET		X				
	aAggPortActorPort	ATTRIBUTE	GET		X				
	aAggPortActorPortPriority	ATTRIBUTE	GET-SET		X				
	aAggPortPartnerAdminPort	ATTRIBUTE	GET-SET		X				
	aAggPortPartnerOperPort	ATTRIBUTE	GET		X				
	aAggPortPartnerAdminPortPriority	ATTRIBUTE	GET-SET		X				

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Table 30–2—Link Aggregation capabilities *(continued)*

				DTE					
	Object name	Object type	Operations supported	Basic Package (mandatory)	Mandatory Package (mandatory)	Recommended Package (optional)	Optional Package (optional)	Aggregation Port Statistics (optional)	Aggregation Port Debug Information (optional)
	aAggPortPartnerOperPortPriority	ATTRIBUTE	GET		X				
	aAggPortActorAdminState	ATTRIBUTE	GET-SET		X				
	aAggPortActorOperState	ATTRIBUTE	GET		X				
	aAggPortPartnerAdminState	ATTRIBUTE	GET-SET		X				
	aAggPortPartnerOperState	ATTRIBUTE	GET		X				
	aAggPortAggregateOrIndividual	ATTRIBUTE	GET		X				
oAggPortStats (30.7.3) Note—This object is deprecated by IEEE Std 802.1AX-2008									
	aAggPortStatsID	ATTRIBUTE	GET					X	
	aAggPortStatsLACPDUsRx	ATTRIBUTE	GET					X	
	aAggPortStatsMarkerPDUsRx	ATTRIBUTE	GET					X	
	aAggPortStatsMarkerResponsePDUsRx	ATTRIBUTE	GET					X	
	aAggPortStatsUnknownRx	ATTRIBUTE	GET					X	
	aAggPortStatsIllegalRx	ATTRIBUTE	GET					X	
	aAggPortStatsLACPDUsTx	ATTRIBUTE	GET					X	
	aAggPortStatsMarkerPDUsTx	ATTRIBUTE	GET					X	
	aAggPortStatsMarkerResponsePDUsTx	ATTRIBUTE	GET					X	
oAggPortDebugInformation (30.7.4) Note—This object is deprecated by IEEE Std 802.1AX-2008									
	aAggPortDebugInformationID	ATTRIBUTE	GET						X
	aAggPortDebugRxState	ATTRIBUTE	GET						X
	aAggPortDebugLastRxTime	ATTRIBUTE	GET						X
	aAggPortDebugMuxState	ATTRIBUTE	GET						X
	aAggPortDebugMuxReason	ATTRIBUTE	GET						X
	aAggPortDebugActorChurnState	ATTRIBUTE	GET						X
	aAggPortDebugPartnerChurnState	ATTRIBUTE	GET						X
	aAggPortDebugActorChurnCount	ATTRIBUTE	GET						X
	aAggPortDebugPartnerChurnCount	ATTRIBUTE	GET						X

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Table 30–2—Link Aggregation capabilities *(continued)*

				DTE					
	Object name	Object type	Operations supported	Basic Package (mandatory)	Mandatory Package (mandatory)	Recommended Package (optional)	Optional Package (optional)	Aggregation Port Statistics (optional)	Aggregation Port Debug Information (optional)
	aAggPortDebugActorSyncTransitionCount	ATTRIBUTE	GET						X
	aAggPortDebugPartnerSyncTransitionCount	ATTRIBUTE	GET						X
	aAggPortDebugActorChangeCount	ATTRIBUTE	GET						X
	aAggPortDebugPartnerChangeCount	ATTRIBUTE	GET						X
Common Attributes Template									
	aCMCounter	ATTRIBUTE	GET		X	X	X	X	X

Table 30–3—WIS capabilities

				WIS Basic Package (mandatory)	WIS Recommended Package (optional)
oWIS managed object class (30.8.1)					
	aWISID	ATTRIBUTE	GET	X	
	aSectionStatus	ATTRIBUTE	GET	X	
	aSectionSESThreshold	ATTRIBUTE	GET-SET		X
	aSectionSESs	ATTRIBUTE	GET		X
	aSectionESs	ATTRIBUTE	GET		X
	aSectionSEFSs	ATTRIBUTE	GET		X
	aSectionCVs	ATTRIBUTE	GET		X
	aJ0ValueTX	ATTRIBUTE	GET-SET		X
	aJ0ValueRX	ATTRIBUTE	GET		X
	aLineStatus	ATTRIBUTE	GET	X	

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Table 30–3—WIS capabilities

				WIS Basic Package (mandatory)	WIS Recommended Package (optional)
	aLineSESThreshold	ATTRIBUTE	GET-SET		X
	aLineSESs	ATTRIBUTE	GET		X
	aLineESs	ATTRIBUTE	GET		X
	aLineCVs	ATTRIBUTE	GET		X
	aFarEndLineSESs	ATTRIBUTE	GET		X
	aFarEndLineESs	ATTRIBUTE	GET		X
	aFarEndLineCVs	ATTRIBUTE	GET		X
	aPathStatus	ATTRIBUTE	GET	X	
	aPathSESThreshold	ATTRIBUTE	GET-SET		X
	aPathSESs	ATTRIBUTE	GET		X
	aPathESs	ATTRIBUTE	GET		X
	aPathCVs	ATTRIBUTE	GET		X
	aJ1ValueTX	ATTRIBUTE	GET-SET		X
	aJ1ValueRX	ATTRIBUTE	GET		X
	aFarEndPathStatus	ATTRIBUTE	GET	X	
	aFarEndPathSESs	ATTRIBUTE	GET		X
	aFarEndPathESs	ATTRIBUTE	GET		X
	aFarEndPathCVs	ATTRIBUTE	GET		X
Common Attributes Template					
	aCMCounter	ATTRIBUTE	GET		X

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Table 30–4—DTE Power via MDI capabilities

				PSE Basic Package (mandatory)	PSE Recommended Package (optional)	Midspan Basic Capability (mandatory)	PD Basic Package (mandatory)
oResourceTypeID managed object							
	aResourceTypeIDName	ATTRIBUTE	GET			X	
	aResourceInfo	ATTRIBUTE	GET			X	
oMidSpan managed object class (30.10.1)							
	aMidSpanID	ATTRIBUTE	GET			X	
	aMidSpanPSEGroupCapacity	ATTRIBUTE	GET			X	
	aMidSpanPSEGroupMap	ATTRIBUTE	GET			X	
	nMidSpanPSEGroupMapChange	NOTIFICATION				X	
oPSEGroup managed object class (30.10.2)							
	aPSEGroupID	ATTRIBUTE	GET			X	
	aPSECapacity	ATTRIBUTE	GET			X	
	aPSEMap	ATTRIBUTE	GET			X	
	nPSEMapChange	NOTIFICATION				X	
oPSE managed object class (30.9.1)							
	aPSEID	ATTRIBUTE	GET	X			
	aPSEAdminState	ATTRIBUTE	GET	X			
	aPSEPowerPairsControlAbility	ATTRIBUTE	GET	X			
	aPSEPowerPairs	ATTRIBUTE	GET-SET	X			
	aPSEPowerDetectionStatus	ATTRIBUTE	GET	X			
	aPSEPowerClassification	ATTRIBUTE	GET		X		
	aPSEInvalidSignatureCounter	ATTRIBUTE	GET		X		
	aPSEPowerDeniedCounter	ATTRIBUTE	GET		X		
	aPSEOverLoadCounter	ATTRIBUTE	GET		X		
	aPSEShortCounter	ATTRIBUTE	GET		X		
	aPSEMPSAbsentCounter	ATTRIBUTE	GET		X		
	acPSEAdminControl	ACTION		X			
	aPSEActualPower	ATTRIBUTE	GET		X		
	aPSEPowerAccuracy	ATTRIBUTE	GET		X		
	aPSECumulativeEnergy	ATTRIBUTE	GET		X		
oPD managed object class (30.9.2)							
	aPDID	ATTRIBUTE	GET				X
Common Attributes Template							
	aCMCounter	ATTRIBUTE	GET		X		

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Table 30–5—EFM capabilities

				DTE				MAU		PME		
				Multipoint Control Protocol Package (conditional)	Operation Administration Maintenance Package (conditional)	Optical Multipoint Emulation Package (conditional)	Optical Multipoint Emulation Monitor Package (optional)	PCS Code Error Monitor Package (optional)	Forward Error Correction Package (conditional)	Basic Package (mandatory)	PME Aggregation Package (optional)	10P/2B Package (mandatory)
oMPCP managed object class (30.3.5)												
	aMPCPID	ATTRIBUTE	GET	X								
	aMPCPAdminState	ATTRIBUTE	GET	X								
	aMPCPMode	ATTRIBUTE	GET	X								
	aMPCPLinkID	ATTRIBUTE	GET	X								
	aMPCPRemoteMACAddress	ATTRIBUTE	GET	X								
	aMPCPRegistrationState	ATTRIBUTE	GET	X								
	aMPCPMACCtrlFramesTransmitted	ATTRIBUTE	GET	X								
	aMPCPMACCtrlFramesReceived	ATTRIBUTE	GET	X								
	aMPCPTxGate	ATTRIBUTE	GET	X								
	aMPCPTxRegAck	ATTRIBUTE	GET	X								
	aMPCPTxRegister	ATTRIBUTE	GET	X								
	aMPCPTxRegRequest	ATTRIBUTE	GET	X								
	aMPCPTxReport	ATTRIBUTE	GET	X								
	aMPCPRxGate	ATTRIBUTE	GET	X								
	aMPCPRxRegAck	ATTRIBUTE	GET	X								
	aMPCPRxRegister	ATTRIBUTE	GET	X								
	aMPCPRxRegRequest	ATTRIBUTE	GET	X								
	aMPCPRxReport	ATTRIBUTE	GET	X								
	aMPCPTransmitElapsed	ATTRIBUTE	GET	X								
	aMPCPReceiveElapsed	ATTRIBUTE	GET	X								
	aMPCPRoundTripTime	ATTRIBUTE	GET	X								
	aMPCPDiscoveryWindowsSent	ATTRIBUTE	GET	X								
	aMPCPDiscoveryTimeout	ATTRIBUTE	GET	X								
	aMPCPMaximumPendingGrants	ATTRIBUTE	GET	X								
	aMPCPRecognizedMulticastIDs	ATTRIBUTE	GET	X								
	acMPCPAdminControl	ACTION		X								

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Table 30–5—EFM capabilities *(continued)*

				DTE				MAU		PME		
				Multipoint Control Protocol Package (conditional)	Operation Administration Maintenance Package (conditional)	Optical Multipoint Emulation Package (conditional)	Optical Multipoint Emulation Monitor Package (optional)	PCS Code Error Monitor Package (optional)	Forward Error Correction Package (conditional)	Basic Package (mandatory)	PME Aggregation Package (optional)	10P/2B Package (mandatory)
oOAM managed object class (30.3.6)												
	aMACControlID	ATTRIBUTE	GET		X							
	aOAMAdminState	ATTRIBUTE	GET		X							
	aOAMDiscoveryState	ATTRIBUTE	GET		X							
	aOAMRemoteMACAddress	ATTRIBUTE	GET		X							
	aOAMLocalConfiguration	ATTRIBUTE	GET		X							
	aOAMRemoteConfiguration	ATTRIBUTE	GET		X							
	aOAMLocalPDUConfiguration	ATTRIBUTE	GET		X							
	aOAMRemotePDUConfiguration	ATTRIBUTE	GET		X							
	aOAMLocalFlagsField	ATTRIBUTE	GET		X							
	aOAMRemoteFlagsField	ATTRIBUTE	GET		X							
	aOAMLocalRevision	ATTRIBUTE	GET		X							
	aOAMRemoteRevision	ATTRIBUTE	GET		X							
	aOAMLocalState	ATTRIBUTE	GET		X							
	aOAMRemoteState	ATTRIBUTE	GET		X							
	aOAMRemoteVendorOUI	ATTRIBUTE	GET		X							
	aOAMRemoteVendorSpecificInfo	ATTRIBUTE	GET		X							
	aOAMUnsupportedCodesTx	ATTRIBUTE	GET		X							
	aUnsupportedOpcodesReceived	ATTRIBUTE	GET		X							
	aOAMInformationTx	ATTRIBUTE	GET		X							
	aOAMInformationRx	ATTRIBUTE	GET		X							
	aOAMUniqueEventNotificationTx	ATTRIBUTE	GET		X							
	aOAMDuplicateEventNotificationTx	ATTRIBUTE	GET		X							
	aOAMUniqueEventNotificationRx	ATTRIBUTE	GET		X							
	aOAMDuplicateEventNotificationRx	ATTRIBUTE	GET		X							
	aOAMLoopbackControlTx	ATTRIBUTE	GET		X							
	aOAMLoopbackControlRx	ATTRIBUTE	GET		X							
	aOAMVariableRequestTx	ATTRIBUTE	GET		X							
	aOAMVariableRequestRx	ATTRIBUTE	GET		X							
	aOAMVariableResponseTx	ATTRIBUTE	GET		X							
	aOAMVariableResponseRx	ATTRIBUTE	GET		X							

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Table 30–5—EFM capabilities *(continued)*

				DTE				MAU		PME		
				Multipoint Control Protocol Package (conditional)	Operation Administration Maintenance Package (conditional)	Optical Multipoint Emulation Package (conditional)	Optical Multipoint Emulation Monitor Package (optional)	PCS Code Error Monitor Package (optional)	Forward Error Correction Package (conditional)	Basic Package (mandatory)	PME Aggregation Package (optional)	10P/2B Package (mandatory)
	aOAMOrganizationSpecificTx	ATTRIBUTE	GET		X							
	aOAMOrganizationSpecificRx	ATTRIBUTE	GET		X							
	aOAMLocalErrSymPeriodConfig	ATTRIBUTE	GET		X							
	aOAMLocalErrSymPeriodEvent	ATTRIBUTE	GET		X							
	aOAMLocalErrFrameConfig	ATTRIBUTE	GET		X							
	aOAMLocalErrFrameEvent	ATTRIBUTE	GET		X							
	aOAMLocalErrFramePeriodConfig	ATTRIBUTE	GET		X							
	aOAMLocalErrFramePeriodEvent	ATTRIBUTE	GET		X							
	aOAMLocalErrFrameSecsSummaryConfig	ATTRIBUTE	GET		X							
	aOAMLocalErrFrameSecsSummaryEvent	ATTRIBUTE	GET		X							
	aOAMRemoteErrSymPeriodEvent	ATTRIBUTE	GET		X							
	aOAMRemoteErrFrameEvent	ATTRIBUTE	GET		X							
	aOAMRemoteErrFramePeriodEvent	ATTRIBUTE	GET		X							
	aOAMRemoteErrFrameSecsSummaryEvent	ATTRIBUTE	GET		X							
	aFramesLostDueToOAMError	ATTRIBUTE	GET		X							
	acOAMAdminControl	ACTION			X							
oOMPEmulation managed object class (30.3.7)												
	aOMPEmulationID	ATTRIBUTE	GET			X						
	aOMPEmulationType	ATTRIBUTE	GET			X						
	aSLDErrors	ATTRIBUTE	GET			X						
	aCRC8Errors	ATTRIBUTE	GET			X						
	aGoodLLID	ATTRIBUTE	GET				X					
	aONUPONcastLLID	ATTRIBUTE	GET				X					
	aOLTPONcastLLID	ATTRIBUTE	GET				X					
	aBadLLID	ATTRIBUTE	GET				X					
oMAU managed object class (30.5.1)												
	aPCSCodingViolation	ATTRIBUTE	GET					X				
	aFECAbility	ATTRIBUTE	GET						X			
	aFECmode	ATTRIBUTE	GET-SET						X			
	aFECCorrectedBlocks	ATTRIBUTE	GET						X			
	aFECUncorrectableBlocks	ATTRIBUTE	GET						X			

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Table 30–5—EFM capabilities *(continued)*

			DTE				MAU		PME		
			Multipoint Control Protocol Package (conditional)	Operation Administration Maintenance Package (conditional)	Optical Multipoint Emulation Package (conditional)	Optical Multipoint Emulation Monitor Package (optional)	PCS Code Error Monitor Package (optional)	Forward Error Correction Package (conditional)	Basic Package (mandatory)	PME Aggregation Package (optional)	10P/2B Package (mandatory)
oPAF managed object class (30.11.1)											
aPAFID	ATTRIBUTE	GET							X		
aPhyEnd	ATTRIBUTE	GET							X		
aPHYCurrentStatus	ATTRIBUTE	GET							X		
aPAFSupported	ATTRIBUTE	GET							X		
aPAFAdminState	ATTRIBUTE	GET-SET								X	
aLocalPAFCapacity	ATTRIBUTE	GET								X	
aLocalPMEAvailable	ATTRIBUTE	GET								X	
aLocalPMEAggregate	ATTRIBUTE	GET								X	
aRemotePAFSupported	ATTRIBUTE	GET								X	
aRemotePAFCapacity	ATTRIBUTE	GET								X	
aRemotePMEAggregate	ATTRIBUTE	GET								X	
oPME managed object class (30.11.2)											
aPMEID	ATTRIBUTE	GET									X
aPMEAdminState	ATTRIBUTE	GET-SET									X
aPMEStatus	ATTRIBUTE	GET									X
aPMESNRMgn	ATTRIBUTE	GET									X
aTCCodingViolations	ATTRIBUTE	GET									X
aProfileSelect	ATTRIBUTE	GET-SET									X
aOperatingProfile	ATTRIBUTE	GET									X
aPMEFECCorrectedBlocks	ATTRIBUTE	GET									X
aPMEFECUncorrectableBlocks	ATTRIBUTE	GET									X
aTCCRCErrors	ATTRIBUTE	GET									X
Common Attributes Template											
aCMCounter	ATTRIBUTE	GET	X	X	X	X	X	X		X	X

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Table 30–6—TimeSync Capabilities

				Support for Time Sync(mandatory)
oTimeSync managed object				
	aTimeSyncCapabilityTX	ATTRIBUTE	GET	X
	aTimeSyncCapabilityRX	ATTRIBUTE	GET	X
	aTimeSyncDelayTXmax	ATTRIBUTE	GET	X
	aTimeSyncDelayTXmin	ATTRIBUTE	GET	X
	aTimeSyncDelayRXmax	ATTRIBUTE	GET	X
	aTimeSyncDelayRXmin	ATTRIBUTE	GET	X

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Table 30–7—LLDP capabilities

				LLDP Basic Package (mandatory)	LLDP MAC/PHY Configuration/Status Local Package (conditional)	LLDP MAC/PHY Configuration/Status Remote Package (conditional)	LLDP Power via MDI Local Package (conditional)	LLDP Power via MDI Remote Package (conditional)	LLDP Link Aggregation Local Package (conditional)	LLDP Link Aggregation Remote Package (conditional)	LLDP Maximum Frame Size Local Package (conditional)	LLDP Maximum Frame Size Remote Package (conditional)	LLDP EEE Local Package (optional)	LLDP EEE Remote Package (optional)
oLldpXdot3Config managed object class (30.12.1)														
	aLldpXdot3PortConfigTLVsTxEnable	ATTRIBUTE	GET-SET	X										
oLldpXdot3LocSystemsGroup managed object class (30.12.2)														
	aLldpXdot3LocPortAutoNegSupported	ATTRIBUTE	GET		X									
	aLldpXdot3LocPortAutoNegEnabled	ATTRIBUTE	GET		X									
	aLldpXdot3LocPortAutoNegAdvertisedCap	ATTRIBUTE	GET		X									
	aLldpXdot3LocPortOperMauType	ATTRIBUTE	GET		X									
	aLldpXdot3LocPowerPortClass	ATTRIBUTE	GET				X							
	aLldpXdot3LocPowerMDISupported	ATTRIBUTE	GET				X							
	aLldpXdot3LocPowerMDIEnabled	ATTRIBUTE	GET				X							
	aLldpXdot3LocPowerPairControlable	ATTRIBUTE	GET				X							
	aLldpXdot3LocPowerPairs	ATTRIBUTE	GET				X							
	aLldpXdot3LocPowerClass	ATTRIBUTE	GET				X							
	aLldpXdot3LocLinkAggStatus	ATTRIBUTE	GET						X					
	aLldpXdot3LocLinkAggPortId	ATTRIBUTE	GET						X					
	aLldpXdot3LocMaxFrameSize	ATTRIBUTE	GET								X			
	aLldpXdot3LocPowerType	ATTRIBUTE	GET				X							
	aLldpXdot3LocPowerSource	ATTRIBUTE	GET				X							
	aLldpXdot3LocPowerPriority	ATTRIBUTE	GET-SET				X							
	aLldpXdot3LocPDRequestedPowerValue	ATTRIBUTE	GET				X							
	aLldpXdot3LocPSEAllocatedPowerValue	ATTRIBUTE	GET				X							
	aLldpXdot3LocResponseTime	ATTRIBUTE	GET				X							
	aLldpXdot3LocReady	ATTRIBUTE	GET				X							
	aLldpXdot3LocReducedOperationPowerValue	ATTRIBUTE	GET				X							
	aLldpXdot3LocTxTwSys	ATTRIBUTE	GET										X	
	aLldpXdot3LocTxTwSysEcho	ATTRIBUTE	GET										X	
	aLldpXdot3LocRxTwSys	ATTRIBUTE	GET										X	
	aLldpXdot3LocRxTwSysEcho	ATTRIBUTE	GET										X	
	aLldpXdot3LocFbTwSys	ATTRIBUTE	GET										X	
	aLldpXdot3TxDllReady	ATTRIBUTE	GET										X	

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Table 30–7—LLDP capabilities *(continued)*

				LLDP Basic Package (mandatory)	LLDP MAC/PHY Configuration/Status Local Package (conditional)	LLDP MAC/PHY Configuration/Status Remote Package (conditional)	LLDP Power via MDI Local Package (conditional)	LLDP Power via MDI Remote Package (conditional)	LLDP Link Aggregation Local Package (conditional)	LLDP Link Aggregation Remote Package (conditional)	LLDP Maximum Frame Size Local Package (conditional)	LLDP Maximum Frame Size Remote Package (conditional)	LLDP EEE Local Package (optional)	LLDP EEE Remote Package (optional)
	aLldpXdot3RxDllReady	ATTRIBUTE	GET										X	
	aLldpXdot3LocDllEnabled	ATTRIBUTE	GET										X	
	aLldpXdot3LocTxFw	ATTRIBUTE	GET										X	
	aLldpXdot3LocTxFwEcho	ATTRIBUTE	GET										X	
	aLldpXdot3LocRxFw	ATTRIBUTE	GET										X	
	aLldpXdot3LocRxFwEcho	ATTRIBUTE	GET										X	
oLldpXdot3RemSystemsGroup managed object class (30.12.3)														

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Table 30–7—LLDP capabilities *(continued)*

				LLDP Basic Package (mandatory)	LLDP MAC/PHY Configuration/Status Local Package (conditional)	LLDP MAC/PHY Configuration/Status Remote Package (conditional)	LLDP Power via MDI Local Package (conditional)	LLDP Power via MDI Remote Package (conditional)	LLDP Link Aggregation Local Package (conditional)	LLDP Link Aggregation Remote Package (conditional)	LLDP Maximum Frame Size Local Package (conditional)	LLDP Maximum Frame Size Remote Package (conditional)	LLDP EEE Local Package (optional)	LLDP EEE Remote Package (optional)
	aLldpXdot3RemPortAutoNegSupported	ATTRIBUTE	GET			X								
	aLldpXdot3RemPortAutoNegEnabled	ATTRIBUTE	GET			X								
	aLldpXdot3RemPortAutoNegAdvertisedCap	ATTRIBUTE	GET			X								
	aLldpXdot3RemPortOperMauType	ATTRIBUTE	GET			X								
	aLldpXdot3RemPowerPortClass	ATTRIBUTE	GET					X						
	aLldpXdot3RemPowerMDISupported	ATTRIBUTE	GET					X						
	aLldpXdot3RemPowerMDIEnabled	ATTRIBUTE	GET					X						
	aLldpXdot3RemPowerPairControlable	ATTRIBUTE	GET					X						
	aLldpXdot3RemPowerPairs	ATTRIBUTE	GET					X						
	aLldpXdot3RemPowerClass	ATTRIBUTE	GET					X						
	aLldpXdot3RemLinkAggStatus	ATTRIBUTE	GET							X				
	aLldpXdot3RemLinkAggPortId	ATTRIBUTE	GET							X				
	aLldpXdot3RemMaxFrameSize	ATTRIBUTE	GET									X		
	aLldpXdot3RemPowerType	ATTRIBUTE	GET					X						
	aLldpXdot3RemPowerSource	ATTRIBUTE	GET					X						
	aLldpXdot3RemPowerPriority	ATTRIBUTE	GET					X						
	aLldpXdot3RemPDRequestedPowerValue	ATTRIBUTE	GET					X						
	aLldpXdot3RemPSEAllocatedPowerValue	ATTRIBUTE	GET					X						
	aLldpXdot3RemTxTwSys	ATTRIBUTE	GET											X
	aLldpXdot3RemTxTwSysEcho	ATTRIBUTE	GET											X
	aLldpXdot3RemRxTwSys	ATTRIBUTE	GET											X
	aLldpXdot3RemRxTwSysEcho	ATTRIBUTE	GET											X
	aLldpXdot3RemFbTwSys	ATTRIBUTE	GET											X
	aLldpXdot3RemTxFw	ATTRIBUTE	GET											X
	aLldpXdot3RemTxFwEcho	ATTRIBUTE	GET											X
	aLldpXdot3RemRxFw	ATTRIBUTE	GET											X
	aLldpXdot3RemRxFwEcho	ATTRIBUTE	GET											X

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30.3 Layer management for DTEs

30.3.1 MAC entity managed object class

This subclause formally defines the behaviours for the oMACEntity managed object class attributes, actions, and notifications.

30.3.1.1 MAC entity attributes

30.3.1.1.1 aMACID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of aMACID is assigned so as to uniquely identify a MAC among the subordinate managed objects of the containing object.;

30.3.1.1.2 aFramesTransmittedOK

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
A count of frames that are successfully transmitted. This counter is incremented when the TransmitStatus is reported as transmitOK. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2).;

30.3.1.1.3 aSingleCollisionFrames

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 13 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
A count of frames that are involved in a single collision, and are subsequently transmitted successfully. This counter is incremented when the result of a transmission is reported as transmitOK and the attempt value is 2. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2). The contents of this attribute are undefined for MAC entities operating in full duplex mode.;

30.3.1.1.4 aMultipleCollisionFrames

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 11 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
A count of frames that are involved in more than one collision and are subsequently transmitted

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successfully. This counter is incremented when the TransmitStatus is reported as transmitOK and the value of the attempts variable is greater than 2 and less or equal to attemptLimit. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2). The contents of this attribute are undefined for MAC entities operating in full duplex mode.;

30.3.1.1.5 aFramesReceivedOK

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

A count of frames that are successfully received (receiveOK). This does not include frames received with frame-too-long, FCS, length or alignment errors, or frames lost due to internal MAC sublayer error. This counter is incremented when the ReceiveStatus is reported as receiveOK. The actual update occurs in the LayerMgmtReceiveCounters procedure (5.2.4.3).;

30.3.1.1.6 aFrameCheckSequenceErrors

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

A count of receive frames that are an integral number of octets in length and do not pass the FCS check. This does not include frames received with frame-too-long, or frame-too-short (frame fragment) error. This counter is incremented when the ReceiveStatus is reported as frameCheckError. The actual update occurs in the LayerMgmtReceiveCounters procedure (5.2.4.3).

NOTE—Coding errors detected by the Physical Layer for speeds above 10 Mb/s will cause the frame to fail the FCS check.;

30.3.1.1.7 aAlignmentErrors

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

A count of frames that are not an integral number of octets in length and do not pass the FCS check. This counter is incremented when the ReceiveStatus is reported as alignmentError. The actual update occurs in the LayerMgmtReceiveCounters procedure (5.2.4.3). This counter will not increment for group encoding schemes encoding greater than 4 bits per group.;

30.3.1.1.8 aOctetsTransmittedOK

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 230 000 counts per second at 10 Mb/s

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BEHAVIOUR DEFINED AS:

A count of data and padding octets of frames that are successfully transmitted. This counter is incremented when the TransmitStatus is reported as transmitOK. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2).;

30.3.1.1.9 aFramesWithDeferredXmissions

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 13 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

A count of frames whose transmission was delayed on its first attempt because the medium was busy. This counter is incremented when the Boolean variable deferred has been asserted by the TransmitLinkMgmt function (4.2.8). Frames involved in any collisions are not counted. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2). The contents of this attribute are undefined for MAC entities operating in full duplex mode.;

30.3.1.1.10 aLateCollisions

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

A count of the times that a collision has been detected later than one slotTime from the start of the packet transmission. A late collision is counted twice, i.e., both as a collision and as a lateCollision. This counter is incremented when the lateCollisionCount variable is nonzero. The actual update is incremented in the LayerMgmtTransmitCounters procedure (5.2.4.2). The contents of this attribute are undefined for MAC entities operating in full duplex mode.;

30.3.1.1.11 aFramesAbortedDueToXSColls

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 3255 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

A count of the frames that, due to excessive collisions, are not transmitted successfully. This counter is incremented when the value of the attempts variable equals attemptLimit during a transmission. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2). The contents of this attribute are undefined for MAC entities operating in full duplex mode.;

30.3.1.1.12 aFramesLostDueToIntMACXmitError

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 75 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

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A count of frames that would otherwise be transmitted by the station, but could not be sent due to an internal MAC sublayer transmit error. If this counter is incremented, then none of the other counters in this section are incremented. The exact meaning and mechanism for incrementing this counter is implementation dependent.;

30.3.1.1.13 aCarrierSenseErrors

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
A count of times that the carrierSense variable was not asserted or was deasserted during the transmission of a frame without collision. This counter is incremented when the carrierSenseFailure flag is true at the end of transmission. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2). The contents of this attribute are undefined for MAC entities operating in full duplex mode.;

30.3.1.1.14 aOctetsReceivedOK

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 1 230 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
A count of data and padding octets in frames that are successfully received. This does not include octets in frames received with frame-too-long, FCS, length or alignment errors, or frames lost due to internal MAC sublayer error. This counter is incremented when the result of a reception is reported as a receiveOK status. The actual update occurs in the LayerMgmtReceiveCounters procedure (5.2.4.3).;

30.3.1.1.15 aFramesLostDueToIntMACRcvError

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
A count of frames that would otherwise be received by the station, but could not be accepted due to an internal MAC sublayer receive error. If this counter is incremented, then none of the other counters in this section are incremented. The exact meaning and mechanism for incrementing this counter is implementation dependent.;

30.3.1.1.16 aPromiscuousStatus

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
A GET operation returns the value “true” for promiscuous mode enabled, and “false” otherwise.

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Frames without errors received solely because this attribute has the value “true” are counted as frames received correctly; frames received in this mode that do contain errors update the appropriate error counters.

A SET operation to the value “true” provides a means to cause the LayerMgmtRecognizeAddress function to accept frames regardless of their destination address.

A SET operation to the value “false” causes the MAC sublayer to return to the normal operation of carrying out address recognition procedures for station, broadcast, and multicast group addresses (LayerMgmtRecognizeAddress function).;

30.3.1.1.17 aReadMulticastAddressList

ATTRIBUTE

APPROPRIATE SYNTAX:
SEQUENCE OF MAC addresses

BEHAVIOUR DEFINED AS:
The current multicast address list.;

30.3.1.1.18 aMulticastFramesXmittedOK

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
A count of frames that are successfully transmitted, as indicated by the status value transmitOK, to a group destination address other than broadcast. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2).;

30.3.1.1.19 aBroadcastFramesXmittedOK

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
A count of the frames that were successfully transmitted as indicated by the TransmitStatus transmitOK, to the broadcast address. Frames transmitted to multicast addresses are not broadcast frames and are excluded. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2).;

30.3.1.1.20 aFramesWithExcessiveDeferral

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 412 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

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A count of frames that deferred for an excessive period of time. This counter may only be incremented once per LLC transmission. This counter is incremented when the excessDefer flag is set. The actual update occurs in the LayerMgmtTransmitCounters procedure (5.2.4.2). The contents of this attribute are undefined for MAC entities operating in full duplex mode and also when connected to a PHY utilizing the MAC-PHY Rate Matching defined in 61.2.1.1.;

30.3.1.1.21 aMulticastFramesReceivedOK

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

A count of frames that are successfully received and are directed to an active nonbroadcast group address. This does not include frames received with frame-too-long, FCS, length or alignment errors, or frames lost due to internal MAC sublayer error. This counter is incremented as indicated by the receiveOK status, and the value in the destinationField. The actual update occurs in the LayerMgmtReceiveCounters procedure (5.2.4.3).;

30.3.1.1.22 aBroadcastFramesReceivedOK

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

A count of frames that are successfully received and are directed to the broadcast group address. This does not include frames received with frame-too-long, FCS, length or alignment errors, or frames lost due to internal MAC sublayer error. This counter is incremented as indicated by the receiveOK status, and the value in the destinationField. The actual update occurs in the LayerMgmtReceiveCounters procedure (5.2.4.3).;

30.3.1.1.23 aInRangeLengthErrors

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

A count of MAC frames received with a Length/Type field (see 3.2.6) value between the minimum MAC client data size that does not require padding and maxBasicDataSize (see 4.2.7.1) inclusive, that does not match the number of data octets received. The counter also increments for frames whose Length/Type field value is less than the minimum allowed MAC client data size that does not require padding and the number of data octets received is greater than the minimum MAC client data size that does not require padding. The actual update occurs in the LayerMgmtReceiveCounters procedure (5.2.4.3).;

30.3.1.1.24 aOutOfRangeLengthField

ATTRIBUTE

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APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
A count of MAC frames received with a Length/Type field value that is greater than maxBasicDataSize (see 4.2.7.1). The actual update occurs in the LayerMgmtReceiveCounters procedure (5.2.4.3).

NOTE—Before IEEE Std 802.3x-1997, this counter was incremented by frames containing "Type" fields. Due to the modification to legitimize "Type" fields, such frames will now increment aFramesReceivedOK and this counter may only increment with a Length/Type field value that is between maxBasicDataSize and minTypeValue, exclusive (see 4.2.7.1 and 4.2.9).;

30.3.1.1.25 aFrameTooLongErrors

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 815 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
A count of MAC frames received that exceed maxFrameSizeLimit (see 4.2.7.1). This counter is incremented when the status of a frame reception is frameTooLong. The actual update occurs in the LayerMgmtReceiveCounters procedure (5.2.4.3).;

30.3.1.1.26 aMACEnableStatus

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
True if MAC sublayer is enabled and false if disabled. This is accomplished by setting or checking the values of the receiveEnabled and transmitEnabled variables. Setting to true provides a means to cause the MAC sublayer to enter the normal operational state at idle. The PLS is reset by this operation (see 7.2.2.2.1). This is accomplished by setting receiveEnabled and transmitEnabled to true.
Setting to false causes the MAC sublayer to end all transmit and receive operations, leaving it in a disabled state. This is accomplished by setting receiveEnabled and transmitEnabled to false.;

30.3.1.1.27 aTransmitEnableStatus

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
True if transmission is enabled and false otherwise. This is accomplished by setting or checking the value of the transmitEnabled variable.
Setting this to true provides a means to enable MAC sublayer frame transmission (TransmitFrame function). This is accomplished by setting transmitEnabled to true.
Setting this to false will inhibit the transmission of further frames by the MAC sublayer (TransmitFrame function). This is accomplished by setting transmitEnabled to false.;

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30.3.1.1.28 aMulticastReceiveStatus

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
True if multicast receive is enabled, and false otherwise. Setting this to true provides a means to cause the MAC sublayer to return to the normal operation of multicast frame reception. Setting this to false will inhibit the reception of further multicast frames by the MAC sublayer.;

30.3.1.1.29 aReadWriteMACAddress

ATTRIBUTE

APPROPRIATE SYNTAX:
MACAddress

BEHAVIOUR DEFINED AS:
Read the MAC station address or change the MAC station address to the one supplied (RecognizeAddress function). Note that the supplied station address shall not have the group bit set and shall not be the null address.;

30.3.1.1.30 aCollisionFrames

ATTRIBUTE

APPROPRIATE SYNTAX:
A SEQUENCE of 32 generalized nonresettable counters. Each counter has a maximum increment rate of 13 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
A histogram of collision activity. The indices of this array (1 to attemptLimit – 1) denote the number of collisions experienced in transmitting a frame. Each element of this array contains a counter that denotes the number of frames that have experienced a specific number of collisions. When the TransmitStatus is reported as transmitOK and the value of the attempts variable equals n, then collisionFrames[n–1] counter is incremented. The elements of this array are incremented in the LayerMgmtTransmitCounters procedure (5.2.4.2). The contents of this attribute are undefined for MAC entities operating in full duplex mode.;

30.3.1.1.31 aMACCapabilities

ATTRIBUTE

APPROPRIATE SYNTAX:
A SEQUENCE that meets the requirements of the description below:

half duplex	Capable of operating in half duplex mode
full duplex	Capable of operating in full duplex mode

BEHAVIOUR DEFINED AS:
This indicates the duplex capabilities of the MAC.;

30.3.1.1.32 aDuplexStatus

ATTRIBUTE

APPROPRIATE SYNTAX:

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An ENUMERATED VALUE that has one of the following entries:

half duplex	Half duplex mode
full duplex	Full duplex mode
unknown	Duplex status unknown

BEHAVIOUR DEFINED AS:

A GET operation returns the current mode of operation of the MAC entity, either half duplex, full duplex, or unknown. A SET operation changes the mode of operation of the MAC entity to the indicated value. A SET operation shall have no effect on a device whose mode cannot be changed through management or that can only operate in a single mode.;

30.3.1.1.33 aRateControlAbility

ATTRIBUTE

APPROPRIATE SYNTAX:

BOOLEAN

BEHAVIOUR DEFINED AS:

"True" for operating speeds above 1000 Mb/s where Rate Control through lowering the average data rate of the MAC sublayer, with frame granularity, is supported (see 4.2.3.2.2), and "false" otherwise.;

30.3.1.1.34 aRateControlStatus

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has one of the following entries:

rate control off	Rate control mode disabled
rate control on	Rate control mode enabled
unknown	Rate control mode unknown

BEHAVIOUR DEFINED AS:

A GET operation returns the current Rate Control mode of operation of the MAC sublayer.

A SET operation changes the mode of operation of the MAC sublayer to the indicated value. A SET operation shall have no effect on a device whose mode cannot be changed through management or that can only operate in a single mode.

This attribute maps to the variable ifsStretchMode (see 4.2.7.2).;

30.3.1.1.35 aDeferControlAbility

ATTRIBUTE

APPROPRIATE SYNTAX:

BOOLEAN

BEHAVIOUR DEFINED AS:

The enumeration "true" is returned when the interframe spacing is accomplished within the MAC sublayer (see 4A.2.3.2.3), the enumeration "false" is returned otherwise.;

30.3.1.1.36 aDeferControlStatus

ATTRIBUTE

APPROPRIATE SYNTAX:

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An ENUMERATED VALUE that has one of the following entries:

unknown	defer control mode unknown
defer control off	defer control mode disabled
defer control on	defer control mode enabled

BEHAVIOUR DEFINED AS:

A GET operation returns the current Defer Control mode of operation of the MAC. A SET operation changes the mode of operation of the MAC sublayer to the indicated value. A SET operation shall have no effect on a device whose mode cannot be changed through management or that can only operate in a single mode.

This attribute maps to the variable deferenceMode (see 4A.2.7.2).;

30.3.1.1.37 aMaxFrameLength

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has one of the following entries:

unknown	Frame length capability unknown
basicFrame	Capable of supporting maxBasicFrameSize (1518 octet frames)
qTaggedFrame	Capable of supporting maxBasicFrameSize + qTagPrefixSize (1522 octet frames)
envelopeFrame	Capable of supporting maxEnvelopeFrameSize (2000 octet frames)

BEHAVIOUR DEFINED AS:

This indicates the MAC frame length at which the aFramesTooLong counter is incremented.

30.3.1.1.38 aSlowProtocolFrameLimit

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

The maximum number of Slow Protocol frames of a given subtype that can be transmitted in a one-second period. The default value is 10.;

30.3.1.2 MAC entity actions

30.3.1.2.1 acInitializeMAC

ACTION

APPROPRIATE SYNTAX:

None required

BEHAVIOUR DEFINED AS:

This action provides a means to call the Initialize procedure (4.2.7.4). This action also results in the initialization of the PLS.;

30.3.1.2.2 acAddGroupAddress

ACTION

APPROPRIATE SYNTAX:

MACAddress

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BEHAVIOUR DEFINED AS:

Add the supplied multicast group address to the address recognition filter (RecognizeAddress function).;

30.3.1.2.3 acDeleteGroupAddress

ACTION

APPROPRIATE SYNTAX:

MACAddress

BEHAVIOUR DEFINED AS:

Delete the supplied multicast group address from the address recognition filter (RecognizeAddress function).;

30.3.1.2.4 acExecuteSelfTest

ACTION

APPROPRIATE SYNTAX:

None required

BEHAVIOUR DEFINED AS:

Execute a self-test and report the results (success or failure). The actual mechanism employed to carry out the self-test is not defined in this standard. If PHY loopback is accessible through a Clause 22 MII, Clause 35 GMII, or Clause 45 MDIO interface, then this action shall also invoke a data integrity test using PHY loopback, returning to normal operation on completion of the test. In the case of a Clause 45 MDIO Interface where multiple loopbacks are available, the loopback in the MMD closest to the MDI should be used.;

30.3.2 PHY device managed object class

This subclause formally defines the behaviours for the oPHYEntity managed object class attributes, actions and notifications. Management of that portion of the physical sublayer whose physical containment within the DTE is optional is outside the scope of this clause.

30.3.2.1 PHY device attributes

30.3.2.1.1 aPHYID

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

The value of aPHYID is assigned so as to uniquely identify a PHY, i.e., Physical Layer among the subordinate managed objects of system (systemID and system are defined in ISO/IEC 10165-2:1992 [SMI], Definition of management information).;

30.3.2.1.2 aPhyType

ATTRIBUTE

APPROPRIATE SYNTAX:

other	Undefined
unknown	Initializing, true state or type not yet known
none	MII present and nothing connected

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2BASE-TL	Clause 61 0.5 Mb/s to 5.5 Mb/s 64/65-octet
10 Mb/s	Clause 7 10 Mb/s Manchester
10PASS-TS	Clause 61 2.5 Mb/s to 100 Mb/s 64/65-octet
100BASE-T4	Clause 23 100 Mb/s 8B/6T
100BASE-X	Clause 24 or subclause 66.1 100 Mb/s 4B/5B
100BASE-T2	Clause 32 100 Mb/s PAM5X5
1000BASE-X	Clause 36 or subclause 66.2 1000 Mb/s 8B/10B
1000BASE-T	Clause 40 1000 Mb/s 4D-PAM5
10GBASE-X	Clause 48 10 Gb/s 4 lane 8B/10B
10GBASE-R	Clause 49 10 Gb/s 64B/66B
10GBASE-W	Clause 49 10 Gb/s 64B/66B and Clause 50 WIS
10GBASE-T	Clause 55 10 Gb/s DSQ128
10GBASE-PR	Clause 76 10/10G-EPON 10 Gb/s 64B/66B
10/1GBASE-PRX	Clause 76 10/1G-EPON 10 Gb/s 64B/66B downstream and 1 Gb/s 8B/10B upstream
40GBASE-R	Clause 82 40 Gb/s multi-PCS lane 64B/66B
100GBASE-R	Clause 82 100 Gb/s multi-PCS lane using 2-level PAM
100GBASE-P	Clause 82 100 Gb/s multi-PCS lane using >2-level PAM

BEHAVIOUR DEFINED AS:

A read-only value that identifies the PHY type. The enumeration of the type is such that the value matches the clause number of this International Standard that specifies the particular PHY. The value of this attribute maps to the value of aMAUType. The enumeration “none” can only occur in a standard implementation where an MII exists and there is nothing connected. However, the attribute aMIIDetect should be used to determine whether an MII exists or not.;

30.3.2.1.3 aPhyTypeList

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE that meets the requirements of the description below:

other	Undefined
unknown	Initializing, true state or type not yet known
none	MII present and nothing connected
2BASE-TL	Clause 61 0.5 Mb/s to 5.5 Mb/s 64/65-octet
10 Mb/s	Clause 7 10 Mb/s Manchester
10PASS-TS	Clause 61 2.5 Mb/s to 100 Mb/s 64/65-octet
100BASE-T4	Clause 23 100 Mb/s 8B/6T
100BASE-X	Clause 24 or subclause 66.1 100 Mb/s 4B/5B
100BASE-T2	Clause 32 100 Mb/s PAM5X5
1000BASE-X	Clause 36 or subclause 66.2 1000 Mb/s 8B/10B
1000BASE-T	Clause 40 1000 Mb/s 4D-PAM5
10GBASE-X	Clause 48 10 Gb/s 4 lane 8B/10B
10GBASE-R	Clause 49 10 Gb/s 64B/66B
10GBASE-W	Clause 49 10 Gb/s 64B/66B and Clause 50 WIS
10GBASE-T	Clause 55 10 Gb/s DSQ128
10GBASE-PR	Clause 76 10/10G-EPON 10 Gb/s 64B/66B
10/1GBASE-PRX	Clause 76 10/1G-EPON 10 Gb/s 64B/66B downstream and 1 Gb/s 8B/10B upstream
40GBASE-R	Clause 82 40 Gb/s multi-PCS lane 64B/66B
100GBASE-R	Clause 82 100 Gb/s multi-PCS lane using 2-level PAM
100GBASE-P	Clause 82 100 Gb/s multi-PCS lane using >2-level PAM

BEHAVIOUR DEFINED AS:

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A read-only list of the possible types that the PHY could be, identifying the ability of the PHY. If Clause 28, Clause 37, or Clause 73 Auto-Negotiation is present, then this attribute will map to the local technology ability or advertised ability of the local device.;

NOTE—At 10 Gb/s the ability of the PMD must be taken into account when reporting the possible types that the PHY could be.;

30.3.2.1.4 aSQETestErrors

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

A count of times that the SQE_TEST_ERROR was received. The SQE_TEST_ERROR is set in accordance with the rules for verification of the SQE detection mechanism in the PLS Carrier Sense function (see 7.2.4.6). The SQE test function is not a part of 100 or 1000 Mb/s PHY operation, and so SQETestErrors will not occur in 100 or 1000 Mb/s PHYs. The contents of this attribute are undefined for full duplex operation.;

30.3.2.1.5 aSymbolErrorDuringCarrier

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 160 000 counts per second for 100 Mb/s implementations

BEHAVIOUR DEFINED AS:

For 100 Mb/s operation it is a count of the number of times when valid carrier was present and there was at least one occurrence of an invalid data symbol (see 23.2.1.4, 24.2.2.1.7, and 32.3.4.1).
For half duplex operation at 1000 Mb/s, it is a count of the number of times the receiving media is non-idle (a carrier event) for a period of time equal to or greater than slotTime (see 4.2.4), and during which there was at least one occurrence of an event that causes the PHY to indicate “Data reception error” or “Carrier Extend Error” on the GMII (see Table 35–2).
For full duplex operation at 1000 Mb/s, it is a count of the number of times the receiving media is non-idle (a carrier event) for a period of time equal to or greater than minFrameSize, and during which there was at least one occurrence of an event that causes the PHY to indicate “Data reception error” on the GMII (see Table 35–2).
For operation at 10 Gb/s, 40 Gb/s, and 100 Gb/s, it is a count of the number of times the receiving media is non-idle (the time between the Start of Packet Delimiter and the End of Packet Delimiter as defined by 46.2.5 and 81.2.5) for a period of time equal to or greater than minFrameSize, and during which there was at least one occurrence of an event that causes the PHY to indicate “Receive Error” on the XGMII (see Table 46–4), the XLGMII, or the CGMII (see Table 81–3).
At all speeds this counter shall be incremented only once per valid CarrierEvent and if a collision is present this counter shall not increment.;

30.3.2.1.6 aMIIDetect

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has one of the following entries:
unknown
present, nothing connected

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present, connected
absent

BEHAVIOUR DEFINED AS:

An attribute of the PhyEntity managed object class indicating whether an MII connector is physically present, and if so whether it is detectably connected as specified in 22.2.2.14.;

30.3.2.1.7 aPhyAdminState

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has the following entries:
disabled
enabled

BEHAVIOUR DEFINED AS:

A disabled PHY neither transmits nor receives. The PHY shall be explicitly enabled to restore operation. The acPhyAdminControl action provides this ability. The port enable/disable function as reported by this attribute is preserved across DTE reset including loss of power. Only one PHY per MAC can be enabled at any one time. Setting a PHY to the enabled state using the action acPhyAdminControl will result in all other instances of PHY (indicated by PhyID) instantiated within the same MAC to be disabled. If a Clause 22 MII or Clause 35 GMII is present then setting this attribute to “disabled” will result in electrical isolation as defined in 22.2.4.1.6, Isolate; and setting this attribute to “enabled” will result in normal operation as defined in 22.2.4.1.5, Power down; and 22.2.4.1.6, Isolate. For all MMDs that provide a Clause 45 MDIO Interface within the PHY, setting this attribute to “enabled” will result in the MMD Low-power bit being set for normal operation. MMDs that support Low Power are the PMA/PMD MMD (see 45.2.1.1.2 and 45.2.1.2.5), the WIS MMD (see 45.2.2.1.3 and 45.2.2.2.3), the PCS MMD (see 45.2.3.1.3 and 45.2.3.2.8), the PHY XS MMD (see 45.2.4.1.3 and 45.2.4.2.8) and the DTE XS MMD (see 45.2.5.1.3 and 45.2.5.2.8).;

30.3.2.1.8 aTransmitLPIMicroseconds

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 000 000 counts per second

BEHAVIOUR DEFINED AS:

A count reflecting the amount of time that the LPI_REQUEST parameter has the value ASSERT. The request is indicated to the PHY according to the requirements of the RS (see 22.7, 35.4, 46.4).;

30.3.2.1.9 aReceiveLPIMicroseconds

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 000 000 counts per second

BEHAVIOUR DEFINED AS:

A count reflecting the amount of time that the LPI_INDICATION parameter has the value ASSERT. The indication reflects the state of the PHY according to the requirements of the RS (see 22.7, 35.4, 46.4).;

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30.3.2.1.10 aTransmitLPITransitions

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 50 000 counts per second at 100 Mb/s; 90 000 counts per second at 1000 Mb/s; and 230 000 counts per second at 10 Gb/s

BEHAVIOUR DEFINED AS:
A count of occurrences of the transition from state LPI_DEASSERTED to state LPI_ASSERTED of the LPI transmit state diagram is the RS. The state transition corresponds to the assertion of the LPI_REQUEST parameter. The request is indicated to the PHY according to the requirements of the RS (see 22.7, 35.4, 46.4).;

30.3.2.1.11 aReceiveLPITransitions

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 50 000 counts per second at 100 Mb/s; 90 000 counts per second at 1000 Mb/s; and 230 000 counts per second at 10 Gb/s

BEHAVIOUR DEFINED AS:
A count of occurrences of the transition from DEASSERT to ASSERT of the LPI_INDICATE parameter. The indication reflects the state of the PHY according to the requirements of the RS (see 22.7, 35.4, 46.4).;

30.3.2.2 PHY device actions

30.3.2.2.1 acPhyAdminControl

ACTION

APPROPRIATE SYNTAX:
Same as aPortAdminState

BEHAVIOUR DEFINED AS:
This action provides a means to alter aPhyAdminState. Setting a PHY to the enabled state will result in all other instances of PHY being disabled.;

30.3.3 MAC control entity object class

This subclause formally defines the behaviours for the oMACControlEntity managed object class attributes.

30.3.3.1 aMACControlID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of aMACControlID is assigned so as to uniquely identify a MAC Control entity among the subordinate managed objects of the containing object.;

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30.3.3.2 aMACControlFunctionsSupported

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE that meets the requirements of the description below:

PAUSE	PAUSE command implemented
MPCP	MPCP implemented
PFC	PFC implemented
EXTENSION	EXTENSION MAC Control frame supported

BEHAVIOUR DEFINED AS:

A read-write list of the possible MAC Control functions implemented within the device. Each function implemented will have an associated MAC Control Function Entity object class.;

30.3.3.3 aMACControlFramesTransmitted

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

A count of MAC Control frames passed to the MAC sublayer for transmission. This counter is incremented when a MA_CONTROL.request primitive is generated within the MAC Control sublayer.;

30.3.3.4 aMACControlFramesReceived

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

A count of MAC Control frames passed by the MAC sublayer to the MAC Control sublayer. This counter is incremented when a ReceiveFrame function call returns a valid frame with a lengthOrType field value equal to the reserved Type for 802.3_MAC_Control as specified in 31.4.1.3.;

30.3.3.5 aUnsupportedOpcodesReceived

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

A count of MAC Control frames received that contain an opcode from Table 31A–1 that is not supported by the device. This counter is incremented when a ReceiveFrame function call returns a valid frame with a lengthOrType field value equal to the reserved Type for 802.3_MAC_Control as specified in 31.4.1.3, and with an opcode for a function that is not supported by the device.;

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30.3.3.6 aPFCEnableStatus

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has one of the following entries:
enabled
disabled

BEHAVIOUR DEFINED AS:

A read-only value that indicates whether PFC MAC Control operation is enabled. The value enabled indicates that operation of PFC MAC Control is enabled and operation of PAUSE MAC Control is disabled. The value disabled indicates that transmission and reception of PFC MAC Control is not enabled and PAUSE MAC Control may operate if it has been enabled through another mechanism.;

NOTE 1—aPFCEnableStatus is read-only to avoid the risk of it being set to a conflicting value with enablement of PFC in the MAC Control Client. It is intended that an implementation locally sets the value to enabled when the MAC Control Client has PFC enabled for any priority and to disabled when the MAC Control Client has PFC disabled for all priorities.

NOTE 2—There is no mechanism in this Clause to enable and disable PAUSE transmit and receive for PHYs without autonegotiation. IEEE Std 802.3.1 provides dot3PauseAdminMode to enable and disable PAUSE in the absence of autonegotiation.

30.3.4 PAUSE entity managed object class

This subclause formally defines the behaviours for the oMACControlFunctionEntity managed object class attributes.

30.3.4.1 aPAUSELinkDelayAllowance

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

A GET operation returns the value, in bits, of the allowance made by the PAUSE MAC Control entity for round-trip propagation delay of the full duplex link. A SET operation changes the value of the allowance made by the PAUSE MAC Control entity for round-trip propagation delay of the full duplex link to the indicated value, in bits.;

30.3.4.2 aPAUSEMACCtrlFramesTransmitted

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

A count of PAUSE frames passed to the MAC sublayer for transmission. This counter is incremented when a MA_CONTROL.request primitive is generated within the MAC Control sublayer with an opcode indicating the PAUSE operation.;

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30.3.4.3 aPAUSEMACCtrlFramesReceived

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
A count of MAC Control frames passed by the MAC sublayer to the MAC Control sublayer. This counter is incremented when a ReceiveFrame function call returns a valid frame with: (1) a lengthOrType field value equal to the reserved Type for 802.3_MAC_Control as specified in 31.4.1.3, and (2) an opcode indicating the PAUSE operation.;

30.3.5 MPCP managed object class

This subclause formally defines the behaviours for the oMPCP managed object class attributes and actions.

30.3.5.1 MPCP Attributes

30.3.5.1.1 aMPCPID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of aMPCPID is assigned so as to uniquely identify an MPCP entity among the subordinate managed objects of the containing object.;

30.3.5.1.2 aMPCPAdminState

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that has the following entries:
enabled
disabled

BEHAVIOUR DEFINED AS:
A read-only value that identifies the operational state of the Multipoint MAC Control sublayer. An interface that can provide the Multipoint MAC Control sublayer functions specified in Clause 64 or Clause 77 is enabled to do so when this attribute has the enumeration “enabled”. When this attribute has the enumeration “disabled”, the interface acts as it would if it had no Multipoint MAC Control sublayer. The operational state of the Multipoint MAC Control sublayer can be changed using the acMPCPAdminControl action.;

30.3.5.1.3 aMPCPMode

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that has the following entries:
OLT
ONU

BEHAVIOUR DEFINED AS:

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A read-only value that identifies the operational mode of the Multipoint MAC Control sublayer. An interface that can provide the Multipoint MAC Control sublayer functions specified in Clause 64 and Clause 77 operates as an OLT when this attribute has the enumeration "OLT". When this attribute has the enumeration "ONU", the interface acts as an ONU.;

30.3.5.1.4 aMPCPLinkID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A read-only value that identifies the Logical Link identity (LLID) associated with the MAC port as specified in 65.1.3.2.2 or 76.2.6.1.3.2, as appropriate.;

30.3.5.1.5 aMPCPRemoteMACAddress

ATTRIBUTE

APPROPRIATE SYNTAX:
MACAddress

BEHAVIOUR DEFINED AS:
A read-only value that identifies the source_address parameter of the last MPCPDU passed to MAC Control.

This value is updated on reception of a valid frame with (1) a destinationField equal to the reserved multicast address for MAC Control specified in 31A, (2) lengthOrType field value equal to the reserved Type for MAC Control as specified in 31A, (3) an opcode value reserved for one of MPCP messages, as specified in 31A.;

30.3.5.1.6 aMPCPRegistrationState

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that has the following entries:

unregistered	unregistered
registering	registering with link-partner
registered	registered with a link-partner

BEHAVIOUR DEFINED AS:
A read-only value that identifies the operational state of an individual instance of Multipoint MAC Control. When this attribute has the enumeration "unregistered" the interface is ready for registering a link partner. When this attribute has the enumeration "registering" the interface is in the process of registering a link-partner. When this attribute has the enumeration "registered" the interface has an established and operational link-partner.

NOTE—This attribute may be used by layer management mechanisms or OAM client to obtain the status of logical links in P2MP networks. Specifically, in implementations where the OAM sublayer is interfaced with Multipoint MAC Control, theOAM_CTRL.request (local_link_status) primitive specified in 57.2.5.3 should be mapped to this attribute as follows:

When the value of this attribute changes from "registering" to "registered", an OAM_CTRL.request primitive with parameter local_link_status = OK is generated.

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When the value of this attribute changes from “registered” to “unregistered”, an OAM_CTRL.request primitive with parameter local_link_status = FAIL is generated.;

30.3.5.1.7 aMPCPMACCtrlFramesTransmitted

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 600 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:

A count of MPCP frames passed to the MAC sublayer for transmission.

Increment counter by one when a MA_CONTROL.request service primitive is generated within the MAC Control sublayer with an opcode indicating an MPCP frame.;

30.3.5.1.8 aMPCPMACCtrlFramesReceived

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 600 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:

A count of MPCP frames passed by the MAC sublayer to the MAC Control sublayer.

Increment counter by one when a ReceiveFrame function call returns a valid frame with: (1) a lengthOrType field value equal to the reserved Type for 802.3_MAC_Control as specified in 31.4.1.3, and (2) an opcode indicating an MPCP frame.;

30.3.5.1.9 aMPCPTxGate

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 600 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:

A count of the number of times a GATE MPCP frames transmission occurs.

Increment the counter by one when a MA_CONTROL.request service primitive is generated within the MAC Control sublayer with an opcode indicating a GATE MPCPDU.;

30.3.5.1.10 aMPCPTxRegAck

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 600 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:

A count of the number of times a REGISTER_ACK MPCP frames transmission occurs.

Increment the counter by one when a MA_CONTROL.request service primitive is generated

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within the MAC Control sublayer with an opcode indicating a REGISTER_ACK MPCPDU.;

30.3.5.1.11 aMPCPTxRegister

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 1 600 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:
A count of the number of times a REGISTER MPCP frames transmission occurs.

Increment the counter by one when a MA_CONTROL.request service primitive is generated within the MAC Control sublayer with an opcode indicating a REGISTER MPCPDU.;

30.3.5.1.12 aMPCPTxRegRequest

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 1 600 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:
A count of the number of times a REGISTER_REQ MPCP frames transmission occurs.

Increment the counter by one when a MA_CONTROL.request service primitive is generated within the MAC Control sublayer with an opcode indicating a REGISTER_REQ MPCPDU.;

30.3.5.1.13 aMPCPTxReport

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 1 600 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:
A count of the number of times a REPORT MPCP frames transmission occurs.

Increment the counter by one when a MA_CONTROL.request service primitive is generated within the MAC Control sublayer with an opcode indicating a REPORT MPCPDU.;

30.3.5.1.14 aMPCPRxGate

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 1 600 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:
A count of the number of times a GATE MPCP frames reception occurs.

Increment the counter by one when a ReceiveFrame function call returns a valid frame with: (1) a destinationField equal to the reserved multicast address for MAC Control specified in 31A, or unique physical address associated with this station, (2) a lengthOrType field value equal to the

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reserved Type for 802.3_MAC_Control as specified in 31.4.1.3, (3) an opcode indicating a GATE MPCPDU.;

30.3.5.1.15 aMPCPRxRegAck

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 600 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:

A count of the number of times a REGISTER_ACK MPCP frames reception occurs.

Increment the counter by one when a ReceiveFrame function call returns a valid frame with: (1) a destinationField equal to the reserved multicast address for MAC Control specified in 31A, (2) a lengthOrType field value equal to the reserved Type for 802.3_MAC_Control as specified in 31.4.1.3, (3) an opcode indicating a REGISTER_ACK MPCPDU.;

30.3.5.1.16 aMPCPRxRegister

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 600 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:

A count of the number of times a REGISTER MPCP frames reception occurs.

Increment the counter by one when a ReceiveFrame function call returns a valid frame with: (1) a destinationField equal to the unique physical address associated with this station, (2) a lengthOrType field value equal to the reserved Type for 802.3_MAC_Control as specified in 31.4.1.3, (3) an opcode indicating a REGISTER MPCPDU.;

30.3.5.1.17 aMPCPRxRegRequest

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 600 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:

A count of the number of times a REGISTER_REQ MPCP frames reception occurs.

Increment the counter by one when a ReceiveFrame function call returns a valid frame with: (1) a destinationField equal to the reserved multicast address for MAC Control specified in 31A, (2) a lengthOrType field value equal to the reserved Type for 802.3_MAC_Control as specified in 31.4.1.3, (3) an opcode indicating a REGISTER_REQ MPCPDU.;

30.3.5.1.18 aMPCPRxReport

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 600 000

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counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:

A count of the number of times a REPORT MPCP frames reception occurs.

Increment the counter by one when a ReceiveFrame function call returns a valid frame with: (1) a destinationField equal to the reserved multicast address for MAC Control specified in 31A, (2) a lengthOrType field value equal to the reserved Type for 802.3_MAC_Control as specified in 31.4.1.3, (3) an opcode indicating a REPORT MPCPDU.;

30.3.5.1.19 aMPCPTransmitElapsed

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

A read-only value that reports the interval from last MPCP frame transmission in increments of 16 ns. The value returned shall be (interval from last MPCP frame transmission in ns)/16, where this value exceeds (2^{32}–1) the value (2^{32}–1) shall be returned.;

30.3.5.1.20 aMPCPReceiveElapsed

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

A read-only value that reports the interval from last MPCP frame reception in increments of 16 ns. The value returned shall be (interval from last MPCP frame reception in ns)/16, where this value exceeds (2^{32}–1) the value (2^{32}–1) shall be returned.;

30.3.5.1.21 aMPCPRoundTripTime

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

A read-only value that reports the MPCP round trip time in increments of 16 ns. The value returned shall be (round trip time in ns)/16, where this value exceeds (2^{16}–1) the value (2^{16}–1) shall be returned. This value is only defined for an OLT. The contents of this attribute are undefined for an ONU.;

30.3.5.1.22 aMPCPDiscoveryWindowsSent

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 10 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:

A count of discovery windows generated. The counter is incremented by one for each generated discovery window.;

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30.3.5.1.23 aMPCPDiscoveryTimeout

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 10 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:
A count of the number of times a discovery time-out occurs. The counter is incremented by one for each discovery processing state diagram reset resulting from time-out waiting for message arrival.;

30.3.5.1.24 aMPCPMaximumPendingGrants

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A read-only value that indicates the maximum number of grants an ONU can store. The maximum number of grants an ONU can store has a range of 0 to 255.;

30.3.5.1.25 aMPCPRecognizedMulticastIDs

ATTRIBUTE

APPROPRIATE SYNTAX:
A SEQUENCE of INTEGERS

BEHAVIOUR DEFINED AS:
A An array of read-only values that identify the multicast Logical Link identities (LLID) associated with the MAC port as specified in 65.1.3.3.2 or 76.2.6.1.3.2, as appropriate.; These values are only defined for an ONU. The contents of this attribute are undefined for an OLT.;

30.3.5.2 MPCP Actions

30.3.5.2.1 acMPCPAdminControl

ACTION

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that has the following entries:
enabled
disabled

BEHAVIOUR DEFINED AS:
This action provides a means to alter aMPCPAdminState.;

30.3.6 OAM object class

This subclause formally defines the behaviours for the oOAM managed object class attributes.

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30.3.6.1 OAM Attributes

30.3.6.1.1 aOAMID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of aOAMID is assigned so as to uniquely identify an OAM entity among the subordinate managed objects of the containing object.;

30.3.6.1.2 aOAMAdminState

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that has the following entries:
enabled
disabled

BEHAVIOUR DEFINED AS:
A read-only value that identifies the operational state of the OAM sublayer.

An interface which can provide the OAM sublayer functions specified in Clause 57 will be enabled to do so when this attribute has the enumeration "enabled". When this attribute has the enumeration "disabled" the interface will act as it would if it had no OAM sublayer. The operational state of the OAM sublayer can be changed using the acOAMAdminControl action.;

30.3.6.1.3 aOAMMode

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that has one of the following entries:
passive passive OAM mode
active active OAM mode

BEHAVIOUR DEFINED AS:
A GET operation returns the current mode of the OAM sublayer entity (see 57.2.9), either "passive" or "active." A SET operation changes the mode of operation of the OAM entity to the indicated value. A SET operation shall have no effect on a device whose mode cannot be changed through management or that can only operate in a single mode.;

30.3.6.1.4 aOAMDiscoveryState

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that has one of the following entries:
link fault
active send local
passive wait
send local remote
send local remote ok
send any

BEHAVIOUR DEFINED AS:

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A read-only value that identifies the current state of the OAM Discovery function. The enumerations match the states within the Discovery state diagram Figure 57–5.;

30.3.6.1.5 aOAMRemoteMACAddress

ATTRIBUTE

APPROPRIATE SYNTAX:
MACAddress

BEHAVIOUR DEFINED AS:
The value of the source_address parameter of the last OAMPDU passed by the OAM subordinate sublayer to the OAM sublayer.

This value is updated on reception of a valid frame with (1) a destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3.;

30.3.6.1.6 aOAMLocalConfiguration

ATTRIBUTE

APPROPRIATE SYNTAX:
BIT STRING [SIZE (5)]

BEHAVIOUR DEFINED AS:
A string of five bits corresponding to the OAM Configuration field (see Table 57–8) in the most recently transmitted Information OAMPDU.;

The first bit corresponds to the OAM Mode bit in the OAM Configuration field. The second bit corresponds to the Unidirectional Support bit in the OAM Configuration field. The third bit corresponds to the Remote Loopback Support bit in the OAM Configuration field. The fourth bit corresponds to the Link Events bit in the OAM Configuration field. The fifth bit corresponds to the Variable Retrieval bit in the OAM Configuration field.;

30.3.6.1.7 aOAMRemoteConfiguration

ATTRIBUTE

APPROPRIATE SYNTAX:
BIT STRING [SIZE (5)]

BEHAVIOUR DEFINED AS:
A string of five bits corresponding to the OAM Configuration field (see Table 57–8) in the most recently received Information OAMPDU.

The first bit corresponds to the OAM Mode bit in the OAM Configuration field. The second bit corresponds to the Unidirectional Support bit in the OAM Configuration field. The third bit corresponds to the Remote Loopback Support bit in the OAM Configuration field.The fourth bit corresponds to the Link Events bit in the OAM Configuration field. The fifth bit corresponds to the Variable Retrieval bit in the OAM Configuration field.

This value is updated on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) the OAM

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code equals the OAM Information code as specified in Table 57–4, (5) the frame contains a Local Information TLV (see 57.5.2.1).;

30.3.6.1.8 aOAMLocalPDUConfiguration

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
An eleven bit value corresponding to the Maximum OAMPDU Size value within the OAMPDU Configuration field (see Table 57–9) in the most recently transmitted OAMPDU.;

30.3.6.1.9 aOAMRemotePDUConfiguration

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
An eleven bit value corresponding to the Maximum OAMPDU Size value within the OAMPDU Configuration field (see Table 57–9) in the most recently received Information OAMPDU.

This value is updated on reception of a valid frame with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) the OAM code equals the OAM Information code as specified in Table 57–4, (5) the frame contains a Local Information TLV (see 57.5.2.1).;

30.3.6.1.10 aOAMLocalFlagsField

ATTRIBUTE

APPROPRIATE SYNTAX:
BIT STRING [SIZE (7)]

BEHAVIOUR DEFINED AS:
A string of seven bits corresponding to the Flags field (see Table 57–3) in the most recently transmitted OAMPDU.

The first bit corresponds to the Link Fault bit in the Flags field. The second bit corresponds to the Dying Gasp bit in the Flags field. The third bit corresponds to the Critical Event bit in the Flags field. The fourth bit corresponds to the Local Evaluating bit in the Flags field. The fifth bit corresponds to the Local Stable bit in the Flags field. The sixth bit corresponds to the Remote Evaluating bit in the Flags field. The seventh bit corresponds to the Remote Stable bit in the Flags field.;

30.3.6.1.11 aOAMRemoteFlagsField

ATTRIBUTE

APPROPRIATE SYNTAX:
BIT STRING [SIZE (7)]

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BEHAVIOUR DEFINED AS:

A string of seven bits corresponding to the Flags field (see Table 57–3) in the most recently received OAMPDU.

The first bit corresponds to the Link Fault bit in the Flags field. The second bit corresponds to the Dying Gasp bit in the Flags field. The third bit corresponds to the Critical Event bit in the Flags field. The fourth bit corresponds to the Local Evaluating bit in the Flags field. The fifth bit corresponds to the Local Stable bit in the Flags field. The sixth bit corresponds to the Remote Evaluating bit in the Flags field. The seventh bit corresponds to the Remote Stable bit in the Flags field.

This value is updated on reception of a valid frame with (1) a destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) the OAM code equals one of the codes as specified in Table 57–4.;

30.3.6.1.12 aOAMLocalRevision

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

The value of the Revision field (see 57.5.2.1) in the Local Information TLV of the most recently transmitted Information OAMPDU.;

30.3.6.1.13 aOAMRemoteRevision

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

The value of the Revision field (see 57.5.2.1) in the Local Information TLV of the most recently received Information OAMPDU.

This value is updated on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) the OAMPDU code equal to the Information code as specified in Table 57–4, (5) the frame contains a Local Information TLV (see 57.5.2.1).;

30.3.6.1.14 aOAMLocalState

ATTRIBUTE

APPROPRIATE SYNTAX:

BIT STRING [SIZE (3)]

BEHAVIOUR DEFINED AS:

A string of three bits corresponding to the State field (see Table 57–7) of the most recently transmitted Information OAMPDU. The first and second bits corresponds to the Parser Action bits in the State field. The third bit corresponds to the Multiplexer Action bit in the State field.;

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30.3.6.1.15 aOAMRemoteState

ATTRIBUTE

APPROPRIATE SYNTAX:
BIT STRING [SIZE (3)]

BEHAVIOUR DEFINED AS:
A string of three bits corresponding to the State field (see Table 57–7) of the most recently received Information OAMPDU. The first and second bits corresponds to the Parser Action bits in the State field. The third bit corresponds to the Multiplexer Action bit in the State field.

This value is updated on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) the OAMPDU code equal to the Information code as specified in Table 57–4, (5) the frame contains a Local Information TLV (see 57.5.2.1).;

30.3.6.1.16 aOAMRemoteVendorOUI

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of the OUI/CID field (see Table 57–10) of the most recently received Information OAMPDU.

This value is updated on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) a OAMPDU code equal to the Information code as specified in Table 57–4, (5) the frame contains a Local Information TLV (see 57.5.2.1).;

30.3.6.1.17 aOAMRemoteVendorSpecificInfo

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of the Vendor Specific Information field (see Table 57–11) of the most recently received Information OAMPDU.

This value is updated on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) the OAMPDU code equal to the Information code as specified in Table 57–4, (5) the frame contains a Local Information TLV (see 57.5.2.1).;

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30.3.6.1.18 aOAMUnsupportedCodesTx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in 57A.2.

BEHAVIOUR DEFINED AS:

A count of OAMPDUs passed to the OAM subordinate sublayer for transmission that are not supported by the device. This counter is incremented when a CTL:OAMI.request service primitive is generated within the OAM sublayer with an OAM code for a function that is not supported by the device.;

30.3.6.1.19 aOAMUnsupportedCodesRx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in 57A.2.

BEHAVIOUR DEFINED AS:

A count of OAMPDUs received that contain an OAM code from Table 57–4 that are not supported by the device. This counter is incremented on reception of a valid frame with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) an OAMPDU code for a function that is not supported by the device.;

30.3.6.1.20 aOAMInformationTx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in 57A.2.

BEHAVIOUR DEFINED AS:

A count of OAMPDUs passed to the OAM subordinate sublayer for transmission that contain the OAM Information code specified in Table 57–4. This counter is incremented when a CTL:OAMI.request service primitive is generated within the OAM sublayer with an OAMPDU code indicating an Information OAMPDU.;

30.3.6.1.21 aOAMInformationRx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in 57A.2.

BEHAVIOUR DEFINED AS:

A count of OAMPDUs received that contain the OAM Information code specified in Table 57–4. This counter is incremented on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in

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Table 57A–3, (4) the OAMPDU code equals the OAM Information code and is supported by the device.;

30.3.6.1.22 aOAMUniqueEventNotificationTx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in 57A.2.

BEHAVIOUR DEFINED AS:

A count of OAMPDUs passed to the OAM subordinate sublayer for transmission that contain the Event Notification code specified in Table 57–4. This counter is incremented when a CTL:OAMI.request service primitive is generated within the OAM sublayer, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) the OAMPDU code equals the Event Notification code, (5) the Sequence Number field is not equal to the Sequence Number field of the last transmitted Event Notification OAMPDU.;

30.3.6.1.23 aOAMDuplicateEventNotificationTx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in 57A.2.

BEHAVIOUR DEFINED AS:

A count of OAMPDUs passed to the OAM subordinate sublayer for transmission that contain the Event Notification code specified in Table 57–4. This counter is incremented when a CTL:OAMI.request service primitive is generated within the OAM sublayer, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) the OAMPDU code equals the Event Notification code, (5) the Sequence Number field is equal to the Sequence Number field of the last transmitted Event Notification OAMPDU.;

30.3.6.1.24 aOAMUniqueEventNotificationRx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in 57A.2.

BEHAVIOUR DEFINED AS:

A count of the OAMPDUs received that contain the Event Notification code specified in Table 57–4. This counter is incremented on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) the OAMPDU code equals the Event Notification code, (5) the Sequence Number field is not equal to the Sequence Number field of the last received Event

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Notification OAMPDU and is supported by the device.;

30.3.6.1.25 aOAMDuplicateEventNotificationRx

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in 57A.2.

BEHAVIOUR DEFINED AS:
A count of the OAMPDUs received that contain the Event Notification code specified in Table 57–4. This counter is incremented on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) the OAMPDU code equals the Event Notification code, (5) the Sequence Number field is equal to the Sequence Number field of the last received Event Notification OAMPDU.;

30.3.6.1.26 aOAMLoopbackControlTx

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in 57A.2.

BEHAVIOUR DEFINED AS:
A count of OAMPDUs passed to the OAM subordinate sublayer for transmission that contain the Loopback Control code specified in Table 57–4. This counter is incremented when a CTL:OAMI.request service primitive is generated within the OAM sublayer with an OAM code indicating a Loopback Control OAMPDU.;

30.3.6.1.27 aOAMLoopbackControlRx

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in 57A.2.

BEHAVIOUR DEFINED AS:
A count of OAMPDUs received that contain the Loopback Control code specified in Table 57–4. This counter is incremented on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) the OAMPDU code equals the Loopback Control code and is supported by the device.;

30.3.6.1.28 aOAMVariableRequestTx

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in 57A.2.

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BEHAVIOUR DEFINED AS:

A count of OAMPDUs passed to the OAM subordinate sublayer for transmission that contain the Variable Request code specified in Table 57–4. This counter is incremented when a CTL:OAMI.request service primitive is generated within the OAM sublayer with an OAM code indicating a Variable Request OAMPDU.;

30.3.6.1.29 aOAMVariableRequestRx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in 57A.2.

BEHAVIOUR DEFINED AS:

A count of OAMPDUs received that contain the Variable Request code specified in Table 57–4. This counter is incremented on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) the OAMPDU code equals the Variable Request code and is supported by the device.;

30.3.6.1.30 aOAMVariableResponseTx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in 57A.2.

BEHAVIOUR DEFINED AS:

A count of OAMPDUs passed to the OAM subordinate sublayer for transmission that contain the Variable Response code specified in Table 57–4. This counter is incremented when a CTL:OAMI.request service primitive is generated within the OAM sublayer with an OAM code indicating a Variable Response OAMPDU.;

30.3.6.1.31 aOAMVariableResponseRx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in 57A.2.

BEHAVIOUR DEFINED AS:

A count of OAMPDUs received that contain the Variable Response code specified in Table 57–4. This counter is incremented on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) the OAMPDU code equals the Variable Response code and is supported by the device.;

30.3.6.1.32 aOAMOrganizationSpecificTx

ATTRIBUTE

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APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in 57A.2.

BEHAVIOUR DEFINED AS:

A count of Organization Specific OAMPDUs passed to the OAM subordinate sublayer for transmission that contain the Organization Specific code specified in Table 57–4. This counter is incremented when a CTL:OAMI.request service primitive is generated within the OAM sublayer with an OAM code indicating an Organization Specific OAMPDU.;

30.3.6.1.33 aOAMOrganizationSpecificRx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of Slow_Protocol_Frames as defined in 57A.2.

BEHAVIOUR DEFINED AS:

A count of OAMPDUs received that contain the Organization Specific code specified in Table 57–4. This counter is incremented on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) a Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) the OAMPDU code equals the Organization Specific code and is supported by the device.;

30.3.6.1.34 aOAMLocalErrSymPeriodConfig

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE of two instances of the type INTEGER

BEHAVIOUR DEFINED AS:

The first integer is an eight-octet value indicating the duration of the Errored Symbol Period Event (see 57.5.3.1) window, in terms of symbols.
The second integer is an eight-octet value indicating the number of errored symbols in the period that must be met or exceeded in order for the Errored Symbol Period Event to be generated.;

30.3.6.1.35 aOAMLocalErrSymPeriodEvent

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE of six instances of the type INTEGER
The first INTEGER represents the Event Time Stamp field
The second INTEGER represents the Errored Symbol Window field
The third INTEGER represents the Errored Symbol Threshold field
The fourth INTEGER represents the Errored Symbols field
The fifth INTEGER represents the Error Running Total field
The sixth INTEGER represents the Event Running Total field

BEHAVIOUR DEFINED AS:

A sequence of six integers corresponding to the respective fields in the most recently transmitted Errored Symbol Period Event TLV in an Event Notification OAMPDU (see 57.4.3.2).

This sequence is updated when a CTL:OAMI.request service primitive is generated within the

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OAM sublayer with an OAMPDU Code field value equal to the Event Notification code as specified in Table 57–4 and Event TLV Type field equal to the Errored Symbol Period Event value as specified in Table 57–12.;

30.3.6.1.36 aOAMLocalErrFrameConfig

ATTRIBUTE

APPROPRIATE SYNTAX:
A SEQUENCE of two instances of the type INTEGER

BEHAVIOUR DEFINED AS:
The first integer is a two-octet value indicating the duration of the Errored Frame Event (see 57.5.3.2) window, in terms of number of 100 ms intervals. The second integer is a four-octet value indicating the number of errored frames in the period that must be met or exceeded in order for the Errored Frame Event to be generated.;

30.3.6.1.37 aOAMLocalErrFrameEvent

ATTRIBUTE

APPROPRIATE SYNTAX:
A SEQUENCE of six instances of the type INTEGER
The first INTEGER represents the Event Time Stamp field
The second INTEGER represents the Errored Frame Window field
The third INTEGER represents the Errored Frame Threshold field
The fourth INTEGER represents the Errored Frames field
The fifth INTEGER represents the Error Running Total field
The sixth INTEGER represents the Event Running Total field

BEHAVIOUR DEFINED AS:
A sequence of six integers corresponding to the respective fields in the most recently transmitted Errored Frame Event TLV in an Event Notification OAMPDU (see 57.4.3.2).

This sequence is updated when a CTL:OAMI.request service primitive is generated within the OAM sublayer with an OAMPDU Code field value equal to the Event Notification code as specified in Table 57–4 and Event TLV Type field equal to the Errored Frame Event value as specified in Table 57–12.;

30.3.6.1.38 aOAMLocalErrFramePeriodConfig

ATTRIBUTE

APPROPRIATE SYNTAX:
A SEQUENCE of two instances of the type INTEGER

BEHAVIOUR DEFINED AS:
The first integer is a four-octet value indicating the duration of the Errored Frame Period Event (see 57.5.3.3) window, in terms of the number of frames in the window.

The second integer is a four-octet value indicating the number of errored frames in the period that must be met or exceeded in order for the Errored Frame Period Event to be generated.;

30.3.6.1.39 aOAMLocalErrFramePeriodEvent

ATTRIBUTE

APPROPRIATE SYNTAX:

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A SEQUENCE of six instances of the type INTEGER
The first INTEGER represents the Event Time Stamp field
The second INTEGER represents the Errored Frame Window field
The third INTEGER represents the Errored Frame Threshold field
The fourth INTEGER represents the Errored Frames field
The fifth INTEGER represents the Error Running Total field
The sixth INTEGER represents the Event Running Total field

BEHAVIOUR DEFINED AS:

A sequence of six integers corresponding to the respective fields in the most recently transmitted Errored Frame Period Event TLV in an Event Notification OAMPDU (see 57.4.3.2).

This sequence is updated when a CTL:OAMI.request service primitive is generated within the OAM sublayer with an OAMPDU Code field value equal to the Event Notification code as specified in Table 57–4 and Event TLV Type field equal to the Errored Frame Period Event value as specified in Table 57–12.;

30.3.6.1.40 aOAMLocalErrFrameSecsSummaryConfig

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE of two instances of the type INTEGER

BEHAVIOUR DEFINED AS:

The first integer is a two-octet value indicating the duration of the Errored Frame Seconds Summary Event (see 57.5.3.4) window, in terms of number of 100 ms intervals. The second integer is a two-octet value indicating the number of errored frame seconds in the period that must be met or exceeded in order for the Errored Frame Seconds Summary Event to be generated.;

30.3.6.1.41 aOAMLocalErrFrameSecsSummaryEvent

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE of six instances of the type INTEGER
The first INTEGER represents the Event Time Stamp field
The second INTEGER represents the Errored Frame Seconds Summary Window field
The third INTEGER represents the Errored Frame Seconds Summary Threshold field
The fourth INTEGER represents the Errored Frame Seconds Summary field
The fifth INTEGER represents the Error Running Total field
The sixth INTEGER represents the Event Running Total field

BEHAVIOUR DEFINED AS:

A sequence of six integers corresponding to the respective fields in the most recently transmitted Errored Frame Seconds Summary Event TLV in an Event Notification OAMPDU (see 57.4.3.2).

This sequence is updated when a CTL:OAMI.request service primitive is generated within the OAM sublayer with an OAMPDU Code field value equal to the Event Notification code as specified in Table 57–4 and Event TLV Type field equal to the Errored Frame Seconds Summary Event value as specified in Table 57–12.;

30.3.6.1.42 aOAMRemoteErrSymPeriodEvent

ATTRIBUTE

APPROPRIATE SYNTAX:

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A SEQUENCE of six instances of the type INTEGER
The first INTEGER represents the Event Time Stamp field
The second INTEGER represents the Errored Symbol Window field
The third INTEGER represents the Errored Symbol Threshold field
The fourth INTEGER represents the Errored Symbols field
The fifth INTEGER represents the Error Running Total field
The sixth INTEGER represents the Event Running Total field

BEHAVIOUR DEFINED AS:

A sequence of six integers corresponding to the respective fields in the most recently received Errored Symbol Period Event TLV in an Event Notification OAMPDU (see 57.4.3.2).

This sequence is updated on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) OAMPDU Code field value equal to the Event Notification code as specified in Table 57–4, (5) an Event TLV Type field equal to the Errored Symbol Period Event value as specified in Table 57–12.

If more than one Event TLV of the same Event Type is present within an Event Notification OAMPDU, the Event with the most recent timestamp should be used.;

30.3.6.1.43 aOAMRemoteErrFrameEvent

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE of six instances of the type INTEGER
The first INTEGER represents the Event Time Stamp field
The second INTEGER represents the Errored Frame Window field
The third INTEGER represents the Errored Frame Threshold field
The fourth INTEGER represents the Errored Frames field
The fifth INTEGER represents the Error Running Total field
The sixth INTEGER represents the Event Running Total field

BEHAVIOUR DEFINED AS:

A sequence of six integers corresponding to the respective fields in the most recently received Errored Frame Event TLV in an Event Notification OAMPDU (see 57.4.3.2).

This sequence is updated on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) OAMPDU Code field value equal to the Event Notification code as specified in Table 57–4, (5) an Event TLV Type field equal to the Errored Frame Event value as specified in Table 57–12.

If more than one Event TLV of the same Event Type is present within an Event Notification OAMPDU, the Event with the most recent timestamp should be used.;

30.3.6.1.44 aOAMRemoteErrFramePeriodEvent

ATTRIBUTE

APPROPRIATE SYNTAX:

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A SEQUENCE of six instances of the type INTEGER
The first INTEGER represents the Event Time Stamp field
The second INTEGER represents the Errored Frame Window field
The third INTEGER represents the Errored Frame Threshold field
The fourth INTEGER represents the Errored Frames field
The fifth INTEGER represents the Error Running Total field
The sixth INTEGER represents the Event Running Total field

BEHAVIOUR DEFINED AS:

A sequence of six integers corresponding to the respective fields in the most recently received Errored Frame Period Event TLV in an Event Notification OAMPDU (see 57.4.3.2).

This sequence is updated on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) OAMPDU Code field value equal to the Event Notification code as specified in Table 57–4, (5) an Event TLV Type field equal to the Errored Frame Period Event value as specified in Table 57–12.

If more than one Event TLV of the same Event Type is present within an Event Notification OAMPDU, the Event with the most recent timestamp should be used.;

30.3.6.1.45 aOAMRemoteErrFrameSecsSummaryEvent

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE of six instances of the type INTEGER
The first INTEGER represents the Event Time Stamp field
The second INTEGER represents the Errored Frame Seconds Summary Window field
The third INTEGER represents the Errored Frame Seconds Summary Threshold field
The fourth INTEGER represents the Errored Frame Seconds Summary field
The fifth INTEGER represents the Error Running Total field
The sixth INTEGER represents the Event Running Total field

BEHAVIOUR DEFINED AS:

A sequence of six integers corresponding to the respective fields in the most recently received Errored Frame Seconds Summary Event TLV in an Event Notification OAMPDU (see 57.4.3.2).

This sequence is updated on reception of a valid frame, with (1) destinationField equal to the reserved multicast address for Slow_Protocols specified in Table 57A–1, (2) lengthOrType field value equal to the reserved Type for Slow_Protocols as specified in Table 57A–2, (3) Slow_Protocols subtype value equal to the subtype reserved for OAM as specified in Table 57A–3, (4) OAMPDU Code field value equal to the Event Notification code as specified in Table 57–4, (5) an Event TLV Type field equal to the Errored Frame Seconds Summary Event value as specified in Table 57–12.

If more than one Event TLV of the same Event Type is present within an Event Notification OAMPDU, the Event with the most recent timestamp should be used.;

30.3.6.1.46 aFramesLostDueToOAMError

ATTRIBUTE

APPROPRIATE SYNTAX:

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Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

A count of frames that would otherwise be transmitted by the OAM sublayer, but could not be due to an internal OAM sublayer transmit error. If this counter is incremented, then none of the other counters in this section are incremented. The exact meaning and mechanism for incrementing this counter is implementation dependent.;

30.3.6.2 OAM Actions

30.3.6.2.1 acOAMAdminControl

ACTION

APPROPRIATE SYNTAX:

Same as aPortAdminState

BEHAVIOUR DEFINED AS:

This action provides a means to alter aOAMAdminState.;

30.3.7 OMPEmulation managed object class

This subclause formally defines the behaviours for the oOMPEmulation managed object class attributes.

30.3.7.1 OMPEmulation Attributes

30.3.7.1.1aOMPEmulationID

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

The value of aOAMID is assigned so as to uniquely identify an OMPEmulation entity among the subordinate managed objects of the containing object.;

30.3.7.1.2aOMPEmulationType

ATTRIBUTE

APPROPRIATE SYNTAX:

A ENUMERATION that meets the requirements of the description below:

unknown	initializing, true state or type not yet known
OLT	sublayer operating in OLT mode
ONU	sublayer operating in ONU mode

BEHAVIOUR DEFINED AS:

A read only value that indicates that mode of operation of the Reconciliation Sublayer for Point to Point Emulation (see 65.1.3.1 or 76.2.6.1.1, as appropriate).;

30.3.7.1.3aSLDErrors

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 500 000

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counts per second at 1000 Mb/s

BEHAVIOUR DEFINED AS:

A count of frames received that do not contain a valid SLD field as defined in 65.1.3.3.1or 76.2.6.1.3.1, as appropriate.;

30.3.7.1.4aCRC8Errors

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 500 000 counts per second at 1000 Mb/s

BEHAVIOUR DEFINED AS:

A count of frames received that contain a valid SLD field, as defined in 65.1.3.3.1or 76.2.6.1.3.1, as appropriate, but do not pass the CRC-8 check as defined in 65.1.3.3.3 or 76.2.6.1.3.3, as appropriate.;

30.3.7.1.5aGoodLLID

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 500 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:

A count of frames received that contain a valid SLD field in an OLT, as defined in 65.1.3.3.1 or 76.2.6.1.3.1, as appropriate, and pass the CRC-8 check, as defined in 65.1.3.3.3 or 76.2.6.1.3.3, as appropriate.;

30.3.7.1.6aONUPONcastLLID

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 500 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:

A count of frames received that: 1) contain a valid SLD field in an ONU, 2) meet the rules for frame acceptance, and 3) pass the CRC-8 check. The SLD is defined in 65.1.3.3.1 or 76.2.6.1.3.1, as appropriate. The rules for LLID acceptance are defined in 65.1.3.3.2 or 76.2.6.1.3.2, as appropriate. The CRC-8 check is defined in 65.1.3.3.3 or 76.2.6.1.3.3, as appropriate.;

30.3.7.1.7aOLTPONcastLLID

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 500 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:

A count of frames received that contain a valid SLD field in an OLT, as defined in 65.1.3.3.1 or 76.2.6.1.3.1, as appropriate, passes the CRC-8 check, as defined in 65.1.3.3.3 or 76.2.6.1.3.3, as appropriate, and the frame meets the rule for acceptance defined in 65.1.3.3.2 or 76.2.6.1.3.2, as appropriate.;

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30.3.7.1.8aBadLLID

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 1 500 000 counts per second at 1000 Mb/s.

BEHAVIOUR DEFINED AS:
A count of frames received that contain a valid SLD field in an OLT, and pass the CRC-8 check, but are discarded due to the LLID check. The SLD is defined in 65.1.3.3.1 or 76.2.6.1.3.1, as appropriate. The CRC-8 check is defined in 65.1.3.3.3 or 76.2.6.1.3.3, as appropriate. The LLID check is defined in 65.1.3.3.2 or 76.2.6.1.3.2, as appropriate.;

30.3.8 EXTENSION entity managed object class

This subclause formally defines the behaviours for the oEXTENSION managed object class attributes.

30.3.8.1 aEXTENSIONMACCtrlFramesTransmitted

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 1 600 000 counts per second at 1000 Mb/s

BEHAVIOUR DEFINED AS:
A count of EXTENSION frames passed to the MAC sublayer for transmission. This counter is incremented when a MA_CONTROL.request primitive is generated within the MAC Control sublayer with an opcode indicating the EXTENSION operation.;

30.3.8.2 aEXTENSIONMACCtrlFramesReceived

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 1 600 000 counts per second at 1000 Mb/s

BEHAVIOUR DEFINED AS:
A count of MAC Control frames passed by the MAC sublayer to the MAC Control sublayer. This counter is incremented when a ReceiveFrame function call returns a valid frame with: (1) a lengthOrType field value equal to the reserved Type for 802.3_MAC_Control as specified in 31.4.1.3, and (2) an opcode indicating the EXTENSION operation.;

30.3.8.3 aEXTENSIONMACCtrlStatus

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that has the following entries: enabled disabled

BEHAVIOUR DEFINED AS:
A read-write value that identifies the current (when read) or target (when set) operational state of the EXTENSION MAC Control function (when read), as specified in Annex 31C.;

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30.4 Layer management for 10, 100, and 1000 Mb/s baseband repeaters

30.4.1 Repeater managed object class

This subclause formally defines the behaviours for the oRepeater managed object class, attributes, actions, and notifications.

30.4.1.1 Repeater attributes

30.4.1.1.1 aRepeaterID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of aRepeaterID is assigned so as to uniquely identify a repeater among the subordinate managed objects of system (systemID and system are defined in ISO/IEC 10165-2:1992 [SMI], Definition of management information).;

30.4.1.1.2 aRepeaterType

ATTRIBUTE

APPROPRIATE SYNTAX:
An INTEGER that meets the requirements of the following description:

9	10 Mb/s Baseband
271	100 Mb/s Baseband, Class I
272	100 Mb/s Baseband, Class II
41	1000 Mb/s Baseband
other	See 30.2.5
unknown	Initializing, true state or type not yet known

BEHAVIOUR DEFINED AS:
Returns a value that identifies the CSMA/CD repeater type. The enumeration of the type is such that the value matches the clause number of the standard that specifies the particular repeater, with further numerical identification for the repeater classes within the same clause.;

30.4.1.1.3 aRepeaterGroupCapacity

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The aRepeaterGroupCapacity is the number of groups that can be contained within the repeater. Within each managed repeater, the groups are uniquely numbered in the range from 1 to aRepeaterGroupCapacity.

Some groups may not be present in a given repeater instance, in which case the actual number of groups present is less than aRepeaterGroupCapacity. The number of groups present is never greater than aRepeaterGroupCapacity.;

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30.4.1.1.4 aGroupMap

ATTRIBUTE

APPROPRIATE SYNTAX:
BITSTRING

BEHAVIOUR DEFINED AS:
A string of bits which reflects the current configuration of units that are viewed by group managed objects. The length of the bitstring is “aRepeaterGroupCapacity” bits. The first bit relates to group 1. A “1” in the bitstring indicates presence of the group, “0” represents absence of the group.;

30.4.1.1.5 aRepeaterHealthState

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE LIST that has the following entries:

other	undefined or unknown
ok	no known failures
repeaterFailure	known to have a repeater related failure
groupFailure	known to have a group related failure
portFailure	known to have a port related failure
generalFailure	has a failure condition, unspecified type

BEHAVIOUR DEFINED AS:
The aRepeaterHealthState attribute indicates the operational state of the repeater. The aRepeaterHealthData and aRepeaterHealthText attributes may be consulted for more specific information about the state of the repeater’s health. In case of multiple kinds of failures (e.g., repeater failure and port failure), the value of this attribute shall reflect the highest priority in the following order:
repeater failure
group failure
port failure
general failure;

30.4.1.1.6 aRepeaterHealthText

ATTRIBUTE

APPROPRIATE SYNTAX:
A PrintableString, 255 characters max

BEHAVIOUR DEFINED AS:
The aRepeaterHealthText attribute is a text string that provides information relevant to the operational state of the repeater. Repeater vendors may use this mechanism to provide detailed failure information or instructions for problem resolution.

The contents are vendor specific.;

30.4.1.1.7 aRepeaterHealthData

ATTRIBUTE

APPROPRIATE SYNTAX:
OCTET STRING, 0–255

BEHAVIOUR DEFINED AS:

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The aRepeaterHealthData attribute is a block of data octets that provides information relevant to the operational state of the repeater. The encoding of this data block is vendor dependent. Repeater vendors may use this mechanism to provide detailed failure information or instructions for problem resolution.;

30.4.1.1.8 aTransmitCollisions

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 75 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

For a Clause 9 repeater, the counter increments every time the repeater state diagram enters the TRANSMIT COLLISION state from any state other than ONE PORT LEFT (Figure 9–2). For a Clause 27 repeater, the counter increments every time the Repeater Core state diagram enters the JAM state as a result of Activity(ALL) > 1 (Figure 27–2). For a Clause 41 repeater, the counter increments every time the Repeater Unit state diagram enters the JAM state (Figure 41–2).

NOTE—Some non-collision events such as false carriers will cause the repeater unit to enter the JAM state and increment this counter.;

30.4.1.2 Repeater actions

30.4.1.2.1 acResetRepeater

ACTION

APPROPRIATE SYNTAX:

None required

BEHAVIOUR DEFINED AS:

This causes a transition to the START state of Figure 9–2 for a Clause 9 repeater, to the START state of Figure 27–2 for a Clause 27 repeater, or to the START state of Figure 41–2 for a Clause 41 repeater. The repeater performs a disruptive self-test that has the following characteristics:

1. The components are not specified
2. The test resets the repeater but without affecting management information about the repeater
3. The test does not inject packets onto any segment
4. Packets received during the test may or may not be transferred
5. The test does not interfere with management functions

This causes a nRepeaterReset notification to be sent.;

30.4.1.2.2 acExecuteNonDisruptiveSelfTest

ACTION

APPROPRIATE SYNTAX:

None required

BEHAVIOUR DEFINED AS:

The repeater performs a vendor-specific, non-disruptive self-test that has the following characteristics:

1. The components are not specified
2. The test does not change the state of the repeater or management information about the repeater
3. The test does not inject packets onto any segment
4. The test does not prevent the transfer of any packets

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5. Completion of the test causes a nRepeaterHealth to be sent.;

30.4.1.3 Repeater notifications

30.4.1.3.1 nRepeaterHealth

NOTIFICATION

APPROPRIATE SYNTAX:

A SEQUENCE of three data types. The first is mandatory, the following two are optional. The first is the value of the attribute aRepeaterHealthState. The second is the value of the attribute aRepeaterHealthText. The third is the value of the attribute aRepeaterHealthData

BEHAVIOUR DEFINED AS:

This notification conveys information related to the operational state of the repeater. See the aRepeaterHealthState, aRepeaterHealthText, and aRepeaterHealthData attributes for descriptions of the information that is sent.

The nRepeaterHealth notification is sent only when the health state of the repeater changes. The nRepeaterHealth notification shall contain repeaterHealthState. repeaterHealthData and repeaterHealthText may or may not be included. The nRepeaterHealth notification is not sent as a result of powering up a repeater.;

30.4.1.3.2 nRepeaterReset

NOTIFICATION

APPROPRIATE SYNTAX:

A SEQUENCE of three data types. The first is mandatory, the following two are optional. The first is the value of the attribute aRepeaterHealthState. The second is the value of the attribute aRepeaterHealthText. The third is the value of the attribute aRepeaterHealthData

BEHAVIOUR DEFINED AS:

This notification conveys information related to the operational state of the repeater. The nRepeaterReset notification is sent when the repeater is reset as the result of a power-on condition or upon completion of the acResetRepeater action. The nRepeaterReset notification shall contain repeaterHealthState. repeaterHealthData and repeaterHealthText may or may not be included.;

30.4.1.3.3 nGroupMapChange

NOTIFICATION

APPROPRIATE SYNTAX:

BITSTRING

BEHAVIOUR DEFINED AS:

This notification is sent when a change occurs in the group structure of a repeater. This occurs only when a group is logically removed from or added to a repeater. The nGroupMapChange notification is not sent when powering up a repeater. The value of the notification is the updated value of the aGroupMap attribute.;

30.4.2 Group managed object class

This subclause formally defines the behaviours for the oGroup managed object class, attributes, actions, and notifications.

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30.4.2.1 Group attributes

30.4.2.1.1 aGroupID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A value unique within the repeater. The value of aGroupID is assigned so as to uniquely identify a group among the subordinate managed objects of the containing object (oRepeater). This value is never greater than aRepeaterGroupCapacity.;

30.4.2.1.2 aGroupPortCapacity

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The aGroupPortCapacity is the number of ports contained within the group. Valid range is 1–1024. Within each group, the ports are uniquely numbered in the range from 1 to aGroupPortCapacity. Some ports may not be present in a given group instance, in which case the actual number of ports present is less than aGroupPortCapacity. The number of ports present is never greater than aGroupPortCapacity.;

30.4.2.1.3 aPortMap

ATTRIBUTE

APPROPRIATE SYNTAX:
BitString

BEHAVIOUR DEFINED AS:
A string of bits that reflects the current configuration of port managed objects within this group. The length of the bitstring is “aGroupPortCapacity” bits. The first bit relates to group 1. A “1” in the bitstring indicates presence of the port, “0” represents absence of the port.;

30.4.2.2 Group notifications

30.4.2.2.1 nPortMapChange

NOTIFICATION

APPROPRIATE SYNTAX:
BitString

BEHAVIOUR DEFINED AS:
This notification is sent when a change occurs in the port structure of a group. This occurs only when a port is logically removed from or added to a group. The nPortMapChange notification is not sent when powering up a repeater. The value of the notification is the updated value of the aPortMap attribute.;

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30.4.3 Repeater port managed object class

This subclause formally defines the behaviours for the oRepeaterPort managed object class, attributes, actions, and notifications.

30.4.3.1 Port attributes

30.4.3.1.1 aPortID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A value unique in the group. It is assumed that ports are partitioned into groups that also have IDs. The value of aPortID is assigned so as to uniquely identify a repeater port among the subordinate managed objects of the containing object (oGroup). This value can never be greater than aGroupPortCapacity.;

30.4.3.1.2 aPortAdminState

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE LIST that has the following entries:
disabled
enabled

BEHAVIOUR DEFINED AS:
A disabled port neither transmits nor receives. The port shall be explicitly enabled to restore operation. The acPortAdminControl action provides this ability. The port enable/disable function as reported by this attribute is preserved across repeater reset including loss of power. aPortAdminState takes precedence over auto-partition and functionally operates between the auto-partition mechanism and the AUI/PMA, PCS/PMA, or GMII/PCS as applicable. For a Clause 9 and Clause 27 repeater, the port auto-partition is reinitialized upon acPortAdminControl taking the value “enabled.” For a Clause 41 repeater, the port auto-partition, receive jabber and carrier integrity functions are reinitialized upon acPortAdminControl taking the value “enabled.”;

30.4.3.1.3 aAutoPartitionState

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE LIST that has the following entries:
autoPartitioned
notAutoPartitioned

BEHAVIOUR DEFINED AS:
The aAutoPartitionState flag indicates whether the port is currently partitioned by the repeater’s auto-partition protection. The conditions that cause port partitioning are specified in partition state diagram in Clause 9, Clause 27, and Clause 41. They are not differentiated here. A Clause 27 and Clause 41 repeater port partitions on entry to the PARTITION WAIT state of the partition state diagram (Figure 27–8 and Figure 41–4).;

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30.4.3.1.4 aReadableFrames

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 15 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
A representation of the total frames of valid frame length. Increment counter by one for each frame whose OctetCount is greater than or equal to minFrameSize and for which the FCSError and CollisionEvent signals are not asserted, and for which the attribute aFramesTooLong has not been incremented. Additionally, for 1000 Mb/s repeaters, this count shall only be incremented for frames which are received within a CarrierEvent which has a ActivityDuration of greater than or equal to (slotTime + JamSize) BT (see 4.4.2).

NOTE—This statistic provides one of the parameters necessary for obtaining the packet error ratio.;

30.4.3.1.5 aReadableOctets

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 1 240 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
Increment counter by OctetCount for each frame which has been determined to be a readable frame.

NOTE—This statistic provides an indicator of the total data transferred.;

30.4.3.1.6 aFrameCheckSequenceErrors

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 15 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
Increment counter by one for each frame with the FCSError signal asserted and the FramingError and CollisionEvent signals deasserted and whose OctetCount is greater than or equal to minFrameSize and for which the attribute aFramesTooLong has not been incremented.;

30.4.3.1.7 aAlignmentErrors

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 15 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
Increment counter by one for each frame with the FCSError and FramingError signals asserted and CollisionEvent signal deasserted and whose OctetCount is greater than or equal to minFrameSize and for which the attribute aFramesTooLong has not been incremented. If aAlignmentErrors is incremented then the aFrameCheckSequenceErrors attribute shall not be incremented for the same

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frame. This counter will not increment for 8 bit wide group encoding schemes.;

30.4.3.1.8 aFramesTooLong

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 815 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

Increment counter by one for each frame whose OctetCount is greater than maxFrameSizeLimit (see 4.2.7.1 and 4.4.2). If aFrameTooLong is counted then neither the aAlignmentErrors nor the aFrameCheckSequenceErrors attribute shall be incremented for the frame.

30.4.3.1.9 aShortEvents

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 75 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

Increment counter by one for each CarrierEvent with ActivityDuration less than ShortEventMaxTime. In the 10 Mb/s case ShortEventMaxTime is greater than 74 BT and less than 82 BT. ShortEventMaxTime has tolerances included to provide for circuit losses between a conformance test point at the AUI and the measurement point within the state diagram. In the 100 Mb/s case ShortEventMaxTime is 84 bits (21 nibbles), and for the 1000 Mb/s case ShortEventMaxTime is 72 bits (9 octets).

NOTE 1—shortEvents may indicate externally generated noise hits which will cause the repeater to transmit Runts to its other ports, or propagate a collision (which may be late) back to the transmitting DTE and damaged frames to the rest of the network.

NOTE 2—implementers may wish to consider selecting the ShortEventMaxTime towards the lower end of the allowed tolerance range to accommodate bit losses suffered through physical channel devices not budgeted for within this standard.

NOTE 3—Note also that the significance of this attribute is different in 10, 100, and 1000 Mb/s collision domains. Clause 9 repeaters perform fragment extension of short events which would be counted as runts on the interconnect ports of other repeaters. Clause 27 repeaters do not perform fragment extension. Clause 41 repeaters support one repeater per collision domain and do not perform fragment extension.;

30.4.3.1.10 aRunts

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 75 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:

Increment counter by one for each CarrierEvent that meets one of the following two conditions. Only one test need be made. a) The ActivityDuration is greater than ShortEventMaxTime and less than ValidPacketMinTime and the CollisionEvent signal is deasserted. b) The OctetCount is less than 64, the ActivityDuration is greater than ShortEventMaxTime, and the CollisionEvent signal is deasserted. For 10 and 100 Mb/s repeaters, ValidPacketMinTime is greater than or equal to

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552 BT and less than 565 BT. A CarrierEvent greater than or equal to 552 BT but less than 565 BT may or may not be counted as a runt. At 10 Mb/s an event whose length is greater than 74 BT but less than 82 BT shall increment either the aShortEvents attribute or the aRunts attribute, but not both. ValidPacketMinTime has tolerances included to provide for circuit losses between a conformance test point at the AUI and the measurement point within the state diagram.
For 1000 Mb/s repeaters, ValidPacketMinTime is 4136 BT.

NOTE—Runts usually indicate collision fragments, a normal network event. In certain situations associated with large diameter networks a percentage of runts may exceed ValidPacketMinTime.;

30.4.3.1.11 aCollisions

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 75 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
This counter increments for any CarrierEvent signal on any port in which the CollisionEvent signal on this port is asserted.;

30.4.3.1.12 aLateEvents

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 75 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
For a Clause 9 repeater port this counter increments for each CarrierEvent in which the CollIn(X) variable transitions to the value SQE (see 9.6.6.2) while the ActivityDuration is greater than the LateEventThreshold. For a Clause 27 and Clause 41 repeater port this counter increments for each CarrierEvent in which the CollisionEvent signal assertion occurs while the ActivityDuration is greater than the LateEventThreshold. In both cases such a CarrierEvent is counted twice, as both an aCollision and as an aLateEvent.
For 10 and 100 Mb/s repeaters, the LateEventThreshold is greater than 480 BT and less than 565 BT. LateEventThreshold has tolerances included to permit an implementation to build a single threshold to serve as both the LateEventThreshold and ValidPacketMinTime threshold. For 1000 Mb/s repeaters, the LateEventThreshold is equal to ValidPacketMinTime.;

30.4.3.1.13 aVeryLongEvents

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 250 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
For a Clause 9 repeater port this counter increments for each CarrierEvent whose ActivityDuration is greater than the MAU Jabber Lockup Protection timer TW3 (see 9.6.1, 9.6.5). For a Clause 27 and Clause 41 repeater port this counter increments on entry to the RX JABBER state of the receive timer state diagram (Figure 27–7 and Figure 41–3). Other counters may be incremented as appropriate.;

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30.4.3.1.14 aDataRateMismatches

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter

BEHAVIOUR DEFINED AS:
Increment counter by one for each frame received by this port that meets all of the conditions required by only one of the following three measurement methods:

Measurement method A, which is valid for 10 and 100 Mb/s operation only: a) The CollisionEvent signal is not asserted. b) The ActivityDuration is greater than ValidPacketMinTime. c) The received frequency (data rate) is detectably mismatched from the local transmit frequency.

Measurement method B, which is valid for 10 and 100 Mb/s operation only: a) The CollisionEvent signal is not asserted. b) The OctetCount is greater than 63. c) The received frequency (data rate) is detectably mismatched from the local transmit frequency.

Measurement method C, which is valid for 1000 Mb/s operation only: The received frequency (data rate) is detectably mismatched from the local transmit frequency.

The exact degree of mismatch is vendor specific and is to be defined by the vendor for conformance testing. When this event occurs, other counters whose increment conditions were satisfied may or may not also be incremented, at the implementer's discretion.

NOTE—Whether or not the repeater was able to maintain data integrity is beyond the scope of this standard.;

30.4.3.1.15 aAutoPartitions

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter

BEHAVIOUR DEFINED AS:
Increment counter by one for each time that the repeater has automatically partitioned this port. The conditions that cause a Clause 9 repeater port to partition are specified in the partition state diagram in Clause 9. They are not differentiated here. A Clause 27 and Clause 41 repeater port partitions on entry to the PARTITION WAIT state of the partition state diagram (Figure 27–8 and Figure 41–4).;

30.4.3.1.16 aIsolates

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 400 counts per second at 100 Mb/s

BEHAVIOUR DEFINED AS:
Increment counter by one each time that the repeater port automatically isolates as a consequence of false carrier events. The conditions that cause a port to automatically isolate are as defined by the transition from the FALSE CARRIER state to the LINK UNSTABLE state of the carrier integrity state diagram (Figure 27–9 and Figure 41–5).

NOTE—Isolates do not affect the value of aPortAdminState.;

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30.4.3.1.17 aSymbolErrorDuringPacket

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 160 000 counts per second for 100 Mb/s implementations

BEHAVIOUR DEFINED AS:
A count of the number of times when valid length packet was received at the port and there was at least one occurrence of an invalid data symbol. This can increment only once per valid CarrierEvent. A collision presence at any port of the repeater containing port N, will not cause this attribute to increment.;

30.4.3.1.18 aLastSourceAddress

ATTRIBUTE

APPROPRIATE SYNTAX:
MACAddress

BEHAVIOUR DEFINED AS:
The Source Address of the last readable Frame received by this port.;

30.4.3.1.19 aSourceAddressChanges

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 15 000 counts per second at 10 Mb/s

BEHAVIOUR DEFINED AS:
Increment counter by one each time that the aLastSourceAddress attribute has changed.

NOTE—This may indicate whether a link is connected to a single DTE or another multi-user segment.;

30.4.3.1.20 aBursts

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 235 000 counts per second at 1000 Mb/s

BEHAVIOUR DEFINED AS:
This counter is valid for 1000 Mb/s operation only. This counter increments by one for each CarrierEvent with ActivityDuration greater than or equal to slotTime during which the CollisionEvent signal has not been asserted. Note that this counter will not increment for a 10 or 100 Mb/s port as packet bursting is not supported at these speeds.;

30.4.3.2 Port actions

30.4.3.2.1 acPortAdminControl

ACTION

APPROPRIATE SYNTAX:

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Same as aPortAdminStateBEHAVIOUR DEFINED AS:
This action provides a means to alter aPortAdminState. For a Clause 9 and Clause 27 repeater it should exert a BEGIN on the Partitioning state diagram (Figure 9–6 and Figure 27–8) upon taking the value "enabled." For a Clause 41 repeater it shall exert a BEGIN on the receive timer, partition, and carrier integrity state diagrams (Figure 41–3, Figure 41–4, and Figure 41–5) upon taking the value "enabled.";

30.5 Layer management for medium attachment units (MAUs)

30.5.1 MAU managed object class

This subclause formally defines the behaviours for the oMAU managed object class, attributes, actions, and notifications.

The sublayer that connects directly to the media is called MAU for 10 Mb/s operation and its equivalent is the combined PMA and PMD sublayers at higher operating speeds. Because this clause defines management for use at many speeds, it needs to be able to refer to MAUs and the PMA and PMD sublayers as a group. Therefore in this clause, the term MAU will include PMA and PMD sublayers, as well as MAUs, except in those instances where it is explicitly restricted to 10 Mb/s.

30.5.1.1 MAU attributes

30.5.1.1.1 aMAUID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of aMAUID is assigned so as to uniquely identify a MAU among the subordinate managed objects of the containing object.;

30.5.1.1.2 aMAUType

ATTRIBUTE

APPROPRIATE SYNTAX:
A GET-SET ENUMERATION that meets the requirements of the following description:

global	undefined
other	See 30.2.5
unknown	Initializing, true state or type not yet known
AUI	no internal MAU, view from AUI
2BASE-TL	Voice grade twisted-pair cabling PHY as specified in Clause 61 and 63
10BASE5	Thick coax MAU as specified in Clause 8
FOIRL	FOIRL MAU as specified in 9.9
10BASE2	Thin coax MAU as specified in Clause 10
10BROAD36	Broadband DTE MAU as specified in Clause 11
10BASE-T	Twisted-pair cabling MAU as specified in Clause 14, duplex mode unknown
10BASE-THD	Twisted-pair cabling MAU as specified in Clause 14, half duplex mode
10BASE-TFD	Twisted-pair cabling MAU as specified in Clause 14, full duplex mode
10PASS-TS	Voice grade twisted-pair cabling PHY as specified in Clause 61 and 62
10BASE-FP	Passive fiber MAU as specified in Clause 16
10BASE-FB	Synchronous fiber MAU as specified in Clause 17

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10BASE-FL	Asynchronous fiber MAU as specified in Clause 18, duplex mode unknown
10BASE-FLHD	Asynchronous fiber MAU as specified in Clause 18, half duplex mode
10BASE-FLFD	Asynchronous fiber MAU as specified in Clause 18, full duplex mode
100BASE-T4	Four-pair Category 3 twisted-pair cabling as specified in Clause 23
100BASE-TX	Two-pair Category 5 twisted-pair cabling as specified in Clause 25, duplex mode unknown
100BASE-TXHD	Two-pair Category 5 twisted-pair cabling as specified in Clause 25, half duplex mode
100BASE-TXFD	Two-pair Category 5 twisted-pair cabling as specified in Clause 25, full duplex mode
100BASE-BX10D	One single-mode fiber OLT PHY as specified in Clause 58
100BASE-BX10U	One single-mode fiber ONU PHY as specified in Clause 58
100BASE-FX	X fiber over PMD as specified in Clause 26, duplex mode unknown
100BASE-FXHD	X fiber over PMD as specified in Clause 26, half duplex mode
100BASE-FXFD	X fiber over PMD as specified in Clause 26, full duplex mode
100BASE-LX10	Two fiber PHY as specified in Clause 58
100BASE-T2	Two-pair Category 3 twisted-pair cabling as specified in Clause 32, duplex mode unknown
100BASE-T2HD	Two-pair Category 3 twisted-pair cabling as specified in Clause 32, half duplex mode
100BASE-T2FD	Two-pair Category 3 twisted-pair cabling as specified in Clause 32, full duplex mode
1000BASE-X	X PCS/PMA as specified in Clause 36 over undefined PMD, duplex mode unknown
1000BASE-BX10D	One single-mode fiber OLT PHY as specified in Clause 59
1000BASE-BX10U	One single-mode fiber ONU PHY as specified in Clause 59
1000BASE-XHD	X PCS/PMA as specified in Clause 36 over undefined PMD, half duplex mode
1000BASE-XFD	X PCS/PMA as specified in Clause 36 over undefined PMD, full duplex mode
1000BASE-LX	X fiber over long-wavelength laser PMD as specified in Clause 38, duplex mode unknown
1000BASE-LXHD	X fiber over long-wavelength laser PMD as specified in Clause 38, half duplex mode
1000BASE-LXFD	X fiber over long-wavelength laser PMD as specified in Clause 38, full duplex mode
1000BASE-LX10	Two fiber 10 km PHY as specified in Clause 59
1000BASE-PX10-D	One single-mode fiber OMP OLT PHY, as specified in Clause 60, supporting a distance of at least 10 km, and a split of at least 1:16
1000BASE-PX10-U	One single-mode fiber OMP ONU PHY, as specified in Clause 60, supporting a distance of at least 10 km, and a split of at least 1:16
1000BASE-PX20-D	One single-mode fiber OMP OLT PHY, as specified in Clause 60, supporting a distance of at least 20 km, and a split of at least 1:16
1000BASE-PX20-U	One single-mode fiber OMP ONU PHY, as specified in Clause 60, supporting a distance of at least 20 km, and a split of at least 1:16
1000BASE-PX30-D	One single-mode fiber OMP OLT PHY, as specified in Clause 60, supporting a distance of at least 20 km, and a split of at least 1:32
1000BASE-PX30-U	One single-mode fiber OMP ONU PHY, as specified in Clause 60, supporting a distance of at least 20 km, and a split of at least 1:32
1000BASE-PX40-D	One single-mode fiber OMP OLT PHY as specified in Clause 60, supporting a distance of at least 20 km, and a split of at least 1:64
1000BASE-PX40-U	One single-mode fiber OMP ONU PHY as specified in Clause 60, supporting a distance of at least 20 km, and a split of at least 1:64

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1000BASE-SX	X fiber over short-wavelength laser PMD as specified in Clause 38, duplex mode unknown
1000BASE-SXHD	X fiber over short-wavelength laser PMD as specified in Clause 38, half duplex mode
1000BASE-SXFD	X fiber over short-wavelength laser PMD as specified in Clause 38, full duplex mode
1000BASE-CX	X copper over 150-Ohm balanced cable PMD as specified in Clause 39, duplex mode unknown
1000BASE-CXHD	X copper over 150-Ohm balanced cable PMD as specified in Clause 39, half duplex mode
1000BASE-CXFD	X copper over 150-Ohm balanced cable PMD as specified in Clause 39, full duplex mode
1000BASE-KX	X PCS/PMA over an electrical backplane PMD as specified in Clause 70
1000BASE-T	Four-pair Category 5 twisted-pair cabling PHY as specified in Clause 40, duplex mode unknown
1000BASE-THD	Four-pair Category 5 twisted-pair cabling PHY as specified in Clause 40, half duplex mode
1000BASE-TFD	Four-pair Category 5 twisted-pair cabling PHY as specified in Clause 40, full duplex mode
10GBASE-X	X PCS/PMA as specified in Clause 48 over undefined PMD
10GBASE-LX4	X fiber over 4 lane 1310nm optics as specified in Clause 53
10GBASE-CX4	X copper over 8 pair 100-Ohm balanced cable as specified in Clause 54
10GBASE-KX4	X PCS/PMA over an electrical backplane PMD as specified in Clause 71
10GBASE-R	R PCS/PMA as specified in Clause 49 over undefined PMD
10GBASE-ER	R fiber over 1550nm optics as specified in Clause 52
10GBASE-LR	R fiber over 1310nm optics as specified in Clause 52
10GBASE-SR	R fiber over 850nm optics as specified in Clause 52
10GBASE-LRM	R fiber over 1310nm optics as specified in Clause 68
10GBASE-KR	R PCS/PMA over an electrical backplane PMD as specified in Clause 72
10GBASE-W	W PCS/PMA as specified in Clause 49 and 50 over undefined PMD
10GBASE-EW	W fiber over 1550nm optics as specified in Clause 52
10GBASE-LW	W fiber over 1310nm optics as specified in Clause 52
10GBASE-SW	W fiber over 850nm optics as specified in Clause 52
10GBASE-T	Four-pair twisted-pair balanced copper cabling PHY as specified in Clause 55
10/1GBASE-PRX-D1	One single-mode fiber 10.3125 GBd continuous downstream / 1.25 GBd burst mode upstream OLT PHY as specified in Clause 75
10/1GBASE-PRX-D2	One single-mode fiber 10.3125 GBd continuous downstream / 1.25 GBd burst mode upstream OLT PHY as specified in Clause 75
10/1GBASE-PRX-D3	One single-mode fiber 10.3125 GBd continuous downstream / 1.25 GBd burst mode upstream OLT PHY as specified in Clause 75
10/1GBASE-PRX-D4	One single-mode fiber 10.3125 GBd continuous downstream / 1.25 GBd burst mode upstream OLT PHY as specified in Clause 75
10/1GBASE-PRX-U1	One single-mode fiber 10.3125 GBd continuous downstream / 1.25 GBd burst mode upstream ONU PHY as specified in Clause 75
10/1GBASE-PRX-U2	One single-mode fiber 10.3125 GBd continuous downstream / 1.25 GBd burst mode upstream ONU PHY as specified in Clause 75
10/1GBASE-PRX-U3	One single-mode fiber 10.3125 GBd continuous downstream / 1.25 GBd burst mode upstream ONU PHY as specified in Clause 75
10/1GBASE-PRX-U4	One single-mode fiber 10.3125 GBd continuous downstream / 1.25 GBd burst mode upstream ONU PHY as specified in Clause 75
10GBASE-PR-D1	One single-mode fiber 10.3125 GBd continuous downstream / burst mode upstream OLT PHY as specified in Clause 75
10GBASE-PR-D2	One single-mode fiber 10.3125 GBd continuous downstream / burst

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	mode upstream OLT PHY as specified in Clause 75
10GBASE-PR-D3	One single-mode fiber 10.3125 GBd continuous downstream / burst mode upstream OLT PHY as specified in Clause 75
10GBASE-PR-D4	One single-mode fiber 10.3125 GBd continuous downstream / burst mode upstream OLT PHY as specified in Clause 75
10GBASE-PR-U1	One single-mode fiber 10.3125 GBd continuous downstream / burst mode upstream ONU PHY as specified in Clause 75
10GBASE-PR-U3	One single-mode fiber 10.3125 GBd continuous downstream / burst mode upstream ONU PHY as specified in Clause 75
10GBASE–PR–U4	One single-mode fiber 10.3125 GBd continuous downstream / burst mode upstream ONU PHY as specified in Clause 75
40GBASE-R	Multi-lane PCS as specified in Clause 82 over undefined PMA/PMD
40GBASE-KR4	40GBASE-R PCS/PMA over an electrical backplane PMD as specified in Clause 84
40GBASE-CR4	40GBASE-R PCS/PMA over 4 lane shielded copper balanced cable PMD as specified in Clause 85
40GBASE-SR4	40GBASE-R PCS/PMA over 4 lane multimode fiber PMD as specified in Clause 86
40GBASE-LR4	40GBASE-R PCS/PMA over 4 WDM lane single mode fiber PMD, with long reach, as specified in Clause 87
40GBASE-ER4	40GBASE-R PCS/PMA over 4 WDM lane single mode fiber PMD, with extended reach, as specified in Clause 87
40GBASE-FR	40GBASE-R PCS/PMA over single mode fiber PMD as specified in Clause 89
100GBASE-R	Multi-lane PCS as specified in Clause 82 over undefined 100GBASE-R or 100GBASE-P PMA/PMD
100GBASE-CR4	100GBASE-R PCS/PMA over 4 lane shielded copper balanced cable PMD as specified in Clause 92
100GBASE-KR4	100GBASE-R PCS/PMA over an electrical backplane PMD as specified in Clause 93
100GBASE-KP4	100GBASE-P PCS/PMA over an electrical backplane PMD as specified in Clause 94
100GBASE-CR10	100GBASE-R PCS/PMA over 10 lane shielded copper balanced cable PMD as specified in Clause 85
100GBASE-SR4	100GBASE-R PCS/PMA over 4 lane multimode fiber PMD as specified in Clause 95
100GBASE-SR10	100GBASE-R PCS/PMA over 10 lane multimode fiber PMD as specified in Clause 86
100GBASE-LR4	100GBASE-R PCS/PMA over 4 WDM lane single mode fiber PMD, with long reach, as specified in Clause 88
100GBASE-ER4	100GBASE-R PCS/PMA over 4 WDM lane single mode fiber PMD, with extended reach, as specified in Clause 88
802.9a	Integrated services MAU as specified in IEEE Std 802.9a-1995 (withdrawn)

BEHAVIOUR DEFINED AS:

Returns a value that identifies the internal MAU type. If an AUI is to be identified to access an external MAU, the type “AUI” is returned. A SET operation to one of the possible enumerations indicated by aMAUTypeList will force the MAU into the new operating mode. If a Clause 22 MII or Clause 35 GMII is present, then this will map to the mode force bits specified in 22.2.4.1. If a Clause 45 MDIO Interface is present, then this will map to the PCS type selection bit(s) in the 10G WIS Control 2 register specified in 45.2.2.6.6, the PCS Control 2 register specified in 45.2.3.6.1, the PMA/PMD type selection bits in the PMA/PMD Control 2 register specified in 45.2.1.6, the PMA/PMD control 1 register specified in 45.2.1.1, and the PCS control 1 register

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45.2.3.1. If Clause 28, Clause 37, or Clause 73 Auto-Negotiation is operational, then this will change the advertised ability to the single enumeration specified in the SET operation, and cause an immediate link renegotiation. A change in the MAU type will also be reflected in aPHYType.

The enumerations 1000BASE-X, 1000BASE-XHD, 1000BASE-XFD, 10GBASE-X, 10GBASE-R, 10GBASE-W, 40GBASE-R, and 100GBASE-R shall only be returned if the underlying PMD type is unknown.;

30.5.1.1.3 aMAUTypeList

ATTRIBUTE

APPROPRIATE SYNTAX:
A SEQUENCE of ENUMERATIONS that match the syntax of aMAUType

BEHAVIOUR DEFINED AS:
A GET attribute that returns the possible types that the MAU could be, identifying the ability of the MAU. This attribute maps to aPHYTypeList.;

30.5.1.1.4 aMediaAvailable

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED value list that has the following entries:

other	undefined
unknown	initializing, true state not yet known
available	link or light normal, loopback normal
available reduced	link normal, reduced bandwidth, applies only to 2BASE-TL and 10PASS-TS
not available	link loss or low light, no loopback
remote fault	remote fault with no detail
invalid signal	invalid signal, applies only to 10BASE-FB
remote jabber	remote fault, reason known to be jabber
remote link loss	remote fault, reason known to be far-end link loss
remote test	remote fault, reason known to be test
ready	at least one PME available, applies only to 2BASE-TL and 10PASS-TS
offline	offline, applies only to Clause 37 Auto-Negotiation
auto neg error	Auto-Negotiation Error, applies only to Clause 37 Auto-Negotiation
PMD link fault	PMD/PMA receive link fault
WIS frame loss	WIS loss of frame, applies only to 10GBASE-W
WIS signal loss	WIS loss of signal, applies only to 10GBASE-W
PCS link fault	PCS receive link fault
excessive BER	PCS Bit Error Ratio monitor reporting excessive error ratio
DXS link fault	DTE XGXS receive link fault, applies only to XAUI
PXS link fault	PHY XGXS transmit link fault, applies only to XAUI

BEHAVIOUR DEFINED AS:
If the MAU is a 10 Mb/s link or fiber type (FOIRL, 10BASE-T, 10BASE-F), then this is equivalent to the link test fail state/low light function. For an AUI, 10BASE2, 10BASE5, or 10BROAD36 MAU, this indicates whether or not loopback is detected on the DI circuit. The value of this attribute persists between packets for MAU types AUI, 10BASE5, 10BASE2, 10BROAD36, and 10BASE-FP.
At power-up or following a reset, the value of this attribute will be “unknown” for AUI, 10BASE5, 10BASE2, 10BROAD36, and 10BASE-FP MAUs. For these MAUs loopback will be tested on each transmission during which no collision is detected. If DI is receiving *input* when DO returns

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to IDL after a transmission and there has been no collision during the transmission, then loopback will be detected. The value of this attribute will only change during noncollided transmissions for AUI, 10BASE2, 10BASE5, 10BROAD36, and 10BASE-FP MAUs.

For 100BASE-T2 and 100BASE-T4 PHYs the enumerations match the states within the respective link integrity state diagrams, Figure 32-16 and Figure 23–12. For 100BASE-TX, 100BASE-FX, 100BASE-LX10 and 100BASE-BX10 PHYs the enumerations match the states within the link integrity state diagram Figure 24–15. Any MAU that implements management of Clause 28 or Clause 73 Auto-Negotiation will map remote fault indication to MediaAvailable "remote fault." Any MAU that implements management of Clause 37 Auto-Negotiation will map the received RF1 and RF2 bits as specified in Table 37–3, as follows. Offline maps to the enumeration "offline," Link_Failure maps to the enumeration "remote fault" and Auto-Negotiation Error maps to the enumeration "auto neg error."

The enumeration "remote fault" applies to 10BASE-FB remote fault indication, the 100BASE-X far-end fault indication and nonspecified remote faults from a system running Clause 28 Auto-Negotiation. The enumerations "remote jabber", "remote link loss", or "remote test" should be used instead of "remote fault" where the reason for remote fault is identified in the remote signaling protocol.

Where a Clause 22 MII or Clause 35 GMII is present, a one in the remote fault bit (22.2.4.2.11) maps to the enumeration "remote fault," a zero in the link status bit (22.2.4.2.13) maps to the enumeration "not available." The enumeration "not available" takes precedence over "remote fault."

For 40 Gb/s and 100 Gb/s the enumerations map to value of the link_fault variable (see 81.3.4) within the Link Fault Signaling state diagram (see 81.3.4.1 and Figure 46–11) as follows: the value OK maps to the enumeration "available", the value Local Fault maps to the enumeration "not available" and the value Remote Fault maps to the enumeration "remote fault."

For 2BASE-TL and 10PASS-TS PHYs, the enumeration "unknown" maps to the condition where the PHY is initializing, the enumeration "ready" maps to the condition where at least one PME is available and is ready for handshake, the enumeration "available" maps to the condition where, at the PCS, at least one PME is operationally linked, the enumeration "not available" maps to the condition where the PCS is not operationally linked, the enumeration "available reduced" maps to the condition where a link fault is detected at the receive direction by one or more PMEs in the aggregation group and the enumeration "PMD link fault" maps to the condition where a link fault is detected at the receive direction by all of the PMA/PMDs in the aggregation group.

For 10 Gb/s the enumerations map to value of the link_fault variable within the Link Fault Signaling state diagram (Figure 46–11) as follows: the value OK maps to the enumeration "available", the value Local Fault maps to the enumeration "not available" and the value Remote Fault maps to the enumeration "remote fault". The enumeration "PMD link fault", "WIS frame loss", "WIS signal loss", "PCS link fault", "excessive BER" or "DXS link fault" should be used instead of the enumeration "not available" where the reason for the Local Fault state can be identified through the use of the Clause 45 MDIO Interface. Where multiple reasons for the Local Fault state can be identified only the highest precedence error should be reported. This precedence in descending order is as follows: "PXS link fault", "PMD link fault", "WIS frame loss", "WIS signal loss", "PCS link fault", "excessive BER", "DXS link fault".

Where a Clause 45 MDIO interface is present a zero in the PMA/PMD Receive link status bit (45.2.1.2.4) maps to the enumeration "PMD link fault", a one in the LOF status bit (45.2.2.10.4) maps to the enumeration "WIS frame loss", a one in the LOS status bit (45.2.2.10.5) maps to the enumeration "WIS signal loss", a zero in the PCS Receive link status bit (45.2.3.2.7) maps to the enumeration "PCS link fault", a one in the 10/40/100GBASE-R PCS Latched high BER status bit (45.2.3.14.2) maps to the enumeration "excessive BER", a zero in the DTE XS receive link status bit (45.2.5.2.7) maps to the enumeration "DXS link fault" and a zero in the PHY XS transmit link status bit (45.2.4.2.7) maps to the enumeration "PXS link fault".;

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30.5.1.1.5 aLoseMediaCounter

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 10 counts per second

BEHAVIOUR DEFINED AS:

Counts the number of times that the MediaAvailable attribute changes from the enumeration "available" to any other enumeration. Mandatory for MAU type "AUI," optional for all others.;

30.5.1.1.6 aJabber

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE of two indications. The first, JabberFlag, consists of an ENUMERATED value list that has the following entries:

other	undefined
unknown	initializing, true state not yet known
normal	state is true or normal
fault	state is false, fault, or abnormal

The second, jabberCounter, is a generalized nonresettable counter. This counter has a maximum increment rate of 40 counts per second

BEHAVIOUR DEFINED AS:

If the MAU is in the JABBER state, the jabberFlag portion of the attribute is set to the "fault" value. The jabberCounter portion of the attribute is incremented each time the flag is set to the "fault" value. This attribute returns the value "other" for type AUI. Note that this counter will increment for a 10 Mb/s baseband and broadband MAUs only.;

30.5.1.1.7 aMAUAdminState

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED value list that has the following entries:

other	undefined
unknown	initializing, true state not yet known
operational	powered and connected
standby	inactive but on
shutdown	similar to power down

BEHAVIOUR DEFINED AS:

A MAU in management state "standby" forces DI and CI to idle and the media transmitter to idle or fault, if supported. The management state "standby" only applies to link type MAUs. The state of MediaAvailable is unaffected. A MAU or AUI in the management state "shutdown" assumes the same condition on DI, CI and the media transmitter as if it were powered down or not connected. For an AUI, this management state will remove power from the AUI. The MAU may return the value "undefined" for Jabber and MediaAvailable attributes when it is in this management state. A MAU in the management state "operational" is fully functional, and operates and passes signals to its attached DTE or repeater port in accordance with its specification.;

30.5.1.1.8 aBbMAUXmitRcvSplitType

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APPROPRIATE SYNTAX:

An ENUMERATED value list that has the following entries:

other	undefined
single	single-cable system
dual	dual-cable system, offset normally zero

BEHAVIOUR DEFINED AS:

Returns a value that indicates the type of frequency multiplexing/cabling system used to separate the transmit and receive paths for the 10BROAD36 MAU. All other types return “undefined.”;

30.5.1.1.9 aBroadbandFrequencies

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE of two instances of the type INTEGER.

The first INTEGER represents the Transmitter Carrier Frequency. The value of its INTEGER represents the frequency of the carrier divided by 250 kHz.

The second INTEGER represents the Translation Offset Frequency. The value of its INTEGER represents the frequency of the offset divided by 250 kHz

BEHAVIOUR DEFINED AS:

Returns a value that indicates the transmit carrier frequency and translation offset frequency in MHz/4 for the 10BROAD36 MAU. This allows the frequencies to be defined to a resolution of 250 kHz.;

30.5.1.1.10 aFalseCarriers

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 160 000 counts per second under maximum network load, and 10 counts per second under zero network load, for 100 Mb/s implementations. This counter has a maximum increment rate of 1 600 000 counts per second under maximum network load, and 100 000 counts per second under zero network load, for 1000 Mb/s implementations

BEHAVIOUR DEFINED AS:

A count of the number of false carrier events during IDLE in 100BASE-X and 1000BASE-X links. This counter does not increment at the symbol rate. For 100BASE-X, it can increment after a valid carrier completion at a maximum rate of once per 100 ms until the nextCarrierEvent. For 1000BASE-X, it can increment after a valid carrier completion at a maximum rate of once per 10 µs until the next CarrierEvent.

NOTE—The increased increment rate for this attribute at 1000 Mb/s relative to its increment rate at 100 Mb/s has been provided to improve its use as an indication of line quality.;

30.5.1.1.11 aBIPErrorCount

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE of generalized nonresettable counters. Each counter has a maximum increment rate of 10 000 counts per second for 40 Gb/s implementations and 5 000 counts per second for 100 Gb/s implementations.

BEHAVIOUR DEFINED AS:

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For 40/100GBASE-R PHYs and 100GBASE-P PHYS, an array of BIP error counters. The counters do not increment for other PHY types. The indices of this array (0 to n – 1) denote the PCS lane number where n is the number of PCS lanes in use. Each element of this array contains a count of BIP errors for that PCS lane. Increment the counter by one for each BIP error detected during alignment marker removal in the PCS for the corresponding lane.
If a Clause 45 MDIO Interface to the PCS is present, then this attribute will map to the BIP error counters (see 45.2.3.44 and 45.2.3.45).;

30.5.1.1.12 aLaneMapping

ATTRIBUTE

APPROPRIATE SYNTAX:
A SEQUENCE of INTEGERs.

BEHAVIOUR DEFINED AS:
For 40/100GBASE-R PHYs and 100GBASE-P PHYs, an array of PCS lane identifiers. The indices of this array (0 to n – 1) denote the service interface lane number where n is the number of PCS lanes in use. Each element of this array contains the PCS lane number for the PCS lane that has been detected in the corresponding service interface lane.
If a Clause 45 MDIO Interface to the PCS is present, then this attribute will map to the Lane mapping registers (see 45.2.3.46 and 45.2.3.47).;

30.5.1.1.13 aIdleErrorCount

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
This attribute takes the eight-bit value from the 100BASE-T2 Status register (MII management register 10) bits 7:0 “Idle Error Count” as described in 100BASE-T2, 32.5.3.2.6 and 40.5.;

30.5.1.1.14 aPCSCodingViolation

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 25 000 000 counts per second for 100 Mb/s implementations and 125 000 000 counts per second for 1000 Mb/s implementations.

BEHAVIOUR DEFINED AS:
For 100 Mb/s operation it is a count of the number of events that cause the PHY to indicate “Data reception with errors” on the MII (see Table 22–2). For 1000 Mb/s operation it is a count of the number of events that cause the PHY to indicate “Data reception error” or “Carrier Extend Error” on the GMII (see Table 35–1). The contents of this attribute is undefined when FEC is operating.;

30.5.1.1.15 aFECAbility

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that meets the requirement of the description below

unknown	initializing, true state not yet known
supported	FEC supported

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not supported FEC not supported

BEHAVIOUR DEFINED AS:

A read-only value that indicates if the PHY supports an optional FEC sublayer for forward error correction (see 65.2 and Clause 74) or supports the Clause 91 mandatory RS-FEC.

If a Clause 45 MDIO Interface is present, then this attribute maps to the FEC capability register (see 45.2.8.2 or 45.2.1.92).;

30.5.1.1.16 aFECmode

ATTRIBUTE

APPROPRIATE SYNTAX:

A ENUMERATED VALUE that meets the requirement of the description below

unknown	initializing, true state not yet known
disabled	FEC disabled
enabled	FEC enabled

BEHAVIOUR DEFINED AS:

A read-write value that indicates the mode of operation of the optional FEC sublayer for forward error correction (see 65.2 and Clause 74).

A GET operation returns the current mode of operation of the PHY. A SET operation changes the mode of operation of the PHY to the indicated value. When Clause 73 Auto-Negotiation is enabled for a PHY supporting Clause 74 FEC a SET operation is not allowed and a GET operation maps to the variable FEC_enable in Clause 74.

If a Clause 45 MDIO Interface is present, then this attribute maps to the FEC control register (see 45.2.8.3) for 1000BASE-PX or FEC enable bit in BASE-R FEC control register (see 45.2.1.93).;

30.5.1.1.17 aFECCorrectedBlocks

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE of generalized nonresettable counters. Each counter has a maximum increment rate of 1 200 000 counts per second for 1000 Mb/s implementations, 5 000 000 counts per second for 10 Gb/s and 40 Gb/s implementations, and 2 500 000 counts per second for 100 Gb/s implementations.

BEHAVIOUR DEFINED AS:

For 1000BASE-PX, 10/40/100GBASE-R, 100GBASE-P, 10GBASE-PR, or 10/1GBASE-PRX PHYs, an array of corrected FEC block counters. The counters do not increment for other PHY types. The indices of this array (0 to N – 1) denote the FEC sublayer instance number where N is the number of FEC sublayer instances in use. The number of FEC sublayer instances in use is set to one for PHYs that do not use PCS lanes or use a single FEC instance for multiple FEC lanes. Each element of this array contains a count of corrected FEC blocks for that FEC sublayer instance.

Increment the counter by one for each received block that is corrected by the FEC function in the PHY for the corresponding lane or FEC sublayer instance.

If a Clause 45 MDIO Interface is present, then this attribute maps to the FEC corrected blocks counter(s) (see 45.2.8.5 and 45.2.1.94 for 10GBASE-R, 45.2.3.39 for 10GBASE-PR and 10/

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1GBASE-PRX, 45.2.1.116 for BASE-R, and 45.2.1.103 for RS-FEC).;

30.5.1.1.18 aFECUncorrectableBlocks

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE of generalized nonresettable counters. Each counter has a maximum increment rate of 1 200 000 counts per second for 1000 Mb/s implementations, and 5 000 000 counts per second for 10 Gb/s and 40 Gb/s implementations, and 2 500 000 counts per second for 100 Gb/s implementations.

BEHAVIOUR DEFINED AS:

For 1000BASE-PX, 10/40/100GBASE-R, 100GBASE-P, 10GBASE-PR, or 10/1GBASE-PRX PHYs, an array of uncorrectable FEC block counters. The counters do not increment for other PHY types. The indices of this array (0 to N – 1) denote the FEC sublayer instance number where N is the number of FEC sublayer instances in use. The number of FEC sublayer instances in use is set to one for PHYs that do not use PCS lanes or use a single FEC instance for multiple FEC lanes. Each element of this array contains a count of corrected FEC blocks for that FEC sublayer instance.

Increment the counter by one for each FEC block that is determined to be uncorrectable by the FEC function in the PHY for the corresponding lane or FEC sublayer instance.

If a Clause 45 MDIO Interface is present, then this attribute maps to the FEC uncorrectable blocks counter(s) (see 45.2.8.6 and 45.2.1.95 for 10GBASE-R, 45.2.3.40 for 10GBASE-PR and 10/1GBASE-PRX, 45.2.1.117 for BASE-R, and 45.2.1.104 for RS-FEC).;

30.5.1.1.19 aSNROpMarginChnlA

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

The current SNR operating margin measured at the slicer input for channel A for the 10GBASE-T PMA. It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –12.7 dB to 12.7 dB. If a Clause 45 MDIO Interface to the PMA/PMD is present, then this attribute maps to the SNR operating margin channel A register (see 45.2.1.66).;

30.5.1.1.20 aSNROpMarginChnlB

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

The current SNR operating margin measured at the slicer input for channel B for the 10GBASE-T PMA. It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –12.7 dB to 12.7 dB. If a Clause 45 MDIO Interface to the PMA/PMD is present, then this attribute maps to the SNR operating margin channel B register (see 45.2.1.67).;

30.5.1.1.21 aSNROpMarginChnlC

ATTRIBUTE

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APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The current SNR operating margin measured at the slicer input for channel C for the 10GBASE-T PMA. It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –12.7 dB to 12.7 dB. If a Clause 45 MDIO Interface to the PMA/PMD is present, then this attribute maps to the SNR operating margin channel C register (see 45.2.1.68).;

30.5.1.1.22 aSNROpMarginChnlD

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The current SNR operating margin measured at the slicer input for channel D for the 10GBASE-T PMA. It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –12.7 dB to 12.7 dB. If a Clause 45 MDIO Interface to the PMA/PMD is present, then this attribute maps to the SNR operating margin channel D register (see 45.2.1.69).;

30.5.1.1.23 aEEESupportList

ATTRIBUTE

APPROPRIATE SYNTAX:
A SEQUENCE of ENUMERATIONS that match the syntax of aMAUType

BEHAVIOUR DEFINED AS:
A read-only list of the possible PHY types for which the underlying system supports Energy-Efficient Ethernet (EEE) as defined in Clause 78. If Clause 28 or Clause 73 Auto-Negotiation is present, then this attribute will map to the local technology ability or advertised ability of the local device;

30.5.1.1.24 aLDFastRetrainCount

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 1000 counts per second

BEHAVIOUR DEFINED AS:
A count of the number of 10GBASE-T fast retrains initiated by the local device. The indication reflects the state of the PHY event counter (see 45.2.1.79.2 and 55.4.5.1.).;

30.5.1.1.25 aLPFastRetrainCount

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 1000 counts per second

BEHAVIOUR DEFINED AS:
A count of the number of 10GBASE-T fast retrains initiated by the link partner. The indication reflects the state of the PHY event counter (see 45.2.1.79.1 and 55.4.5.1.).;

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30.5.1.1.26 aRSFECBIPErrorCount

ATTRIBUTE

APPROPRIATE SYNTAX:
A SEQUENCE of generalized nonresetable counters. Each counter has a maximum increment rate of 5 000 counts per second for 100 Gb/s implementations.

BEHAVIOUR DEFINED AS:
For 100GBASE-R and 100GBASE-P PHYs, an array of BIP error counters. The counters do not increment for other PHY types. The indices of this array (0 to N – 1) denote the PCS lane number where N is the number of PCS lanes in use. Each element of this array contains a count of BIP errors for that PCS lane.
Increment the counter by one for each BIP error detected during alignment marker removal in the PCS for the corresponding lane.
If a Clause 45 MDIO Interface is present, then this attribute maps to the BIP error counters (see 45.2.1.108 and 45.2.1.109).;

30.5.1.1.27 aRSFECLaneMapping

ATTRIBUTE

APPROPRIATE SYNTAX:
A SEQUENCE of INTEGERs.

BEHAVIOUR DEFINED AS:
For 100GBASE-R and 100GBASE-P PHYs, an array of PCS lane identifiers. The indices of this array (0 to N – 1) denote the service interface lane number where N is the number of PCS lanes in use. Each element of this array contains the PCS lane number for the PCS lane that has been detected in the corresponding service interface lane.
If a Clause 45 MDIO Interface is present, then this attribute maps to the Lane mapping registers (see 45.2.1.110 and 45.2.1.111).;

30.5.1.1.28 aRSFECBypassAbility

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that meets the requirement of the following description:

unknown	initializing, true state not yet known
supported	FEC bypass ability supported
not supported	FEC bypass ability not supported

BEHAVIOUR DEFINED AS:
A read-only value that indicates if the PHY supports an optional RS-FEC bypass ability (see 91.5.3.3).
If a Clause 45 MDIO Interface is present, then this attribute maps to the RS-FEC status register (see 45.2.1.102).;

30.5.1.1.29 aRSFECIndicationAbility

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that meets the requirement of the following description:

unknown	initializing, true state not yet known
supported	FEC error indication bypass ability supported

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not supported FEC error indication bypass ability not supported

BEHAVIOUR DEFINED AS:

A read-only value that indicates if the PHY supports an optional RS-FEC error indication bypass ability (see 91.5.3.3).
If a Clause 45 MDIO Interface is present, then this attribute maps to the RS-FEC status register (see 45.2.1.102).;

30.5.1.1.30 aRSFECBypassEnable

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that meets the requirement of the following description:

unknown	initializing, true state not yet known
disabled	FEC bypass disabled
enabled	FEC bypass enabled

BEHAVIOUR DEFINED AS:

A read-write value that indicates the mode of operation of the RS-FEC bypass function (see 91.5.3.3).
A GET operation returns the current mode of operation of the RS-FEC. A SET operation changes the mode of operation of the RS-FEC to the indicated value.
If a Clause 45 MDIO Interface is present, then this attribute maps to the RS-FEC control register (see 45.2.1.101).;

30.5.1.1.31 aRSFECIndicationEnable

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that meets the requirement of the following description:

unknown	initializing, true state not yet known
disabled	FEC error indication bypass disabled
enabled	FEC error indication bypass enabled

BEHAVIOUR DEFINED AS:

A read-write value that indicates the mode of operation of the RS-FEC error indication bypass function (see 91.5.3.3).
A GET operation returns the current mode of operation of the RS-FEC. A SET operation changes the mode of operation of the RS-FEC to the indicated value.
If a Clause 45 MDIO Interface is present, then this attribute maps to the RS-FEC control register (see 45.2.1.101).;

30.5.1.2 MAU actions

30.5.1.2.1 acResetMAU

ACTION

APPROPRIATE SYNTAX:

None required

BEHAVIOUR DEFINED AS:

Resets the MAU in the same manner as would a power-off, power-on cycle of at least 0.5 s duration. During the 0.5 s DO, DI, and CI should be idle.;

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30.5.1.2.2 acMAUAdminControl

ACTION

APPROPRIATE SYNTAX:
The same as used for aMAUAdminState

BEHAVIOUR DEFINED AS:
Executing an acMAUAdminControl action causes the MAU to assume the aMAUAdminState attribute value of one of the defined valid management states for control input. The valid inputs are “standby,” “operational,” and “shutdown” state (see the behaviour definition bMAUAdminState for the description of each of these states) except that a “standby” action to a mixing type MAU or an AUI will cause the MAU to enter the “shutdown” management state.;

30.5.1.3 MAU notifications

30.5.1.3.1 nJabber

NOTIFICATION

APPROPRIATE SYNTAX:
The same as used for aJabber

BEHAVIOUR DEFINED AS:
The notification is sent whenever a managed 10 Mb/s baseband or broadband MAU enters the JABBER state.;

30.6 Management for link Auto-Negotiation

30.6.1 Auto-Negotiation managed object class

This subclause formally defines the behaviours for the oAuto-Negotiation managed object class, attributes, actions, and notifications.

30.6.1.1 Auto-Negotiation attributes

30.6.1.1.1 aAutoNegID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of aAutoNegID is assigned so as to uniquely identify an Auto-Negotiation managed object among the subordinate managed objects of the containing object.;

30.6.1.1.2 aAutoNegAdminState

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that has one of the following entries:
enabled
disabled

BEHAVIOUR DEFINED AS:

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An interface which has Auto-Negotiation signaling ability will be enabled to do so when this attribute is in the enabled state. If disabled then the interface will act as it would if it had no Auto-Negotiation signaling.;

30.6.1.1.3 aAutoNegRemoteSignaling

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has one of the following entries:
detected
notdetected

BEHAVIOUR DEFINED AS:

The value indicates whether the remote end of the link is operating Auto-Negotiation signaling or not. It shall take the value detected if, during the previous link negotiation, FLP Bursts, /C/ ordered sets (see 36.2.4.10) or DME signals (see 73.5) were received from the remote end.;

30.6.1.1.4 aAutoNegAutoConfig

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has one of the following entries:
other
configuring
complete
disabled
parallel detect fail

BEHAVIOUR DEFINED AS:

Indicates whether Auto-Negotiation signaling is in progress or has completed. The enumeration "parallel detect fail" maps to a failure in parallel detection as defined in 28.2.3.1 or 73.7.4.1.;

30.6.1.1.5 aAutoNegLocalTechnologyAbility

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE that meets the requirements of the description below:

global	Reserved for future use
other	See 30.2.5
unknown	Initializing, true state or type not yet known
10BASE-T	10BASE-T half duplex as defined in Clause 14
10BASE-TFD	Full duplex 10BASE-T as defined in Clause 14 and Clause 31
100BASE-T4	100BASE-T4 half duplex as defined in Clause 23
100BASE-TX	100BASE-TX half duplex as defined in Clause 25
100BASE-TXFD	Full duplex 100BASE-TX as defined in Clause 25 and Clause 31
FDX PAUSE	PAUSE operation for full duplex links as defined in Annex 31B
FDX APAUSE	Asymmetric PAUSE operation for full duplex links as defined in Clause 37, Annex 28B, and Annex 31B
FDX SPAUSE	Symmetric PAUSE operation for full duplex links as defined in Clause 37, Annex 28B, and Annex 31B
FDX BPAUSE	Asymmetric and Symmetric PAUSE operation for full duplex links as defined in Clause 37, Annex 28B, and Annex 31B
100BASE-T2	100BASE-T2 half duplex as defined in Clause 32

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100BASE-T2FD	Full duplex 100BASE-T2 as defined in Clause 31 and Clause 32
1000BASE-X	1000BASE-X half duplex as specified in Clause 36
1000BASE-XFD	Full duplex 1000BASE-X as specified in Clause 31 and Clause 36
1000BASE-T	1000BASE-T half duplex PHY as specified in Clause 40
1000BASE-TFD	Full duplex 1000BASE-T PHY as specified in Clause 31 and as specified in Clause 40
Rem Fault1	Remote fault bit 1 (RF1) as specified in Clause 37
Rem Fault2	Remote fault bit 2 (RF2) as specified in Clause 37
10GBASE-T	10GBASE-T PHY as specified in Clause 55
1000BASE-KXFD	Full duplex 1000BASE-KX as specified in Clause 70
10GBASE-KX4FD	Full duplex 10GBASE-KX4 as specified in Clause 71
10GBASE-KRFD	Full duplex 10GBASE-KR as specified in Clause 72
40GBASE-KR4	40GBASE-KR4 as specified in Clause 84
40GBASE-CR4	40GBASE-CR4 as specified in Clause 85
100GBASE-CR10	100GBASE-CR10 as specified in Clause 85
100GBASE-CR4	100GBASE-CR4 as specified in Clause 92
100GBASE-KR4	100GBASE-KR4 as specified in Clause 93
100GBASE-KP4	100GBASE-KP4 as specified in Clause 94
Rem Fault	Remote fault bit (RF) as specified in Clause 73
FEC Capable	FEC ability as specified in Clause 73 (see 73.6.5) and Clause 74
FEC Requested	FEC requested as specified in Clause 73 (see 73.6.5) and Clause 74
isoethernet	IEEE Std 802.9 ISLAN-16T

BEHAVIOUR DEFINED AS:

This indicates the technology ability of the local device, as defined in Clause 28, Clause 37, and Clause 73.

30.6.1.1.6 aAutoNegAdvertisedTechnologyAbility

ATTRIBUTE

APPROPRIATE SYNTAX:

Same as aAutoNegLocalTechnologyAbility

BEHAVIOUR DEFINED AS:

This GET-SET attribute maps to the technology ability of the local device, as defined in Clause 28 and Clause 37.

NOTE—This will in every case cause temporary link loss during link renegotiation. If set to a value incompatible with aAutoNegReceivedTechnologyAbility, link negotiation will not be successful and will cause permanent link loss.;

30.6.1.1.7 aAutoNegReceivedTechnologyAbility

ATTRIBUTE

APPROPRIATE SYNTAX:

Same as aAutoNegLocalTechnologyAbility

BEHAVIOUR DEFINED AS:

Indicates the advertised technology ability of the remote hardware. For Clause 28 Auto-Negotiation, this attribute maps to the Technology Ability Field of the last received Auto-Negotiation link codeword(s). For Clause 37 Auto-Negotiation, this attribute maps to bits D0-D13 of the received Config_Reg Base Page (see 37.2.1). For Clause 73 Auto-Negotiation, this attribute maps to bits D10-D13 and D21-D47 of the last received link codeword Base Page (see 73.6).;

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30.6.1.1.8 aAutoNegLocalSelectorAbility

ATTRIBUTE

APPROPRIATE SYNTAX:
A SEQUENCE that meets the requirements of the description on http://www.ieee802.org/3/selectors/selectors.html.

BEHAVIOUR DEFINED AS:
This indicates the value of the selector field of the local hardware. The Selector Field is defined in 28.2.1.2.1 for Clause 28 Auto-Negotiation and 73.6.1 for Clause 73 Auto- Negotiation. The enumeration of the Selector Field indicates the standard that defines the remaining encodings for Auto-Negotiation using that value of enumeration. For Clause 37 Auto-Negotiation devices, a SET of this attribute will have no effect, and a GET will return the enumeration "ethernet".;

30.6.1.1.9 aAutoNegAdvertisedSelectorAbility

ATTRIBUTE

APPROPRIATE SYNTAX:
Same as aAutoNegLocalSelectorAbility

BEHAVIOUR DEFINED AS:
In the case of Clause 28 Auto-Negotiation, this GET-SET attribute maps to the Message Selector Field of the Auto-Negotiation link codeword. For Clause 73 Auto-Negotiation, this attribute maps to the Selector Field of the Clause 73 Auto-Negotiation link codeword (see 73.6.1). A SET operation to a value not available in aAutoNegLocalSelectorAbility will be rejected. A successful SET operation will result in immediate link renegotiation if aAutoNegAdminState is enabled. For Clause 37 Auto-Negotiation devices, a SET of this attribute will have no effect, and a GET will return the enumeration "ethernet".

NOTE—This will in every case cause temporary link loss during link renegotiation. If set to a value incompatible with aAutoNegReceivedSelectorAbility, link negotiation will not be successful and will cause permanent link loss.;

30.6.1.1.10 aAutoNegReceivedSelectorAbility

ATTRIBUTE

APPROPRIATE SYNTAX:
Same as aAutoNegLocalSelectorAbility

BEHAVIOUR DEFINED AS:
In the case of Clause 28 Auto-Negotiation, this attribute indicates the advertised message transmission ability of the remote hardware. It maps to the Message Selector Field of the last received Auto-Negotiation link codeword. For Clause 73 Auto-Negotiation, this attribute indicates the advertised message transmission ability of the remote hardware and maps to the Selector Field of the last received Clause 73 Auto-Negotiation link codeword (see 73.6.1). For Clause 37 Auto-Negotiation devices, a SET of this attribute will have no effect, and a GET will return the enumeration "ethernet".;

30.6.1.2 Auto-Negotiation actions

30.6.1.2.1 acAutoNegRestartAutoConfig

ATTRIBUTE

APPROPRIATE SYNTAX:
None required

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BEHAVIOUR DEFINED AS:

Forces Auto-Negotiation to begin link renegotiation. Has no effect if Auto-Negotiation signaling is disabled.;

30.6.1.2.2 acAutoNegAdminControl

ATTRIBUTE

APPROPRIATE SYNTAX:

Same as aAutoNegAdminState

BEHAVIOUR DEFINED AS:

This action provides a means to turn Auto-Negotiation signaling on or off.;

30.7 Management for Link Aggregation

Subclause 30.7 is deprecated by IEEE Std 802.1AX-2008.

30.7.1 Aggregator managed object class

This subclause formally defines the behaviours for the oAggregator managed object class, attributes, and notifications.

Some of the attributes that are part of the definition of the oAggregator managed object class are derived by summing counter values from attributes of other objects; e.g., to generate a count of received frames for the Aggregator, the individual value for each Aggregation Port contributes to the sum. Where calculations of this form are used, the values that contribute to the Aggregator's attributes are *increments* in the values of the component attributes, not their absolute values. As any individual Aggregation Port is potentially only temporarily attached to its current Aggregator, the count values it contributes to the Aggregator's counters are the increments in its values that it has experienced during the period of time that it has been attached to that Aggregator.

The counter values defined for the Aggregator have been formulated as far as possible to make the Aggregator behave like an individual IEEE 802.3 MAC. The counts of frames received and transmitted are formulated to reflect the counts that would be expected by the MAC Client; they do not include frames transmitted and received as part of the operation of LACP or the Marker protocol, only frames that pass through the interface between the MAC Client and the Aggregator. However, as LACP and the Marker protocol are, as far as the individual MACs are concerned, part of their MAC Client, the RX/TX counters for the individual MACs will reflect both control and data traffic. As counts of errors at the port level cannot always be cleanly delineated between those that occurred as a result of aggregation activity and those that did not, no attempt has been made to separate these aspects of the port error counts. Therefore, there is not necessarily a direct correspondence between the individual MAC counters and the corresponding derived counters at the Aggregator level.

It should also be noted that the counters defined for the Aggregator include values that can only apply to half duplex links. This is consistent with the approach taken in Link Aggregation that a link that can only operate as an individual link is nonetheless considered as being attached to an Aggregator. This simplifies the modelling of managed objects for links that can operate in either half or full duplex, and ensures a consistent presentation of the attributes regardless of the type of links attached to the Aggregator.

NOTE—The operation of autonegotiation may mean that a given link can operate in full duplex or half duplex, depending upon the capabilities of the device(s) connected to it. Keeping the management view the same regardless of a link's current mode of operation allows a consistent management approach to be taken across all types of links.

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30.7.1.1 Aggregator attributes

30.7.1.1.1 aAggID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The unique identifier allocated to this Aggregator by the local System. This attribute identifies an Aggregator instance among the subordinate managed objects of the containing object. This value is read-only.

30.7.1.1.2 aAggDescription

ATTRIBUTE

APPROPRIATE SYNTAX:
A PrintableString, 255 characters max.

BEHAVIOUR DEFINED AS:
A human-readable text string containing information about the Aggregator. This string could include information about the distribution algorithm in use on this Aggregator; for example, “Aggregator 1, Dist Alg=Dest MAC address.” This string is read-only. The contents are vendor specific.;

30.7.1.1.3 aAggName

ATTRIBUTE

APPROPRIATE SYNTAX:
A PrintableString, 255 characters max.

BEHAVIOUR DEFINED AS:
A human-readable text string containing a locally significant name for the Aggregator. This string is read-write.;

30.7.1.1.4 aAggActorSystemID

ATTRIBUTE

APPROPRIATE SYNTAX:
MACAddress

BEHAVIOUR DEFINED AS:
A 6-octet read-write MAC address value used as a unique identifier for the System that contains this Aggregator.

NOTE—From the perspective of the Link Aggregation mechanisms described in Clause 43, only a single combination of Actor’s System ID and System Priority are considered, and no distinction is made between the values of these parameters for an Aggregator and the port(s) that are associated with it (i.e., the protocol is described in terms of the operation of aggregation within a single System). However, the managed objects provided for the Aggregator and the port both allow management of these parameters. The result of this is to permit a single piece of equipment to be configured by management to contain more than one System from the point of view of the operation of Link Aggregation. This may be of particular use in the configuration of equipment that has limited aggregation capability (see 43.6).;

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30.7.1.1.5 aAggActorSystemPriority

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A 2-octet read-write value indicating the priority value associated with the Actor's System ID.;

30.7.1.1.6 aAggAggregateOrIndividual

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
A read-only Boolean value indicating whether the Aggregator represents an Aggregate ("TRUE") or an Individual link ("FALSE").;

30.7.1.1.7 aAggActorAdminKey

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The current administrative value of the Key for the Aggregator. The administrative Key value may differ from the operational Key value for the reasons discussed in 43.6.2. This is a 16-bit read-write value. The meaning of particular Key values is of local significance.;

30.7.1.1.8 aAggActorOperKey

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The current operational value of the Key for the Aggregator. The administrative Key value may differ from the operational Key value for the reasons discussed in 43.6.2. This is a 16-bit read-only value. The meaning of particular Key values is of local significance.;

30.7.1.1.9 aAggMACAddress

ATTRIBUTE

APPROPRIATE SYNTAX:
MACAddress

BEHAVIOUR DEFINED AS:
A 6-octet read-only value carrying the individual MAC address assigned to the Aggregator.;

30.7.1.1.10 aAggPartnerSystemID

ATTRIBUTE

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APPROPRIATE SYNTAX:
MACAddress

BEHAVIOUR DEFINED AS:
A 6-octet read-only MAC address value consisting of the unique identifier for the current protocol Partner of this Aggregator. A value of zero indicates that there is no known Partner. If the aggregation is manually configured, this System ID value will be a value assigned by the local System.;

30.7.1.1.11 aAggPartnerSystemPriority

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A 2-octet read-only value that indicates the priority value associated with the Partner's System ID. If the aggregation is manually configured, this System Priority value will be a value assigned by the local System.;

30.7.1.1.12 aAggPartnerOperKey

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The current operational value of the Key for the Aggregator's current protocol Partner. This is a 16-bit read-only value. If the aggregation is manually configured, this Key value will be a value assigned by the local System.;

30.7.1.1.13 aAggAdminState

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that has one of the following entries:
up
down

BEHAVIOUR DEFINED AS:
This read-write value defines the administrative state of the Aggregator. A value of "up" indicates that the operational state of the Aggregator (aAggOperState) is permitted to be either up or down. A value of "down" forces the operational state of the Aggregator to be down. Changes to the administrative state affect the operational state of the Aggregator only, not the operational state of the Aggregation Ports that are attached to the Aggregator. A GET operation returns the current administrative state. A SET operation changes the administrative state to a new value.;

30.7.1.1.14 aAggOperState

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that has one of the following entries:
up
down

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BEHAVIOUR DEFINED AS:

This read-only value defines the operational state of the Aggregator. The operational state is "up" if one or more of the Aggregation Ports that are attached to the Aggregator are collecting, or both collecting and distributing, and if the value of aAggAdminState for the Aggregator is also "up." If none of the Aggregation Ports that are attached to the Aggregator are collecting and/or distributing, or if there are no Aggregation Ports attached to this Aggregator, then the operational state is "down." An operational state of "up" indicates that the Aggregator is available for use by the MAC Client; a value of "down" indicates that the Aggregator is not available for use by the MAC Client.;

30.7.1.1.15 aAggTimeOfLastOperChange

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

The value of aTimeSinceSystemReset (Annex F.2.1) at the time the interface entered its current operational state. If the current state was entered prior to the last re-initialization of the local network management subsystem, then this object contains a value of zero. This value is read-only.;

30.7.1.1.16 aAggDataRate

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

The current data rate, in bits per second, of the aggregate link. The value is calculated as N times the data rate of a single link in the aggregation, where N is the number of active links. This attribute is read-only.;

30.7.1.1.17 aAggOctetsTxOK

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 230 000 counts per second for a single 10 Mb/s aggregation.

BEHAVIOUR DEFINED AS:

A count of the data and padding octets transmitted by this Aggregator on all Aggregation Ports that are (or have been) members of the aggregation. The count does not include octets transmitted by the Aggregator in frames that carry LACPDUs or Marker PDUs (30.7.3.1.7, 30.7.3.1.8, 30.7.3.1.9). However, it includes frames discarded by the Distribution function of the Aggregator (30.7.1.1.25). This value is read-only.;

30.7.1.1.18 aAggOctetsRxOK

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 230 000 counts per second for a single 10 Mb/s aggregation.

BEHAVIOUR DEFINED AS:

A count of the data and padding octets received by this Aggregator, from the Aggregation Ports

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that are (or have been) members of the aggregation. The count does not include octets received in frames that carry LACP or Marker PDUs (30.7.3.1.2, 30.7.3.1.3, 30.7.3.1.4), or frames discarded by the Collection function of the Aggregator (30.7.1.1.26). This value is read-only.;

30.7.1.1.19 aAggFramesTxOK

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second for a single 10 Mb/s aggregation.

BEHAVIOUR DEFINED AS:

A count of the data frames transmitted by this Aggregator on all Aggregation Ports that are (or have been) members of the aggregation. The count does not include frames transmitted by the Aggregator that carry LACP or Marker PDUs (30.7.3.1.7, 30.7.3.1.8, 30.7.3.1.9). However, it includes frames discarded by the Distribution function of the Aggregator (30.7.1.1.25). This value is read-only.;

30.7.1.1.20 aAggFramesRxOK

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second for a single 10 Mb/s aggregation.

BEHAVIOUR DEFINED AS:

A count of the data frames received by this Aggregator, from the Aggregation Ports that are (or have been) members of the aggregation. The count does not include frames that carry LACP or Marker PDUs (30.7.3.1.2, 30.7.3.1.3, 30.7.3.1.4), or frames discarded by the Collection function of the Aggregator (30.7.1.1.26). This value is read-only.;

30.7.1.1.21 aAggMulticastFramesTxOK

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second for a single 10 Mb/s aggregation.

BEHAVIOUR DEFINED AS:

A count of the data frames transmitted by this Aggregator on all Aggregation Ports that are (or have been) members of the aggregation, to a group destination address other than the broadcast address. The count does not include frames transmitted by the Aggregator that carry LACP or Marker PDUs (30.7.3.1.7, 30.7.3.1.8, 30.7.3.1.9). However, it includes frames discarded by the Distribution function of the Aggregator (30.7.1.1.25). This value is read-only.;

30.7.1.1.22 aAggMulticastFramesRxOK

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second for a single 10 Mb/s aggregation.

BEHAVIOUR DEFINED AS:

A count of the data frames received by this Aggregator, from the Aggregation Ports that are (or

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have been) members of the aggregation, that were addressed to an active group address other than the broadcast address. The count does not include frames that carry LACP or Marker PDUs (30.7.3.1.2, 30.7.3.1.3, 30.7.3.1.4), or frames discarded by the Collection function of the Aggregator (30.7.1.1.26). This value is read-only.;

30.7.1.1.23 aAggBroadcastFramesTxOK

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second for a single 10 Mb/s aggregation.

BEHAVIOUR DEFINED AS:

A count of the broadcast data frames transmitted by this Aggregator on all Aggregation Ports that are (or have been) members of the aggregation. The count does not include frames transmitted by the Aggregator that carry LACP or Marker PDUs (30.7.3.1.7, 30.7.3.1.8, 30.7.3.1.9). However, it includes frames discarded by the Distribution function of the Aggregator (30.7.1.1.25). This value is read-only.;

30.7.1.1.24 aAggBroadcastFramesRxOK

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second for a single 10 Mb/s aggregation.

BEHAVIOUR DEFINED AS:

A count of the broadcast data frames received by this Aggregator, from the Aggregation Ports that are (or have been) members of the aggregation. The count does not include frames that carry LACP or Marker PDUs (30.7.3.1.2, 30.7.3.1.3, 30.7.3.1.4), illegal or unknown protocol frames (30.7.3.1.5, 30.7.3.1.6), or frames discarded by the Collection function of the Aggregator (30.7.1.1.26). This value is read-only.;

30.7.1.1.25 aAggFramesDiscardedOnTx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second for a single 10 Mb/s aggregation.

BEHAVIOUR DEFINED AS:

A count of data frames requested to be transmitted by this Aggregator that were discarded by the Distribution function of the Aggregator when conversations are re-allocated to different ports, due to the requirement to ensure that the conversations are flushed on the old ports in order to maintain proper frame ordering (43A.3), or discarded as a result of excessive collisions by ports that are (or have been) members of the aggregation. This value is read-only.;

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30.7.1.1.26 aAggFramesDiscardedOnRx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second for a single 10 Mb/s aggregation.

BEHAVIOUR DEFINED AS:

A count of data frames, received on all ports that are (or have been) members of the aggregation, that were discarded by the Collection function of the Aggregator as they were received on ports whose Collection function was disabled. This value is read-only.;

30.7.1.1.27 aAggFramesWithTxErrors

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second for a single 10 Mb/s aggregation.

BEHAVIOUR DEFINED AS:

A count of data frames requested to be transmitted by this Aggregator that experienced transmission errors on ports that are (or have been) members of the aggregation. This count does not include frames discarded due to excess collisions. This value is read-only.;

30.7.1.1.28 aAggFramesWithRxErrors

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second for a single 10 Mb/s aggregation.

BEHAVIOUR DEFINED AS:

A count of data frames discarded on reception by all ports that are (or have been) members of the aggregation, or that were discarded by the Collection function of the Aggregator, or that were discarded by the Aggregator due to the detection of an illegal Slow Protocols PDU (30.7.3.1.6). This value is read-only.;

30.7.1.1.29 aAggUnknownProtocolFrames

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 16 000 counts per second for a single 10 Mb/s aggregation.

BEHAVIOUR DEFINED AS:

A count of data frames discarded on reception by all ports that are (or have been) members of the aggregation, due to the detection of an unknown Slow Protocols PDU (30.7.3.1.5). This value is read-only.;

30.7.1.1.30 aAggPortList

ATTRIBUTE

APPROPRIATE SYNTAX:

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A SEQUENCE OF INTEGERs that match the syntax of aAggPortID.

BEHAVIOUR DEFINED AS:

The value of this read-only attribute contains the list of Aggregation Ports that are currently attached to the Aggregator. An empty list indicates that there are no Aggregation Ports attached. Each integer value in the list carries an aAggPortID attribute value (30.7.2.1.1).;

30.7.1.1.31 aAggLinkUpDownNotificationEnable

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has one of the following entries:
enabled
disabled

BEHAVIOUR DEFINED AS:

When set to “enabled,” Link Up and Link Down notifications are enabled for this Aggregator. When set to “disabled,” Link Up and Link Down notifications are disabled for this Aggregator. This value is read-write.;

30.7.1.1.32 aAggCollectorMaxDelay

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

The value of this 16-bit read-write attribute defines the maximum delay, in tens of microseconds, that may be imposed by the Frame Collector between receiving a frame from an Aggregator Parser, and either delivering the frame to its MAC Client or discarding the frame (see 43.2.3.1.1).;

30.7.1.2 Aggregator Notifications

30.7.1.2.1 nAggLinkUpNotification

NOTIFICATION

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

When aAggLinkUpDownNotificationEnable is set to “enabled,” a Link Up notification is generated when the Operational State of the aggregator changes from “down” to “up.” When aAggLinkUpDownNotificationEnable is set to “disabled,” no Link Up notifications are generated. The notification carries the identifier of the Aggregator whose state has changed.;

30.7.1.2.2 nAggLinkDownNotification

NOTIFICATION

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

When aAggLinkUpDownNotificationEnable is set to “enabled,” a Link Down notification is generated when the Operational State of the aggregator changes from “up” to “down.” When aAggLinkUpDownNotificationEnable is set to “disabled,” no Link Down notifications are

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generated. The notification carries the identifier of the Aggregator whose state has changed.;

30.7.2 Aggregation Port managed object class

This subclause formally defines the behaviours for the oAggregationPort managed object class attributes.

30.7.2.1 Aggregation Port Attributes

30.7.2.1.1 aAggPortID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The unique identifier allocated to this Aggregation Port by the local System. This attribute identifies an Aggregation Port instance among the subordinate managed objects of the containing object. This value is read-only.

30.7.2.1.2 aAggPortActorSystemPriority

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A 2-octet read-write value used to define the priority value associated with the Actor's System ID.;

30.7.2.1.3 aAggPortActorSystemID

ATTRIBUTE

APPROPRIATE SYNTAX:
MACAddress

BEHAVIOUR DEFINED AS:
A 6-octet read-only MAC address value that defines the value of the System ID for the System that contains this Aggregation Port.;

30.7.2.1.4 aAggPortActorAdminKey

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The current administrative value of the Key for the Aggregation Port. This is a 16-bit read-write value. The meaning of particular Key values is of local significance.;

30.7.2.1.5 aAggPortActorOperKey

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

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BEHAVIOUR DEFINED AS:

The current operational value of the Key for the Aggregation Port. This is a 16-bit read-only value. The meaning of particular Key values is of local significance.;

30.7.2.1.6 aAggPortPartnerAdminSystemPriority

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

A 2-octet read-write value used to define the administrative value of priority associated with the Partner's System ID. The assigned value is used, along with the value of aAggPortPartnerAdminSystemID, aAggPortPartnerAdminKey, aAggPortPartnerAdminPort, and aAggPortPartnerAdminPortPriority, in order to achieve manually configured aggregation.;

30.7.2.1.7 aAggPortPartnerOperSystemPriority

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

A 2-octet read-only value indicating the operational value of priority associated with the Partner's System ID. The value of this attribute may contain the manually configured value carried in aAggPortPartnerAdminSystemPriority if there is no protocol Partner.;

30.7.2.1.8 aAggPortPartnerAdminSystemID

ATTRIBUTE

APPROPRIATE SYNTAX:

MACAddress

BEHAVIOUR DEFINED AS:

A 6-octet read-write MACAddress value representing the administrative value of the Aggregation Port's protocol Partner's System ID. The assigned value is used, along with the value of aAggPortPartnerAdminSystemPriority, aAggPortPartnerAdminKey, aAggPortPartnerAdminPort, and aAggPortPartnerAdminPortPriority, in order to achieve manually configured aggregation.;

30.7.2.1.9 aAggPortPartnerOperSystemID

ATTRIBUTE

APPROPRIATE SYNTAX:

MACAddress

BEHAVIOUR DEFINED AS:

A 6-octet read-only MACAddress value representing the current value of the Aggregation Port's protocol Partner's System ID. A value of zero indicates that there is no known protocol Partner. The value of this attribute may contain the manually configured value carried in aAggPortPartnerAdminSystemID if there is no protocol Partner.;

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30.7.2.1.10 aAggPortPartnerAdminKey

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The current administrative value of the Key for the protocol Partner. This is a 16-bit read-write value. The assigned value is used, along with the value of aAggPortPartnerAdminSystemPriority, aAggPortPartnerAdminSystemID, aAggPortPartnerAdminPort, and aAggPortPartnerAdminPortPriority, in order to achieve manually configured aggregation.;

30.7.2.1.11 aAggPortPartnerOperKey

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The current operational value of the Key for the protocol Partner. The value of this attribute may contain the manually configured value carried in aAggPortPartnerAdminKey if there is no protocol Partner. This is a 16-bit read-only value.;

30.7.2.1.12 aAggPortSelectedAggID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The identifier value of the Aggregator that this Aggregation Port has currently selected. Zero indicates that the Aggregation Port has not selected an Aggregator, either because it is in the process of detaching from an Aggregator or because there is no suitable Aggregator available for it to select. This value is read-only.;

30.7.2.1.13 aAggPortAttachedAggID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The identifier value of the Aggregator that this Aggregation Port is currently attached to. Zero indicates that the Aggregation Port is not currently attached to an Aggregator. This value is read-only.;

30.7.2.1.14 aAggPortActorPort

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The port number locally assigned to the Aggregation Port. The port number is communicated in

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LACPDUs as the Actor_Port. This value is read-only.;

30.7.2.1.15 aAggPortActorPortPriority

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The priority value assigned to this Aggregation Port. This 16-bit value is read-write.;

30.7.2.1.16 aAggPortPartnerAdminPort

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The current administrative value of the port number for the protocol Partner. This is a 16-bit read-write value. The assigned value is used, along with the value of aAggPortPartnerAdminSystemPriority, aAggPortPartnerAdminSystemID, aAggPortPartnerAdminKey, and aAggPortPartnerAdminPortPriority, in order to achieve manually configured aggregation.;

30.7.2.1.17 aAggPortPartnerOperPort

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The operational port number assigned to this Aggregation Port by the Aggregation Port's protocol Partner. The value of this attribute may contain the manually configured value carried in aAggPortPartnerAdminPort if there is no protocol Partner. This 16-bit value is read-only.;

30.7.2.1.18 aAggPortPartnerAdminPortPriority

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The current administrative value of the port priority for the protocol Partner. This is a 16-bit read-write value. The assigned value is used, along with the value of aAggPortPartnerAdminSystemPriority, aAggPortPartnerAdminSystemID, aAggPortPartnerAdminKey, and aAggPortPartnerAdminPort, in order to achieve manually configured aggregation.;

30.7.2.1.19 aAggPortPartnerOperPortPriority

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

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BEHAVIOUR DEFINED AS:

The priority value assigned to this Aggregation Port by the Partner. The value of this attribute may contain the manually configured value carried in aAggPortPartnerAdminPortPriority if there is no protocol Partner. This 16-bit value is read-only.;

30.7.2.1.20 aAggPortActorAdminState

ATTRIBUTE

APPROPRIATE SYNTAX:

BIT STRING [SIZE (1..8)]

BEHAVIOUR DEFINED AS:

A string of 8 bits, corresponding to the administrative values of Actor_State (43.4.2) as transmitted by the Actor in LACPDUs. The first bit corresponds to bit 0 of Actor_State (LACP_Activity), the second bit corresponds to bit 1 (LACP_Timeout), the third bit corresponds to bit 2 (Aggregation), the fourth bit corresponds to bit 3 (Synchronization), the fifth bit corresponds to bit 4 (Collecting), the sixth bit corresponds to bit 5 (Distributing), the seventh bit corresponds to bit 6 (Defaulted), and the eighth bit corresponds to bit 7 (Expired). These values allow administrative control over the values of LACP_Activity, LACP_Timeout, and Aggregation. This attribute value is read-write.;

30.7.2.1.21 aAggPortActorOperState

ATTRIBUTE

APPROPRIATE SYNTAX:

BIT STRING [SIZE (1..8)]

BEHAVIOUR DEFINED AS:

A string of 8 bits, corresponding to the current operational values of Actor_State (43.4.2) as transmitted by the Actor in LACPDUs. The bit allocations are as defined in 30.7.2.1.20. This attribute value is read-only.;

30.7.2.1.22 aAggPortPartnerAdminState

ATTRIBUTE

APPROPRIATE SYNTAX:

BIT STRING [SIZE (1..8)]

BEHAVIOUR DEFINED AS:

A string of 8 bits, corresponding to the current administrative value of Actor_State for the protocol Partner. The bit allocations are as defined in 30.7.2.1.20. This attribute value is read-write. The assigned value is used in order to achieve manually configured aggregation.;

30.7.2.1.23 aAggPortPartnerOperState

ATTRIBUTE

APPROPRIATE SYNTAX:

BIT STRING [SIZE (1..8)]

BEHAVIOUR DEFINED AS:

A string of 8 bits, corresponding to the current values of Actor_State in the most recently received LACPDU transmitted by the protocol Partner. The bit allocations are as defined in 30.7.2.1.20. In the absence of an active protocol Partner, this value may reflect the manually configured value aAggPortPartnerAdminState. This attribute value is read-only.;

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30.7.2.1.24 aAggPortAggregateOrIndividual

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
A read-only Boolean value indicating whether the Aggregation Port is able to Aggregate ("TRUE") or is only able to operate as an Individual link ("FALSE").;

30.7.3 Aggregation Port Statistics managed object class

This subclause formally defines the behaviours for the oAggPortStats managed object class attributes.

30.7.3.1 Aggregation Port Statistics attributes

30.7.3.1.1 aAggPortStatsID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
This read-only attribute identifies an Aggregation Port Statistics object instance among the subordinate managed objects of the containing object. The value allocated to this attribute shall be the same as the containing oAggregationPort managed object.;

30.7.3.1.2 aAggPortStatsLACPDUsRx

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 5 counts per second.

BEHAVIOUR DEFINED AS:
The number of valid LACPDUs received on this Aggregation Port. This value is read-only.;

30.7.3.1.3 aAggPortStatsMarkerPDUsRx

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 5 counts per second.

BEHAVIOUR DEFINED AS:
The number of valid Marker PDUs received on this Aggregation Port. This value is read-only.;

30.7.3.1.4 aAggPortStatsMarkerResponsePDUsRx

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 5 counts per second.

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BEHAVIOUR DEFINED AS:

The number of valid Marker Response PDUs received on this Aggregation Port. This value is read-only.;

30.7.3.1.5 aAggPortStatsUnknownRx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 50 counts per second.

BEHAVIOUR DEFINED AS:

The number of frames received that either

— Carry the Slow Protocols Ethernet Type value (43B.4), but contain an unknown PDU, or

— Are addressed to the Slow Protocols group MAC Address (43B.3), but do not carry the Slow Protocols Ethernet Type. This value is read-only.;

30.7.3.1.6 aAggPortStatsIllegalRx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 50 counts per second.

BEHAVIOUR DEFINED AS:

The number of frames received that carry the Slow Protocols Ethernet Type value (43B.4), but contain a badly formed PDU or an illegal value of Protocol Subtype (43B.3). This value is read-only.;

30.7.3.1.7 aAggPortStatsLACPDUsTx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 5 counts per second.

BEHAVIOUR DEFINED AS:

The number of LACPDUs transmitted on this Aggregation Port. This value is read-only.;

30.7.3.1.8 aAggPortStatsMarkerPDUsTx

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 5 counts per second.

BEHAVIOUR DEFINED AS:

The number of Marker PDUs transmitted on this Aggregation Port. This value is read-only.;

30.7.3.1.9 aAggPortStatsMarkerResponsePDUsTx

ATTRIBUTE

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APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 5 counts per second.

BEHAVIOUR DEFINED AS:
The number of Marker Response PDUs transmitted on this Aggregation Port. This value is read-only.;

30.7.4 Aggregation Port Debug Information managed object class

This subclause formally defines the behaviours for the oAggPortDebugInformation managed object class attributes.

30.7.4.1 Aggregation Port Debug Information attributes

30.7.4.1.1 aAggPortDebugInformationID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
This read-only attribute identifies an LACP Debug Information object instance among the subordinate managed objects of the containing object. The value allocated to this attribute shall be the same as the containing oAggregationPort managed object.;

30.7.4.1.2 aAggPortDebugRxState

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that has one of the following entries:
current
expired
defaulted
initialize
lacpDisabled
portDisabled

BEHAVIOUR DEFINED AS:
This attribute holds the value “current” if the Receive state machine for the Aggregation Port is in the CURRENT state, “expired” if the Receive state machine is in the EXPIRED state, “defaulted” if the Receive state machine is in the DEFAULTED state, “initialize” if the Receive state machine is in the INITIALIZE state, “lacpDisabled” if the Receive state machine is in the LACP_DISABLED state, or “portDisabled” if the Receive state machine is in the PORT_DISABLED state. This value is read-only.;

30.7.4.1.3 aAggPortDebugLastRxTime

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of aTimeSinceSystemReset (F.2.1) when the last LACPDU was received by this

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Aggregation Port. This value is read-only.;

30.7.4.1.4 aAggPortDebugMuxState

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has one of the following entries:
detached
waiting
attached
collecting
distributing
collecting_distributing

BEHAVIOUR DEFINED AS:

This attribute holds the value "detached" if the Mux state machine (43.4.15) for the Aggregation Port is in the DETACHED state, "waiting" if the Mux state machine for the Aggregation Port is in the WAITING state, "attached" if the Mux state machine for the Aggregation Port is in the ATTACHED state, "collecting" if the Mux state machine for the Aggregation Port is in the COLLECTING state, "distributing" if the Mux state machine for the Aggregation Port is in the DISTRIBUTING state, and "collecting_distributing" if the Mux state machine for the Aggregation Port is in the COLLECTING_DISTRIBUTING state. This value is read-only.;

30.7.4.1.5 aAggPortDebugMuxReason

ATTRIBUTE

APPROPRIATE SYNTAX:

A PrintableString, 255 characters max.

BEHAVIOUR DEFINED AS:

A human-readable text string indicating the reason for the most recent change of Mux machine state. This value is read-only.;

30.7.4.1.6 aAggPortDebugActorChurnState

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has one of the following entries:
noChurn
churn

BEHAVIOUR DEFINED AS:

The state of the Actor Churn Detection machine (43.4.17) for the Aggregation Port. A value of "noChurn" indicates that the state machine is in either the NO_ACTOR_CHURN or the ACTOR_CHURN_MONITOR state, and "churn" indicates that the state machine is in the ACTOR_CHURN state. This value is read-only.;

30.7.4.1.7 aAggPortDebugPartnerChurnState

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has one of the following entries:
noChurn

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churn

BEHAVIOUR DEFINED AS:

The state of the Partner Churn Detection machine (43.4.17) for the Aggregation Port. A value of "noChurn" indicates that the state machine is in either the NO_PARTNER_CHURN or the PARTNER_CHURN_MONITOR state, and "churn" indicates that the state machine is in the PARTNER_CHURN state. This value is read-only.;

30.7.4.1.8 aAggPortDebugActorChurnCount

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 5 counts per second.

BEHAVIOUR DEFINED AS:

Count of the number of times the Actor Churn state machine has entered the ACTOR_CHURN state. This value is read-only.;

30.7.4.1.9 aAggPortDebugPartnerChurnCount

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 5 counts per second.

BEHAVIOUR DEFINED AS:

Count of the number of times the Partner Churn state machine has entered the PARTNER_CHURN state. This value is read-only.;

30.7.4.1.10 aAggPortDebugActorSyncTransitionCount

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 5 counts per second.

BEHAVIOUR DEFINED AS:

Count of the number of times the Actor's Mux state machine (43.4.15) has entered the IN_SYNC state. This value is read-only.;

30.7.4.1.11 aAggPortDebugPartnerSyncTransitionCount

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 5 counts per second.

BEHAVIOUR DEFINED AS:

Count of the number of times the Partner's Mux state machine (43.4.15) has entered the IN_SYNC state. This value is read-only.;

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30.7.4.1.12 aAggPortDebugActorChangeCount

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 5 counts per second.

BEHAVIOUR DEFINED AS:
Count of the number of times the Actor's perception of the LAG ID for this Aggregation Port has changed. This value is read-only.;

30.7.4.1.13 aAggPortDebugPartnerChangeCount

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 5 counts per second.

BEHAVIOUR DEFINED AS:
Count of the number of times the Partner's perception of the LAG ID (43.3.6.1) for this Aggregation Port has changed. This value is read-only.;

30.8 Management for WAN Interface Sublayer (WIS)

30.8.1 WIS managed object class

This subclause formally defines the behaviours for the aWIS managed object class and attributes.

30.8.1.1 WIS attributes

The attributes in 30.8.1.1.1 through 30.8.1.1.28 may be used, possibly in conjunction with other attributes, to derive various system performance monitoring parameters and information.

30.8.1.1.1 aWISID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of aWISID is assigned so as to uniquely identify a WIS among the subordinate managed objects of the containing object.;

30.8.1.1.2 aSectionStatus

ATTRIBUTE

APPROPRIATE SYNTAX:
BIT STRING [SIZE (2)]

BEHAVIOUR DEFINED AS:
A string of 2 bits corresponding to the Section Status (50.3.2.5). The first bit corresponds to the Loss of Signal flag and maps to the LOS bit in the WIS Status 3 register. The second bit corresponds to the Loss of Frame flag and maps to the LOF bit in the WIS Status 3 register. If a

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Clause 45 MDIO Interface to the WIS is present, then this attribute will map to the WIS Status 3 register specified in 45.2.2.10.;

30.8.1.1.3 aSectionSESThreshold

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A GET operation returns the value for *x* for Section SES definition (30.8.1.1.4). A SET operation changes the value for *x* for Section SES definition. After reset (or power-off, power-on cycle), *x* for Section SES returns to the default value 8554.

NOTE—8554 is selected to reflect the number of Section BIP-8 Errors that would occur with a random bit error ratio of 1×10^{-6} (see Annex 50A).;

30.8.1.1.4 aSectionSESs

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 1 count per second independent of speed of operation.

BEHAVIOUR DEFINED AS:
Increment counter by one in a "Severely Errored Second" (SES), i.e., a second that had *x* or more Section BIP-8 Errors (50.3.2.5) or one or more Section Defects, i.e., the LOS flag (50.3.2.5) was equal to 1 or the LOF flag (50.3.2.5) was equal to 1, where *x* is the Section SES threshold defined by aSectionSESThreshold (30.8.1.1.3).;

30.8.1.1.5 aSectionESs

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 1 count per second independent of speed of operation.

BEHAVIOUR DEFINED AS:
Increment counter by one in an "Errored Second" (ES), i.e., a second that had one or more Section BIP-8 Errors (50.3.2.5) or one or more Section Defects, i.e., the LOS flag (50.3.2.5) was equal to 1 or the LOF flag (50.3.2.5) was equal to 1.;

30.8.1.1.6 aSectionSEFSs

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 1 count per second independent of speed of operation.

BEHAVIOUR DEFINED AS:
Increment counter by one in a "Severely Errored Framing Second" (SEFS), i.e., a second containing one or more SEF events (50.3.2.5).;

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30.8.1.1.7 aSectionCVs

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 64 000 counts per second.

BEHAVIOUR DEFINED AS:
For every received B1 octet, increment counter by the number of detected Section BIP-8 Errors (50.3.2.5).;

30.8.1.1.8 aJ0ValueTX

ATTRIBUTE

APPROPRIATE SYNTAX:
OCTET STRING, 15

BEHAVIOUR DEFINED AS:
An 16 octet value defining the transmitter's Section Trace message as defined in 50.3.2.3. The first octet of the string is transmitted first, and the last octet is transmitted last. A SET operation changes the Section Trace message value. A GET operation returns the current Section Trace message value. The default transmitter's Section Trace message is the hexadecimal value 89, followed by 15 NULL characters, the hexadecimal value 00. If a Clause 45 MDIO Interface to the WIS is present, then this attribute will map to the WIS J0 transmit registers specified in 45.2.2.18.;

30.8.1.1.9 aJ0ValueRX

ATTRIBUTE

APPROPRIATE SYNTAX:
OCTET STRING, 15

BEHAVIOUR DEFINED AS:
An 16 octet value indicating the received Section Trace message as defined in 50.3.2.4. The first octet in this string was received first, and the last octet received last. If a Clause 45 MDIO Interface to the WIS is present, then this attribute will map to the WIS J0 receive registers specified in 45.2.2.19.;

30.8.1.1.10 aLineStatus

ATTRIBUTE

APPROPRIATE SYNTAX:
BIT STRING [SIZE (2)]

BEHAVIOUR DEFINED AS:
A string of 2 bits reflecting the Line status (50.3.2.5). The first bit corresponds to the Line Alarm Indication Signal flag and maps to the AIS-L bit. The second bit corresponds to the Line Remote Defect Indication flag and maps to the RDI-L bit. If a Clause 45 MDIO Interface to the WIS is present, then this attribute will map to the WIS Status 3 register specified in 45.2.2.10;

30.8.1.1.11 aLineSESThreshold

ATTRIBUTE

APPROPRIATE SYNTAX:

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INTEGER

BEHAVIOUR DEFINED AS:

A GET operation returns the value for *x* for Line SES definition (30.8.1.1.12). A SET operation changes the value for x for Line SES definition. After WIS reset (or power-off, power-on cycle), *x* for Line SES returns to the default value 9835.;

NOTE—9835 is selected to reflect the number of Line BIP Errors that would occur with a random bit error ratio of 1×10^{-6} (see Annex 50A).;

30.8.1.1.12 aLineSESs

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 count per second independent of speed of operation.

BEHAVIOUR DEFINED AS:

Increment counter by one in a "Severely Errored Second" (SES), i.e., a second that had *x* or more Line BIP Errors (50.3.2.5) or an AIS-L defect was present, i.e., the AIS-L flag (50.3.2.5) was equal to 1, where *x* is the Line SES threshold defined by aLineSESThreshold (30.8.1.1.11).;

30.8.1.1.13 aLineESs

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 count per second independent of speed of operation.

BEHAVIOUR DEFINED AS:

Increment counter by one in an "Errored Second" (ES), i.e., a second that had one or more Line BIP Errors (50.3.2.5) or an AIS-L defect was present, i.e., the AIS-L flag (50.3.2.5) was equal to 1.;

30.8.1.1.14 aLineCVs

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 12 288 000 counts per second at 10 Gb/s.

BEHAVIOUR DEFINED AS:

For every received WIS frame (50.3.2), increment counter by the number of detected Line BIP Errors (50.3.2.5).;

30.8.1.1.15 aFarEndLineSESs

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 count second independent of speed of operation.

BEHAVIOUR DEFINED AS:

Increment counter by one in a "Severely Errored Second" (SES), i.e., a second that had *x* or more Far End Line BIP Errors (50.3.2.5) or an RDI-L defect was present, i.e., the RDI-L flag (50.3.2.5) was equal to 1, where *x* is the Line SES threshold defined by aLineSESThreshold (30.8.1.1.11).;

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30.8.1.1.16 aFarEndLineESs

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 1 count per second independent of speed of operation.

BEHAVIOUR DEFINED AS:
Increment counter by one in an "Errored Second" (ES), i.e., a second that had one or more Far End Line BIP Errors (50.3.2.5) or an RDI-L defect was present, i.e., the RDI-L flag (50.3.2.5) was equal to 1.;

30.8.1.1.17 aFarEndLineCVs

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 2 040 000 counts per second at 10 Gb/s.

BEHAVIOUR DEFINED AS:
For every received WIS frame (50.3.2), increment counter by the number of reported Far End Line BIP Errors (50.3.2.5).;

30.8.1.1.18 aPathStatus

ATTRIBUTE

APPROPRIATE SYNTAX:
BIT STRING [SIZE (4)]

BEHAVIOUR DEFINED AS:
A string of 4 bits corresponding to the Path Status (50.3.2.5). The first bit corresponds to the Loss of Pointer flag and maps to the LOP-P bit, the second bit corresponds to the Alarm Indication Signal and maps to the AIS-P bit, the third bit corresponds to the Path Label Mismatch flag and maps to the PLM-P bit and the fourth bit corresponds to the Path Loss of Cell Delineation flag and maps to the LCD-P bit. If a Clause 45 MDIO Interface to the WIS is present, then this attribute will map to the WIS Status 3 register specified in 45.2.2.10;

30.8.1.1.19 aPathSESThreshold

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A GET operation returns the value for *x* for Path SES definition (30.8.1.1.20). A SET operation changes the value for *x* for Path SES definition. After reset (or power-off, power-on cycle), *x* for Path SES is set to the default value 2400.

NOTE—2400 is selected to reflect the point where 30% of all SPEs have a Path Block Error (see Annex 50A).;

30.8.1.1.20 aPathSESs

ATTRIBUTE

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APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 1 count per second independent of speed of operation.

BEHAVIOUR DEFINED AS:
Increment counter by one in a "Severely Errored Second" (SES), i.e., a second that had *x* or more Path Block Errors (Annex 50A) or one or more Path Defects, i.e., the LOP-P flag (50.3.2.5) was equal to 1, the AIS-P flag (50.3.2.5) was equal to 1, the PLM-P flag (50.3.2.5) was equal to 1, or the LCD-P flag (50.3.2.5) was equal to 1, where *x* is the Path SES threshold defined by aPathSESThreshold (30.8.1.1.19).;

30.8.1.1.21 aPathESs

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 1 count per second independent of speed of operation.

BEHAVIOUR DEFINED AS:
Increment counter by one in an Errored Second (ES), i.e., a second that had one or more Path Block Errors (Annex 50A) or one or more Path Defects, i.e., the LOP-P flag (50.3.2.5) was equal to 1, the AIS-P flag (50.3.2.5) was equal to 1, the PLM-P flag (50.3.2.5) was equal to 1, or the LCD-P flag (50.3.2.5) was equal to 1.;

30.8.1.1.22 aPathCVs

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 8000 counts per second.

BEHAVIOUR DEFINED AS:
Increment counter by one for every received B3 indicating a Path Block Error (Annex 50A).;

30.8.1.1.23 aJ1ValueTX

ATTRIBUTE

APPROPRIATE SYNTAX:
OCTET STRING, 15

BEHAVIOUR DEFINED AS:
An 16 octet value defining the transmitter's Path Trace message as defined in 50.3.2.1. The first octet of the string is transmitted first, and the last octet is transmitted last. A SET operation changes the Path Trace message value. A GET operation returns the current Path Trace message value. The default transmitter's Path Trace message is the hexadecimal value 89, followed by 15 NULL characters, the hexadecimal value 00. If a Clause 45 MDIO Interface to the WIS is present, then this attribute will map to the WIS J1 transmit registers specified in 45.2.2.12.;

30.8.1.1.24 aJ1ValueRX

ATTRIBUTE

APPROPRIATE SYNTAX:
OCTET STRING, 15

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BEHAVIOUR DEFINED AS:

An 16 octet value indicating the received Path Trace message as defined in 50.3.2.4. The first octet in this string was received first, and the last octet received last. If a Clause 45 MDIO Interface to the WIS is present, then this attribute will map to the WIS J1 receive registers specified in 45.2.2.13.;

30.8.1.1.25 aFarEndPathStatus

ATTRIBUTE

APPROPRIATE SYNTAX:

BIT STRING [SIZE (2)]

BEHAVIOUR DEFINED AS:

A string of 2 bits corresponding to the Far End Path Status (50.3.2.5). The first bit corresponds to the Far End Path Label Mismatch/Path Loss of Cell Delineation flag and maps to the Far End PLM-P/LCD-P bit, and the second bit corresponds to the Far End Path Alarm Indication Signal/ Path Loss of Pointer flag and maps to the Far End AIS-P/LOP-P bit. If a Clause 45 MDIO Interface to the WIS is present, then this attribute will map to the WIS Status 3 register specified in 45.2.2.10;

30.8.1.1.26 aFarEndPathSESs

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 count per second independent of speed of operation.

BEHAVIOUR DEFINED AS:

Increment counter by one in a “Severely Errored Second” (SES), i.e., a second that had *x* or more Far End Path Block Errors or one or more Far End Path Defects reported in the Far End PLM-P/ LCD-P, AIS-P, and LOP-P bits (50.3.2.5), where *x* is the Path SES threshold defined by aPathSESThreshold (30.8.1.1.19).;

30.8.1.1.27 aFarEndPathESs

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 1 count per second independent of speed of operation.

BEHAVIOUR DEFINED AS:

Increment counter by one in an “Errored Second” (ES), i.e., a second that had one or more Far End Path Block Errors or one or more Far End Path Defects reported in the Far End PLM-P/LCD-P, AIS-P, and LOP-P bits (50.3.2.5).;

30.8.1.1.28 aFarEndPathCVs

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 8000 counts per second.

BEHAVIOUR DEFINED AS:

Increment counter by one for each received G1 octet indicating a Far End Path Block Error

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reported in REI-P (50.3.2.5).;

30.9 Management for DTE Power via MDI

30.9.1 PSE managed object class

This subclause formally defines the behaviours for the oPSE managed object class attributes and actions.

30.9.1.1 PSE attributes

30.9.1.1.1 aPSEID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of aPSEID is assigned so as to uniquely identify a PSE among the subordinate managed objects of the containing object.;

30.9.1.1.2 aPSEAdminState

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that has one of the following entries:

enabled	PSE functions enabled
disabled	PSE functions disabled

BEHAVIOUR DEFINED AS:
A read-only value that identifies the operational state of the PSE functions. An interface which can provide the PSE functions specified in Clause 33 will be enabled to do so when this attribute has the enumeration “enabled.” When this attribute has the enumeration “disabled” the interface will act as it would if it had no PSE function. The operational state of the PSE function can be changed using the acPSEAdminControl action. If a Clause 22 MII or Clause 35 GMII is present, then this will map to the PSE Enable bit specified in 33.5.1.1.5.;

30.9.1.1.3 aPSEPowerPairsControlAbility

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
Indicates the ability to control which PSE Pinout Alternative (see 33.2.3) is used for PD detection and power. When “true” the PSE Pinout Alternative used can be controlled through the aSectionSESs attribute. When “false” the PSE Pinout Alternative used cannot be controlled through the aSectionSESs attribute. If a Clause 22 MII or Clause 35 GMII is present, then this will map to the Pair Control Ability bit specified in 33.5.1.2.12;

30.9.1.1.4 aPSEPowerPairs

ATTRIBUTE

APPROPRIATE SYNTAX:

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An ENUMERATED VALUE that has one of the following entries:

signal	PSE Pinout Alternative A
spare	PSE Pinout Alternative B

BEHAVIOUR DEFINED AS:

A read-write value that identifies the supported PSE Pinout Alternative specified in 33.2.3. A GET operation returns the PSE Pinout Alternative in use. A SET operation changes the PSE Pinout Alternative used to the indicated value only if the attribute aSectionSESThreshold is "true." If the attribute aSectionSESThreshold is "false" a SET operation has no effect.

The enumeration "signal" indicates that PSE Pinout Alternative A is used for PD detection and power. The enumeration "spare" indicates that PSE Pinout Alternative B is used for PD detection and power. If a Clause 22 MII or Clause 35 GMII is present, then this will map to the Pair Control bits specified in 33.5.1.1.4.;

30.9.1.1.5 aPSEPowerDetectionStatus

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has one of the following entries:

disabled	PSE disabled
searching	PSE searching
deliveringPower	PSE delivering power
test	PSE test mode
fault	PSE fault detected
otherFault	PSE implementation specific fault detected

BEHAVIOUR DEFINED AS:

A read-only value that indicates the current status of the PD Detection function specified in 33.2.5.

The enumeration "disabled" indicates that the PSE State diagram (Figure 33–9) is in the state DISABLED. The enumeration "deliveringPower" indicates that the PSE State diagram is in the state POWER_ON. The enumeration "test" indicates that the PSE State diagram is in the state TEST_MODE. The enumeration "fault" indicates that the PSE State diagram is in the state TEST_ERROR. The enumeration "otherFault" indicates that the PSE State diagram is in the state IDLE due to the variable error_condition = true. The enumeration "searching" indicates the PSE State diagram is in a state other than those listed above. If a Clause 22 MII or Clause 35 GMII is present, then this will map to the PSE Status bits specified in 33.5.1.2.11.

NOTE—A derivative attribute may wish to apply a delay to the use of the "deliveringPower" enumeration as the PSE state diagram will enter then quickly exit the POWER_ON state if a short-circuit or overcurrent condition is present when power is first applied.;

30.9.1.1.6 aPSEPowerClassification

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has one of the following entries:

class0	Class 0 PD
class1	Class 1 PD
class2	Class 2 PD
class3	Class 3 PD
class4	Class 4 PD

BEHAVIOUR DEFINED AS:

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A read-only value that indicates the PD Class of a detected PD as specified in 33.2.6.1.

This value is only valid while a PD is being powered, that is the attribute aLineSESThreshold reporting the enumeration "deliveringPower." If a Clause 22 MII or Clause 35 GMII is present, then this will map to the PD Class bits specified in 33.5.1.2.10.;

30.9.1.1.7 aPSEInvalidSignatureCounter

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 2 counts per second.

BEHAVIOUR DEFINED AS:
This counter is incremented when the PSE state diagram (Figure 33–9) enters the state SIGNATURE_INVALID. If a Clause 22 MII or Clause 35 GMII is present, then this will map to the Invalid Signature bit specified in 33.5.1.2.6.;

30.9.1.1.8 aPSEPowerDeniedCounter

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 2 counts per second.

BEHAVIOUR DEFINED AS:
This counter is incremented when the PSE state diagram (Figure 33–9) enters the state POWER_DENIED. If a Clause 22 MII or Clause 35 GMII is present, then this will map to the Power Denied bit specified in 33.5.1.2.4.;

30.9.1.1.9 aPSEOverLoadCounter

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 2 counts per second.

BEHAVIOUR DEFINED AS:
This counter is incremented when the PSE state diagram (Figure 33–9) enters the state ERROR_DELAY_OVER. If a Clause 22 MII or Clause 35 GMII is present, then this will map to the Overload bit specified in 33.5.1.2.8.;

30.9.1.1.10 aPSEShortCounter

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 2 counts per second.

BEHAVIOUR DEFINED AS:
This counter is incremented when the PSE state diagram (Figure 33–9) enters the state ERROR_DELAY_SHORT. If a Clause 22 MII or Clause 35 GMII is present, then this will map to the Short Circuit bit specified in 33.5.1.2.7.;

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30.9.1.1.11 aPSEMPSAbsentCounter

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 2 counts per second.

BEHAVIOUR DEFINED AS:
This counter is incremented when the PSE state diagram (Figure 33–9) transitions directly from the state POWER_ON to the state IDLE due to tmpdo_timer_done being asserted. If a Clause 22 MII or Clause 35 GMII is present, then this will map to the MPS Absent bit specified in 33.5.1.2.9.;

30.9.1.1.12 aPSEActualPower

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
An integer value indicating present (actual) power being supplied by the PSE as measured at the MDI in milliwatts. The behaviour is undefined if the state of aPSEPowerDetectionStatus is anything other than deliveringPower. The sampling frequency and averaging is vendor-defined.;

30.9.1.1.13 aPSEPowerAccuracy

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
An integer value indicating the accuracy associated with aPSEActualPower in +/- milliwatts.;

30.9.1.1.14 aPSECumulativeEnergy

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. The counter has a maximum increment rate of 100000 per second.

BEHAVIOUR DEFINED AS:
A count of the cumulative energy supplied by the PSE as measured at the MDI in millijoules.;

30.9.1.2 PSE actions

30.9.1.2.1 acPSEAdminControl

ACTION

APPROPRIATE SYNTAX:
Same as aSectionStatus

BEHAVIOUR DEFINED AS:
This action provides a means to alter aSectionStatus.;

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30.9.2 PD managed object class

This subclause formally defines the behaviours for the oPD managed object class attributes.

30.9.2.1 PD attributes

30.9.2.1.1 aPDID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of aPDID is assigned so as to uniquely identify a PD Power via MDI classification local system among the subordinate managed objects of the containing object.;

30.10 Layer management for Midspan

30.10.1 Midspan managed object class

This subclause formally defines the behaviours for the oMidSpan managed object class, attributes, and notifications.

30.10.1.1 Midspan attributes

30.10.1.1.1 aMidSpanID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of aMidSpanID is assigned so as to uniquely identify a Midspan device among the subordinate managed objects of system (systemID and system are defined in ISO/IEC 10165-2:1992 [SMI]).;

30.10.1.1.2 aMidSpanPSEGroupCapacity

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The aMidSpanPSEGroupCapacity is the number of PSE groups that can be contained within the Midspan device. Within each managed Midspan device, the PSE groups are uniquely numbered in the range from 1 to aMidSpanPSEGroupCapacity.

Some PSE groups may not be present in a given Midspan instance, in which case the actual number of PSE groups present is less than aMidSpanPSEGroupCapacity. The number of PSE groups present is never greater than aMidSpanPSEGroupCapacity.;

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30.10.1.1.3 aMidSpanPSEGroupMap

ATTRIBUTE

APPROPRIATE SYNTAX:
BITSTRING

BEHAVIOUR DEFINED AS:
A string of bits which reflects the current configuration of PSE groups that are viewed by PSE group managed objects. The length of the bitstring is "aMidSpanPSEGroupCapacity" bits. The first bit relates to PSE group 1. A "1" in the bitstring indicates presence of the PSE group, "0" represents absence of the PSE group.;

30.10.1.2 Midspan notifications

30.10.1.2.1 nMidSpanPSEGroupMapChange

NOTIFICATION

APPROPRIATE SYNTAX:
BITSTRING

BEHAVIOUR DEFINED AS:
This notification is sent when a change occurs in the PSE group structure of a Midspan device. This occurs only when a PSE group is logically removed from or added to a Midspan device. The nMidSpanPSEGroupMapChange notification is not sent when powering up a Midspan device. The value of the notification is the updated value of the aMidSpanPSEGroupMap attribute.;

30.10.2 PSE Group managed object class

This subclause formally defines the behaviours for the oPSEGroup managed object class, attributes, actions, and notifications.

30.10.2.1 PSE Group attributes

30.10.2.1.1 aPSEGroupID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A value unique within the Midspan device. The value of aPSEGroupID is assigned so as to uniquely identify a PSE group among the subordinate managed objects of the containing object (oMidSpan). This value is never greater than aMidSpanPSEGroupCapacity.;

30.10.2.1.2 aPSECapacity

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The aPSECapacity is the number of PSEs contained within the PSE group. Valid range is 1–1024. Within each PSE group, the PSEs are uniquely numbered in the range from 1 to aPSECapacity. Some PSEs may not be present in a given PSE group instance, in which case the actual number of

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PSEs present is less than aPSECapacity. The number of PSEs present is never greater than aPSECapacity.;

30.10.2.1.3 aPSEMap

ATTRIBUTE

APPROPRIATE SYNTAX:
BitString

BEHAVIOUR DEFINED AS:
A string of bits that reflects the current configuration of PSE managed objects within this PSE group. The length of the bitstring is "aPSECapacity" bits. The first bit relates to PSE 1. A "1" in the bitstring indicates presence of the PSE, "0" represents absence of the PSE.;

30.10.2.2 PSE Group notifications

30.10.2.2.1 nPSEMapChange

NOTIFICATION

APPROPRIATE SYNTAX:
BitString

BEHAVIOUR DEFINED AS:
This notification is sent when a change occurs in the PSE structure of a PSE group. This occurs only when a PSE is logically removed from or added to a PSE group. The nPSEMapChange notification is not sent when powering up a Midspan device. The value of the notification is the updated value of the aPSEMap attribute.;

30.11 Layer Management for Physical Medium Entity (PME)

30.11.1 PAF managed object class

This subclause formally defines the behaviours for the oPAF managed object class attributes.

30.11.1.1 PAFAttributes

30.11.1.1.1 aPAFID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The value of aTCID is assigned so as to uniquely identify a PAF among the subordinate managed objects of the containing object.

30.11.1.1.2 aPhyEnd

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED value that has one of the following entries:

subscriber	subscriber mode of operation
office	office mode of operation

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BEHAVIOUR DEFINED AS:

A read-only value that indicates the subtype of the PHY (see 61.1). The enumeration “subscriber” indicates the PHY is operating as a -R subtype, the enumeration “office” indicates the PHY is operating as a -O subtype.;

30.11.1.1.3 aPHYCurrentStatus

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has the following entries:

noPMEAssigned	no PME assigned in case of PME aggregation
lossOfFraming	one or more PME in aggregation indicates Loss of Framing
lossOfSignal	one or more PME in aggregation indicates Loss of Signal
lossOfPower	one or more PME in aggregation indicates Loss of Power
configInitFailure	configuration initialization failure
noPeerPMEPresent	one or more PME in aggregation indicates no peer PME present
snrMarginViolation	one or more PME in aggregation indicates SNR Margin Violation
lineAttenViolation	one or more PME in aggregation indicates Loop Attenuation Violation

BEHAVIOUR DEFINED AS:

This read-only value indicates the current operational state of the PHY (see 62.3.4.8 and 63.2.2.3).

The enumeration “noPMEAssigned” indicates that the PAF is enabled but that there are no PMEs available for aggregation (no modems assigned), the enumeration “lossOfFraming” indicates one or more PMEs in the aggregation are reporting loss of framing, the enumeration “lossOfSignal” indicates one or more PMEs in the aggregation are reporting loss of signal, the enumeration “lossOfPower” indicates one or more PMEs in the aggregation are reporting loss of power, the enumeration “configInitFailure” indicates configuration initialization failure, the enumeration “noPeerPMEPresent” indicates one or more PMEs in the aggregation are reporting that there was no handshake message/tones send by the remote end during initialization, the enumeration “snrMarginViolation” indicates one or more PMEs in the aggregation are reporting a SNR margin violation and the enumeration “lineAttenViolation” indicates one or more PMEs in the aggregation are reporting a loop attenuation violation.;

30.11.1.1.4 aPAFSupported

ATTRIBUTE

APPROPRIATE SYNTAX:

BOOLEAN

BEHAVIOUR DEFINED AS:

A read-only value that indicates if the TPS-TC supports the PME aggregation function (see 61.2.2). A TPS-TC that can perform PME aggregation on the available PMEs shall return the enumeration “true”. A TPS-TC that is incapable of PME aggregation shall return the enumeration “false”.

If a Clause 45 MDIO Interface to the PCS is present, then this attribute will map to the PAF available bit in the 10P/2B capability register (see 45.2.3.25.1).;

30.11.1.1.5 aPAFAdminState

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has the following entries:

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enabled
disabled

BEHAVIOUR DEFINED AS:

A read-write value that indicates the state of the PME aggregation function (see 61.2.2). When "disabled", PME aggregation will not be performed, when "enabled", PME aggregation will be performed when the link is Up, even on a single PME. As changing the state of the PME aggregation function is a traffic disruptive operation this can only occur when the link is down.

A GET operation returns the current state of the PME aggregation function. A SET operation changes the state of the PME aggregation function to the indicated value only if the attribute aPAFSupported is "true" and the link is down. If the attribute aPAFSupported is "false", or the link is not down, a SET operation has no effect.

If a Clause 45 MDIO Interface to the PCS is present, then this attribute will map to the PAF enable bit in the 10P/2B capability register (see 45.2.3.26.3).;

30.11.1.1.6 aLocalPAFCapacity

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:

The aLocalPAFCapacity is the number of PMEs that can be aggregated by the PME aggregation function (PAF) of the PHY. Valid range is 1–32. Within each PHY, the PMEs are uniquely numbered in the range from 1 to aLocalPAFCapacity. Some PMEs may not be present in a given PHY instance, in which case the actual number of PMEs present is less than aLocalPAFCapacity. The number of PMEs present is never greater than aLocalPAFCapacity.;

30.11.1.1.7 aLocalPMEAvailable

ATTRIBUTE

APPROPRIATE SYNTAX:
BIT STRING [SIZE (32)]

BEHAVIOUR DEFINED AS:

A string of bits that indicates which PMEs are currently available for aggregation by the PME aggregation function (PAF) of the PHY (see 61.1.5.3) and therefore reflects the current configuration of PME managed objects within this PAF. The length of the bitstring is "aLocalPAFCapacity" bits. The first bit relates to PME[0]. A "1" in the bitstring indicates the PME is present and is available to the PAF for aggregation. A "0" in the bitstring indicates the PME is absent and not available to the PAF for aggregation.

If a Clause 45 MDIO Interface to the PCS is present, then this attribute will map to the 10P/2B PME available register (see 45.2.3.27).;

30.11.1.1.8 aLocalPMEAggregate

ATTRIBUTE

APPROPRIATE SYNTAX:
BIT STRING [SIZE (32)]

BEHAVIOUR DEFINED AS:

A string of bits that indicates which PMEs are in an active aggregation in the PHY. The length of

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the bitstring is “aLocalPAFCapacity” bits. The first bit relates to PME[0]. A “1” in the bitstring indicates the PME is in an active aggregation. A “0” in the bitstring indicates the PME is not in an active aggregation.

If a Clause 45 MDIO Interface to the PCS is present, then this attribute will map to the 10P/2B PME available registers (see 45.2.3.28).;

30.11.1.1.9 aRemotePAFSupported

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has the following entries:

unknown	initializing, true state not yet know
supported	PAF supported
not supported	PAF not supported

BEHAVIOUR DEFINED AS:

A read-only value that indicates if the link-partner PHY supports the PME aggregation function (see 61.2.2). When the link-partner PHY can perform PME aggregation on its available PMEs the enumeration “supported” shall be returned. When the link-partner PHY is incapable of PME aggregation the enumeration “not supported” shall be returned.

If a Clause 45 MDIO Interface to the local PCS is present, then this attribute will map to the Remote PAF supported bit in the 10P/2B capability register (see 45.2.3.25.2).;

30.11.1.1.10 aRemotePAFCapacity

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

The aRemotePAFCapacity indicates the number of PME that can be aggregated by the PME aggregation function (PAF) of the link-partner PHY. Valid range is 1–32. Within the link-partner PHY, the PMEs are uniquely numbered in the range from 1 to aRemotePAFCapacity. Some PMEs may not be present in a given PHY instance, in which case the actual number of PMEs present is less than aRemotePAFCapacity. The number of PMEs present is never greater than aRemotePAFCapacity.;

30.11.1.1.11 aRemotePMEAggregate

ATTRIBUTE

APPROPRIATE SYNTAX:

BIT STRING [SIZE (32)]

BEHAVIOUR DEFINED AS:

A string of bits that indicates which PMEs are in an active aggregation in the link-partner PHY. The length of the bitstring is “aRemotePAFCapacity” bits. The first bit relates to PME[0]. A “1” in the bitstring indicates the PME is in an active aggregation. A “0” in the bitstring indicates the PME is not in an active aggregation.

If a Clause 45 MDIO Interface to the local PCS is present, then this attribute will map to the 10P/2B PME available registers (see 45.2.6.10).;

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30.11.2 PME managed object class

This subclause formally defines the behaviours for the oPME managed object class attributes.

30.11.2.1 PME Attributes

30.11.2.1.1 aPMEID

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A value unique within the PAF. The value of aPMEID is assigned so as to uniquely identify a PME among the subordinate managed objects of the containing object (oPAF). This value is never greater than aLocalPAFCapacity.;

30.11.2.1.2 aPMEAdminState

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that has the following entries:
enabled
disabled

BEHAVIOUR DEFINED AS:
A read-write value that indicates the state of the PME. The enumeration “disabled” indicates that the PME is disabled, the enumeration “enabled” indicates that the PME is enabled.
A GET operation returns the current state of the PME. A SET operation changes the state of the PME to the indicated value. The PME is enabled and link initialization initiated when the a SET operation is performed with the value “enabled” when the current value is “disabled”. A SET operation performed with the value “enabled” when the current value is already “enabled” will have shall have no effect.

If a Clause 45 MDIO Interface to the PMA/PMD is present, then this attribute will map to the PMA/PMD link control register (see 45.2.1.11).;

30.11.2.1.3 aPMEStatus

ATTRIBUTE

APPROPRIATE SYNTAX:
A ENUMERATED VALUE that has the following entries:

down not ready	link is down, not ready
down ready	link is down, ready
initializing	link is initializing
10PASS-TS	link is up as 10PASS-TS
2BASE-TL	link is up as 2BASE-TL

BEHAVIOUR DEFINED AS:
A read-only value that indicates the PME status. The enumeration “not ready” indicates that the link is down and handshake tones are not being received from a link partner, the enumeration “ready” indicates that the link is down and that handshake tones are being received from a link partner, the enumeration “initializing” indicates that the link is initializing, the enumeration “10PASS-TS” indicates that the link is up and the remote PHY is a 10PASS-TS PHY and the

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enumeration “2BASE-TL” indicates that the link is up and the remote PHY is a 2BASE-TL PHY.

If a Clause 45 MDIO Interface to the PMA/PMD is present, then this attribute will map to the PMA/PMD link status register (see 45.2.1.16.4).;

30.11.2.1.4 aPMESNRMgn

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A read-only value that indicates the PME current signal-to-noise ratio (SNR) Margin (see 62.3.4.7 and 63.2.2.3) with respect to the received signal in increments of dB rounded down to the nearest dB.

If a Clause 45 MDIO Interface to the PMA/PMD is present, then this attribute will map to the 10P/2B RX SNR margin register (see 45.2.1.20).;

30.11.2.1.5 aTCCodingViolations

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 19 230 counts per second for 10 Mb/s implementations.

BEHAVIOUR DEFINED AS:
A count of 64/65-octet encapsulation error. Increment the counter by one for each 64/65-octet encapsulation error detected by the 64/65-octet receive function (see Figure 61–19).;

If a Clause 45 MDIO Interface to the PCS is present, then this attribute will map to the TC coding violations register (see 45.2.6.12).;

30.11.2.1.6 aProfileSelect

ATTRIBUTE

APPROPRIATE SYNTAX:
SEQUENCE of the type INTEGER

BEHAVIOUR DEFINED AS:
A SEQUENCE of read-write values that indicates the operating profile numbers (see 62A.3.7 and 63A.4) of the PME. A 2BASE-TL PME supports a maximum of six values, 10PASS-TS PME can only support one. The operating profile can only be changed in a PME that is operating within a -O PHY subtype (see 61.1). As changing the operating profile is a traffic disruptive operation this can only occur when the link is down.

A GET operation returns the current operating profile number(s). A SET operation changes the operating profile to the indicated profile number only if the attribute aPHYEnd is “office” and the link is down. If the attribute aPHYEnd is “subscriber”, or the link is not down, a SET operation has no effect. If all values are zero, the PME operation is defined via the Clause 45 register settings (Table 45–42 and Table 45–43) rather than a specific profile.

NOTE 1—The profile selected by a particular value is different for 10PASS-TS and 2BASE-TL PHY types.

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NOTE 2—For a 2BASE-TL PHY six profiles per region can be chosen for handshake (see 61.4) and the one with the highest data rate will be used.;

30.11.2.1.7 aOperatingProfile

ATTRIBUTE

APPROPRIATE SYNTAX:

A SEQUENCE of two instances, the first instances PMEProfileState is an ENUMERATED VALUE that has the following entries:

no link	link is down
match	link up using a profile
no match	link up not using a profile
activate failure	link activate failure

The second instances is an INTEGER

BEHAVIOUR DEFINED AS:

The ProfileState portion of the attribute is a read-only value that indicates the state of the operating profile. The enumeration “no link” indicates that the link is down, the enumeration “match” indicates that the link is up and achieved operating parameters match a defined complete profile (63A.3 and Table 63A–1), the enumeration “no match” indicates that the link is up but the achieved operating parameters do not match a defined complete profile and the enumeration “activate failure” indicates that the link failed to come up in any of the selected profiles.

The integer portion of the attribute is a read-only value that indicates the operating profile number. This value is only valid when the ProfileState portion of the attribute is “match”;

30.11.2.1.8 aPMEFECCorrectedBlocks

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 10 000 counts per second for 10 Mb/s implementations.

BEHAVIOUR DEFINED AS:

For a 10PASS-TS PME, a count of corrected FEC blocks. This counter will not increment for other PHY types.

Increment the counter by one for each received block that is corrected by the FEC function in the PME.

If a Clause 45 MDIO Interface to the PMA/PMD is present, then this attribute will map to the 10P FEC correctable errors (see 45.2.1.26).;

30.11.2.1.9 aPMEFECUncorrectableBlocks

ATTRIBUTE

APPROPRIATE SYNTAX:

Generalized nonresettable counter. This counter has a maximum increment rate of 10 000 counts per second for 10 Mb/s implementations.

BEHAVIOUR DEFINED AS:

For a 10PASS-TS PME, a count of uncorrectable FEC blocks. This counter will not increment for other PME types.

Increment the counter by one for each FEC block that is determined to be uncorrectable by the FEC

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function in the PME.

If a Clause 45 MDIO Interface to the PMA/PMD is present, then this attribute will map to the 10P FEC uncorrectable errors counter (see 45.2.1.27).;

30.11.2.1.10 aTCCRCErrors

ATTRIBUTE

APPROPRIATE SYNTAX:
Generalized nonresettable counter. This counter has a maximum increment rate of 19 230 counts per second for 10 Mb/s implementations.

BEHAVIOUR DEFINED AS:
A count of TC-CRC errors.

Increment the counter by one for each TC-CRC error detected by the 64/65-octet receive function (see 61.3.3 and Figure 61–19).;

If a Clause 45 MDIO Interface to the PCS is present, then this attribute will map to the TC CRC error register (see 45.2.6.11).;

30.12 Layer Management for Link Layer Discovery Protocol (LLDP)

30.12.1 LLDP Configuration managed object class

This subclause formally defines the behaviours for the oLldpXdot3Config managed object class attributes.

30.12.1.1 LLDP Configuration attributes

30.12.1.1.1 aLldpXdot3PortConfigTLVsTxEnable

ATTRIBUTE

APPROPRIATE SYNTAX:
BITSTRING

BEHAVIOUR DEFINED AS:
A read-write string of 6 bits indicating, for each of the IEEE 802.3 optional LLDP TLVs, if transmit is enabled on the local LLDP agent by the network management. A "1" in the bitstring indicates transmit of the TLV is enabled, "0" indicates transmit of the TLV is disabled. The value of this attribute is preserved across reset including loss of power.

The first bit indicates if the MAC/PHY configuration/status TLV transmit is enabled, the second bit indicates if the Power via MDI TLV transmit is enabled, the third bit indicates if the deprecated Link Aggregation TLV transmit is enabled, the fourth bit indicates if the Maximum Frame Size TLV transmit is enabled, the fifth bit indicates if the EEE TLV is enabled, and the sixth bit indicates if the EEE Fast Wake TLV is enabled.;

30.12.2 LLDP Local System Group managed object class

This subclause formally defines the behaviours for the oLldpXdot3LocSystemsGroup managed object class attributes.

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30.12.2.1 LLDP Local System Group attributes

30.12.2.1.1 aLldpXdot3LocPortAutoNegSupported

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
A read-only Boolean value used to indicate whether the given port (associated with the local system) supports Auto-negotiation.;

30.12.2.1.2 aLldpXdot3LocPortAutoNegEnabled

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
A read-only Boolean value used to indicate whether port Auto-negotiation is enabled on the given port associated with the local system.;

30.12.2.1.3 aLldpXdot3LocPortAutoNegAdvertisedCap

ATTRIBUTE

APPROPRIATE SYNTAX:
OCTET STRING [SIZE (2)]

BEHAVIOUR DEFINED AS:
A read-only 2-octet value that contains the value (bitmap) of the ifMauAutoNegCapAdvertisedBits object (defined in IETF RFC 4836) which is associated with the given port on the local system.;

30.12.2.1.4 aLldpXdot3LocPortOperMauType

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A read-only 32-bit integer value that indicates the operational MAU type of the given port on the local system.

This object contains an integer value derived from the list position of the corresponding dot3MauType as listed in IETF RFC 4836 (or subsequent revisions) and is equal to the last number in the respective dot3MauType Object Identifier (OID).

For example, if the ifMauType object is dot3MauType1000BaseTHD which corresponds to {dot3MauType 29}, the numerical value of this field is 29. For MAU types not listed in IETF RFC 4836 (or subsequent revisions), the value of this field shall be set to zero.;

30.12.2.1.5 aLldpXdot3LocPowerPortClass

ATTRIBUTE

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APPROPRIATE SYNTAX:
An ENUMERATED VALUE that has one of the following entries:
pClassPSE PSE
pClassPD PD

BEHAVIOUR DEFINED AS:
A read-only value that identifies the port Class of the given port associated with the local system.;

30.12.2.1.6 aLldpXdot3LocPowerMDISupported

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
A read-only Boolean value used to indicate whether the MDI power is supported on the given port associated with the local system.;

30.12.2.1.7 aLldpXdot3LocPowerMDIEnabled

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
A read-only Boolean value used to identify whether MDI power is enabled on the given port associated with the local system.;

30.12.2.1.8 aLldpXdot3LocPowerPairControlable

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
A read-only Boolean value derived from the value of pethPsePortPowerPairsControlAbility object (defined in IETF RFC 3621) and used to indicate whether the pair selection can be controlled on the given port associated with the local system.;

30.12.2.1.9 aLldpXdot3LocPowerPairs

ATTRIBUTE

APPROPRIATE SYNTAX:
The same as used for aPSEPowerPairs

BEHAVIOUR DEFINED AS:
A read-only the value that contains the value of the pethPsePortPowerPairs object (defined in IETF RFC 3621) which is associated with the given port on the local system.;

30.12.2.1.10 aLldpXdot3LocPowerClass

ATTRIBUTE

APPROPRIATE SYNTAX:
The same as used for aPSEPowerClassification

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BEHAVIOUR DEFINED AS:

A read-only the value that contains the value of the pethPsePortPowerClassifications object (defined in IETF RFC 3621) which is associated with the given port on the local system.;

30.12.2.1.11 aLldpXdot3LocLinkAggStatus

ATTRIBUTE

APPROPRIATE SYNTAX:

BITSTRING

BEHAVIOUR DEFINED AS:

The bitmap value which contains the link aggregation capabilities and the current aggregation status of the link (see 79.3.3.1).;

30.12.2.1.12 aLldpXdot3LocLinkAggPortId

ATTRIBUTE

APPROPRIATE SYNTAX:

The same as used for aAggPortID

BEHAVIOUR DEFINED AS:

This object contains the IEEE 802.3 aggregated port identifier, aAggPortID (see 30.7.2.1.1), derived from the ifNumber of the ifIndex for the port component in link aggregation.

If the port is not in link aggregation state and/or it does not support link aggregation, this value should be set to zero.;

30.12.2.1.13 aLldpXdot3LocMaxFrameSize

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

An integer value indicating the maximum supported frame size in octets on the given port of the local system.;

30.12.2.1.14 aLldpXdot3LocPowerType

ATTRIBUTE

APPROPRIATE SYNTAX:

BIT STRING [SIZE (2)]

BEHAVIOUR DEFINED AS:

A GET attribute that returns a bit string indicating whether the local system is a PSE or a PD and whether it is Type 1 or Type 2. The first bit indicates Type 1 or Type 2. The second bit indicates PSE or PD. A PSE shall set this bit to indicate a PSE. A PD shall set this bit to indicate a PD.;

30.12.2.1.15 aLldpXdot3LocPowerSource

ATTRIBUTE

APPROPRIATE SYNTAX:

BIT STRING [SIZE (2)]

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BEHAVIOUR DEFINED AS:

A GET attribute that returns a bit string indicating the power sources of the local system. A PSE indicates whether it is being powered by a primary power source; a backup power source; or unknown. A PD indicates whether it is being powered by a PSE and locally; by a PSE only; or unknown.;

30.12.2.1.16 aLldpXdot3LocPowerPriority

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED value list that has the following entries:

low	low priority PD
high	high priority PD
critical	critical priority PD
unknown	priority unknown

BEHAVIOUR DEFINED AS:

A GET attribute that returns the priority of a PD system. For a PSE, this is the priority that the PSE assigns to the PD. For a PD, this is the priority that the PD requests from the PSE.
A SET operation changes the priority of the PD system to the indicated value.;

30.12.2.1.17 aLldpXdot3LocPDRequestedPowerValue

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

A GET attribute that returns the PD requested power value. For a PD, it is the power value that the PD has currently requested from the remote system. PD requested power value is the maximum input average power the PD ever draws under this power allocation if accepted. For a PSE, it is the power value that the PSE mirrors back to the remote system. This is the PD requested power value that was used by the PSE to compute the power it has currently allocated to the remote system. The PD requested power value is encoded according to Equation (79–1), where *X* is the decimal value of aLldpXdot3LocPDRequestedPowerValue.;

30.12.2.1.18 aLldpXdot3LocPSEAllocatedPowerValue

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

A GET attribute that returns the PSE allocated power value. For a PSE, it is the power value that the PSE has currently allocated to the remote system. The PSE allocated power value is the maximum input average power that the PSE wants the PD to ever draw under this allocation if it is accepted. For a PD, it is the power value that the PD mirrors back to the remote system. This is the PSE allocated power value that was used by the PD to compute the power that it has currently requested from the remote system. The PSE allocated power value is encoded according to Equation (79–2), where *X* is the decimal value of aLldpXdot3LocPSEAllocatedPowerValue.;

30.12.2.1.19 aLldpXdot3LocResponseTime

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APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A GET attribute that returns the response time in seconds of the local system. For a PD, it is the maximum time required to update the value of attribute aLldpXdot3LocPDRequestedPowerValue when the remote system requests the PD to change its max power draw. For a PSE, it is the maximum time required to update the value of attribute aLldpXdot3LocPDRequestedPowerValue when the remote system requests of the PSE a new power value.;

30.12.2.1.20 aLldpXdot3LocReady

ATTRIBUTE

APPROPRIATE SYNTAX:
A BOOLEAN value:

FALSE:	Local system has not completed initialization of the Data Link Layer classification engine and is not ready to receive/transmit an LLDPDU containing a Power via MDI TLV.
TRUE:	Local system has initialized the Data Link Layer classification engine and is ready to receive/transmit an LLDPDU containing a Power via MDI TLV.

BEHAVIOUR DEFINED AS:
A GET operation returns the initialization status of the Data Link Layer classification engine on the local system.;

30.12.2.1.21 aLldpXdot3LocReducedOperationPowerValue

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A GET attribute that returns the reduced operation power value. For a PD, it is a power value that is lower than the currently requested power value. This reduced operation power value represents a power state in which the PD could continue to operate, but with less functionality than at the current PD requested power value. The PSE could optionally use this information in the event that the PSE subsequently requests a lower PD power value than the PD requested power value. For a PSE, it is a power value that the PSE could ask the PD to move to if the PSE wants the PD to move to a lower power state. The definition and encoding of PD requested power value is the same as described in aLldpXdot3LocPDRequestedPowerValue (30.12.2.1.17). The default value for this field is the hexadecimal value FFFF.;

30.12.2.1.22 aLldpXdot3LocTxTwSys

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A GET attribute that returns the value of $T_{w_sys_tx}$ that the local system can support in the transmit direction. This attribute maps to the variable LocTxSystemValue as defined in 78.4.2.3;

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30.12.2.1.23 aLldpXdot3LocTxTwSysEcho

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A GET attribute that returns the value of $T_{w_sys_tx}$ that the remote system is advertising that it can support in the transmit direction and is echoed by the local system under the control of the EEE DLL receiver state diagram. This attribute maps to the variable LocTxSystemValueEcho as defined in 78.4.2.3;

30.12.2.1.24 aLldpXdot3LocRxTwSys

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A GET attribute that returns the value of $T_{w_sys_tx}$ that the local system is requesting in the receive direction. This attribute maps to the variable LocRxSystemValue as defined in 78.4.2.3;

30.12.2.1.25 aLldpXdot3LocRxTwSysEcho

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A GET attribute that returns the value of $T_{w_sys_tx}$ that the remote system is advertising that it is requesting in the receive direction and is echoed by the local system under the control of the EEE DLL transmitter state diagram. This attribute maps to the variable LocRxSystemValueEcho as defined in 78.4.2.3;

30.12.2.1.26 aLldpXdot3LocFbTwSys

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A GET attribute that returns the value of the fallback $T_{w_sys_tx}$ that the local system is advertising to the remote system. This attribute maps to the variable LocFbSystemValue as defined in 78.4.2.3;

30.12.2.1.27 aLldpXdot3TxDllReady

ATTRIBUTE

APPROPRIATE SYNTAX:
A BOOLEAN value:

FALSE:	Local system has not completed initialization of the EEE transmit Data Link Layer management function and is not ready to receive/transmit an LLDPDU containing a EEE TLV.

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TRUE: Local system has initialized the EEE transmit Data Link Layer management function and is ready to receive/transmit an LLDPDU containing a EEE TLV.

BEHAVIOUR DEFINED AS:

A GET operation returns the initialization status of the EEE transmit Data Link Layer management function on the local system.;

30.12.2.1.28 aLldpXdot3RxDllReady

ATTRIBUTE

APPROPRIATE SYNTAX:

A BOOLEAN value:

FALSE: Local system has not completed initialization of the EEE receive Data Link Layer management function and is not ready to receive/transmit an LLDPDU containing a EEE TLV.

TRUE: Local system has initialized the EEE receive Data Link Layer management function and is ready to receive/transmit an LLDPDU containing a EEE TLV.

BEHAVIOUR DEFINED AS:

A GET operation returns the initialization status of the EEE receive Data Link Layer management function on the local system.;

30.12.2.1.29 aLldpXdot3LocDllEnabled

ATTRIBUTE

APPROPRIATE SYNTAX:

A BOOLEAN value:

FALSE: Local system has not completed auto-negotiation with a link partner that has indicated at least one EEE capability.

TRUE: Local system has completed auto-negotiation with a link partner that has indicated at least one EEE capability.

BEHAVIOUR DEFINED AS:

A GET operation returns the status of the EEE capability negotiation on the local system.;

30.12.2.1.30 aLldpXdot3LocTxFw

ATTRIBUTE

APPROPRIATE SYNTAX:

BOOLEAN

BEHAVIOUR DEFINED AS:

A GET attribute that returns the value of LPI_FW that the local system can support in the transmit direction. This attribute maps to the variable LocTxSystemFW as defined in 78.4.2.3;

30.12.2.1.31 aLldpXdot3LocTxFwEcho

ATTRIBUTE

APPROPRIATE SYNTAX:

BOOLEAN

BEHAVIOUR DEFINED AS:

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A GET attribute that returns the value of LPI_FW that the remote system is advertising that it can support in the transmit direction and is echoed by the local system under the control of the EEE DLL receiver state diagram. This attribute maps to the variable LocTxSystemFWEcho as defined in 78.4.2.3;

30.12.2.1.32 aLldpXdot3LocRxFw

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
A GET attribute that returns the value of LPI_FW that the local system is requesting in the receive direction. This attribute maps to the variable LocRxSystemFW as defined in 78.4.2.3;

30.12.2.1.33 aLldpXdot3LocRxFwEcho

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
A GET attribute that returns the value of LPI_FW that the remote system is advertising that it is requesting in the receive direction and is echoed by the local system under the control of the EEE DLL transmitter state diagram. This attribute maps to the variable LocRxSystemFWEcho as defined in 78.4.2.3;

30.12.3 LLDP Remote System Group managed object class

This subclause formally defines the behaviours for the oLldpXdot3RemSystemsGroup managed object class attributes.

30.12.3.1 LLDP Remote System Group attributes

30.12.3.1.1 aLldpXdot3RemPortAutoNegSupported

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
A read-only Boolean value used to indicate whether the given port (associated with the remote system) supports Auto-negotiation.;

30.12.3.1.2 aLldpXdot3RemPortAutoNegEnabled

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
A read-only Boolean value used to indicate whether port Auto-negotiation is enabled on the given port associated with the remote system.;

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30.12.3.1.3 aLldpXdot3RemPortAutoNegAdvertisedCap

ATTRIBUTE

APPROPRIATE SYNTAX:
OCTET STRING [SIZE (2)]

BEHAVIOUR DEFINED AS:
A read-only 2-octet value that contains the value (bitmap) of the ifMauAutoNegCapAdvertisedBits object (defined in IETF RFC 4836) which is associated with the given port on the remote system.;

30.12.3.1.4 aLldpXdot3RemPortOperMauType

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A read-only 32-bit integer value that indicates the operational MAU type of the given port on the remote system.

This object contains an integer value derived from the list position of the corresponding dot3MauType as listed in IETF RFC 4836 (or subsequent revisions) and is equal to the last number in the respective dot3MauType OID.

For example, if the ifMauType object is dot3MauType1000BaseTHD which corresponds to {dot3MauType 29}, the numerical value of this field is 29. For MAU types not listed in IETF RFC 4836 (or subsequent revisions), the value of this field shall be set to zero.;

30.12.3.1.5 aLldpXdot3RemPowerPortClass

ATTRIBUTE

APPROPRIATE SYNTAX:
An ENUMERATED VALUE that has one of the following entries:
pClassPSE PSE
pClassPD PD

BEHAVIOUR DEFINED AS:
A read-only value that identifies the port Class of the given port associated with the remote system.;

30.12.3.1.6 aLldpXdot3RemPowerMDISupported

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
A read-only Boolean value used to indicate whether the MDI power is supported on the given port associated with the remote system.;

30.12.3.1.7 aLldpXdot3RemPowerMDIEnabled

ATTRIBUTE

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APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
A read-only Boolean value used to identify whether MDI power is enabled on the given port associated with the remote system.;

30.12.3.1.8 aLldpXdot3RemPowerPairControlable

ATTRIBUTE

APPROPRIATE SYNTAX:
BOOLEAN

BEHAVIOUR DEFINED AS:
A read-only Boolean value is derived from the value of pethPsePortPowerPairsControlAbility object (defined in IETF RFC 3621) and is used to indicate whether the pair selection can be controlled on the given port associated with the remote system.;

30.12.3.1.9 aLldpXdot3RemPowerPairs

ATTRIBUTE

APPROPRIATE SYNTAX:
The same as used for aPSEPowerPairs

BEHAVIOUR DEFINED AS:
A read-only the value that contains the value of the pethPsePortPowerPairs object (defined in IETF RFC 3621) which is associated with the given port on the remote system.;

30.12.3.1.10 aLldpXdot3RemPowerClass

ATTRIBUTE

APPROPRIATE SYNTAX:
The same as used for aPSEPowerClassification

BEHAVIOUR DEFINED AS:
A read-only the value that contains the value of the pethPsePortPowerClassifications object (defined in IETF RFC 3621) which is associated with the given port on the remote system.;

30.12.3.1.11 aLldpXdot3RemLinkAggStatus

ATTRIBUTE

APPROPRIATE SYNTAX:
BITSTRING

BEHAVIOUR DEFINED AS:
The bitmap value which contains the link aggregation capabilities and the current aggregation status of the link (see 79.3.3.1).;

30.12.3.1.12 aLldpXdot3RemLinkAggPortId

ATTRIBUTE

APPROPRIATE SYNTAX:
The same as used for aAggPortID

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BEHAVIOUR DEFINED AS:

This object contains the IEEE 802.3 aggregated port identifier, aAggPortID (see 30.7.2.1.1), derived from the ifNumber of the ifIndex for the port component in link aggregation.

If the port is not in link aggregation state and/or it does not support link aggregation, this value should be set to zero.;

30.12.3.1.13 aLldpXdot3RemMaxFrameSize

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

An integer value indicating the maximum supported frame size in octets on the given port of the remote system.;

30.12.3.1.14 aLldpXdot3RemPowerType

ATTRIBUTE

APPROPRIATE SYNTAX:

BIT STRING [SIZE (2)]

BEHAVIOUR DEFINED AS:

A GET attribute that returns a bit string indicating whether the remote system is a PSE or a PD and whether it is Type 1 or Type 2. The first bit indicates Type 1 or Type 2. The second bit indicates PSE or PD.;

30.12.3.1.15 aLldpXdot3RemPowerSource

ATTRIBUTE

APPROPRIATE SYNTAX:

BIT STRING [SIZE (2)]

BEHAVIOUR DEFINED AS:

A GET attribute that returns a bit string indicating the power sources of the remote system. When the remote system is a PSE, it indicates whether it is being powered by a primary power source; a backup power source; or unknown. When the remote system is a PD, it indicates whether it is being powered by a PSE and locally; locally only; by a PSE only; or unknown.;

30.12.3.1.16 aLldpXdot3RemPowerPriority

ATTRIBUTE

APPROPRIATE SYNTAX:

An ENUMERATED value list that has the following entries:

low	low priority PD
high	high priority PD
critical	critical priority PD
unknown	priority unknown

BEHAVIOUR DEFINED AS:

A GET operation returns the priority of the PD system received from the remote system. For a PSE, this is the priority that the remote system requests from the PSE. For a PD, this is the priority that the remote system has assigned to the PD.;

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30.12.3.1.17 aLldpXdot3RemPDRequestedPowerValue

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A GET attribute that returns the PD requested power value that was used by the remote system to compute the power value that is has currently allocated to the PD. For a PSE, it is the PD requested power value received from the remote system. The definition and encoding of PD requested power value is the same as described in aLldpXdot3LocPDRequestedPowerValue (30.12.2.1.17).;

30.12.3.1.18 aLldpXdot3RemPSEAllocatedPowerValue

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A GET attribute that returns the PSE allocated power value received from the remote system. For a PSE, it is the PSE allocated power value that was used by the remote system to compute the power value that it has currently requested from the PSE. For a PD, it is the PSE allocated power value received from the remote system. The definition and encoding of PSE allocated power value is the same as described in aLldpXdot3LocPSEAllocatedPowerValue (30.12.2.1.18).;

30.12.3.1.19 aLldpXdot3RemTxTwSys

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A GET attribute that returns the value of $T_{w_sys_tx}$ that the remote system can support in the transmit direction. This attribute maps to the variable RemTxSystemValue as defined in 78.4.2.3;

30.12.3.1.20 aLldpXdot3RemTxTwSysEcho

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
A GET attribute that returns the value of $T_{w_sys_tx}$ that the local system is advertising that it can support in the transmit direction as echoed by the remote system under the control of the EEE DLL receiver state diagram. This attribute maps to the variable RemTxSystemValueEcho as defined in 78.4.2.3;

30.12.3.1.21 aLldpXdot3RemRxTwSys

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

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BEHAVIOUR DEFINED AS:

A GET attribute that returns the value of $T_{w_sys_tx}$ that the remote system is requesting in the receive direction. This attribute maps to the variable RemRxSystemValue as defined in 78.4.2.3;

30.12.3.1.22 aLldpXdot3RemRxTwSysEcho

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

A GET attribute that returns the value of $T_{w_sys_tx}$ that the local system is advertising that it is requesting in the receive direction as echoed by the remote system under the control of the EEE DLL transmitter state diagram. This attribute maps to the variable RemRxSystemValueEcho as defined in 78.4.2.3;

30.12.3.1.23 aLldpXdot3RemFbTwSys

ATTRIBUTE

APPROPRIATE SYNTAX:

INTEGER

BEHAVIOUR DEFINED AS:

A GET attribute that returns the value of fallback $T_{w_sys_tx}$ that the remote system is advertising. This attribute maps to the variable RemFbSystemValue as defined in 78.4.2.3;

30.12.3.1.24 aLldpXdot3RemTxFw

ATTRIBUTE

APPROPRIATE SYNTAX:

BOOLEAN

BEHAVIOUR DEFINED AS:

A GET attribute that returns the value of LPI_FW that the remote system can support in the transmit direction. This attribute maps to the variable RemTxSystemFW as defined in 78.4.2.3;

30.12.3.1.25 aLldpXdot3RemTxFwEcho

ATTRIBUTE

APPROPRIATE SYNTAX:

BOOLEAN

BEHAVIOUR DEFINED AS:

A GET attribute that returns the value of LPI_FW that the local system is advertising that it can support in the transmit direction as echoed by the remote system under the control of the EEE DLL receiver state diagram. This attribute maps to the variable RemTxSystemFWEcho as defined in 78.4.2.3;

30.12.3.1.26 aLldpXdot3RemRxFw

ATTRIBUTE

APPROPRIATE SYNTAX:

BOOLEAN

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BEHAVIOUR DEFINED AS:

A GET attribute that returns the value of LPI_FW that the remote system is requesting in the receive direction. This attribute maps to the variable RemRxSystemFW as defined in 78.4.2.3;

30.12.3.1.27 aLldpXdot3RemRxFwEcho

ATTRIBUTE

APPROPRIATE SYNTAX:

BOOLEAN

BEHAVIOUR DEFINED AS:

A GET attribute that returns the value of LPI_FW that the local system is advertising that it is requesting in the receive direction as echoed by the remote system under the control of the EEE DLL transmitter state diagram. This attribute maps to the variable RemRxSystemFWEcho as defined in 78.4.2.3;

30.13 Management for oTimeSync entity

If the optional TimeSync function is implemented, then the oTimeSync managed object class shall be implemented in its entirety. All attributes of this managed object class are mandatory. TimeSync management is optional with respect to all other CSMA/CD management.

30.13.1 TimeSync entity managed object class

This subclause formally defines the behaviours for the oTimeSync managed object class attributes.

30.13.1.1 aTimeSyncCapabilityTX

ATTRIBUTE

APPROPRIATE SYNTAX:

BOOLEAN

BEHAVIOUR DEFINED AS:

True if the TimeSync capability is supported in the transmit path and false otherwise.
If a Clause 45 MDIO Interface to PMA/PMD, WIS, PCS, PHY XS, DTE XS and/or TC is present, then the value stored in this attribute is equal to the logical OR operation over the values stored in the following instantiated MDIO registers (for each MMD, in case of multiple instances) 1.1800.1, 2.1800.1, 3.1800.1, 4.1800.1, 5.1800.1, and 6.1800.1 (see 45.2.1.128, 45.2.2.20, 45.2.3.48, 45.2.4.12, 45.2.5.12, 45.2.6.14, respectively).

30.13.1.2 aTimeSyncCapabilityRX

ATTRIBUTE

APPROPRIATE SYNTAX:

BOOLEAN

BEHAVIOUR DEFINED AS:

True if the TimeSync capability is supported in the receive path and false otherwise.
If a Clause 45 MDIO Interface to PMA/PMD, WIS, PCS, PHY XS, DTE XS and/or TC is present, then the value stored in this attribute is equal to the logical OR operation over the values stored in the following instantiated MDIO registers (for each MMD, in case of multiple instances) 1.1800.0, 2.1800.0, 3.1800.0, 4.1800.0, 5.1800.0, and 6.1800.0 (see 45.2.1.128, 45.2.2.20, 45.2.3.48, 45.2.4.12, 45.2.5.12, 45.2.6.14, respectively).

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30.13.1.3 aTimeSyncDelayTXmax

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The maximum data delay as specified in 90.7, expressed in units of ns.
If a Clause 45 MDIO Interface to PMA/PMD, WIS, PCS, PHY XS, DTE XS and/or TC is present, then the value stored in this attribute represents the maximum transmit path data delay values, consisting of the sum of the values of the registers in the instantiated sublayers (for each MMD, in case of multiple instances):

— for PMA/PMD: 1.1801 and 1.1802, see 45.2.1.129
— for WIS: 2.1801 and 2.1802, see 45.2.2.21
— for PCS: 3.1801 and 3.1802, see 45.2.3.49
— for PHY XS: 4.1801 and 4.1802, see 45.2.4.13
— for DTE XS: 5.1801 and 5.1802, see 45.2.5.13
— for TC: 6.1801 and 6.1802, see 45.2.6.15

30.13.1.4 aTimeSyncDelayTXmin

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The minimum data delay as specified in 90.7, expressed in units of ns.
If a Clause 45 MDIO Interface to PMA/PMD, WIS, PCS, PHY XS, DTE XS and/or TC is present, then the value stored in this attribute represents the minimum transmit path data delay values, consisting of the sum of the values of the registers in the instantiated sublayers (for each MMD, in case of multiple instances):

— for PMA/PMD: 1.1803 and 1.1804, see 45.2.1.129
— for WIS: 2.1803 and 2.1804, see 45.2.2.21
— for PCS: 3.1803 and 3.1804, see 45.2.3.49
— for PHY XS: 4.1803 and 4.1804, see 45.2.4.13
— for DTE XS: 5.1803 and 5.1804, see 45.2.5.13
— for TC: 6.1803 and 6.1804, see 45.2.6.15

30.13.1.5 aTimeSyncDelayRXmax

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The maximum data delay as specified in 90.7, expressed in units of ns.
If a Clause 45 MDIO Interface to PMA/PMD, WIS, PCS, PHY XS, DTE XS and/or TC is present, then the value stored in this attribute represents the maximum receive path data delay values, consisting of the sum of the values of the registers in the instantiated sublayers (for each MMD, in case of multiple instances):

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— for PMA/PMD: 1.1805 and 1.1806, see 45.2.1.130
— for WIS: 2.1805 and 2.1806, see 45.2.2.22
— for PCS: 3.1805 and 3.1806, see 45.2.3.50
— for PHY XS: 4.1805 and 4.1806, see 45.2.4.14
— for DTE XS: 5.1805 and 5.1806, see 45.2.5.14
— for TC: 6.1805 and 6.1806, see 45.2.6.16

30.13.1.6 aTimeSyncDelayRXmin

ATTRIBUTE

APPROPRIATE SYNTAX:
INTEGER

BEHAVIOUR DEFINED AS:
The minimum data delay as specified in 90.7, expressed in units of ns.
If a Clause 45 MDIO Interface to to PMA/PMD, WIS, PCS, PHY XS, DTE XS and/or TC is present, then the value stored in this attribute represents the minimum receive path data delay values, consisting of the sum of the values of the registers in the instantiated sublayers (for each MMD, in case of multiple instances):

— for PMA/PMD: 1.1807 and 1.1808, see 45.2.1.130
— for WIS: 2.1807 and 2.1808, see 45.2.2.22
— for PCS: 3.1807 and 3.1808, see 45.2.3.50
— for PHY XS: 4.1807 and 4.1808, see 45.2.4.14
— for DTE XS: 5.1807 and 5.1808, see 45.2.5.14
— for TC: 6.1807 and 6.1808, see 45.2.6.16

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31. MAC Control

31.1 Overview

This clause specifies an optional MAC Control sublayer (MAC Control) for use with the CSMA/CD MAC. MAC Control provides for real-time control and manipulation of MAC sublayer operation. This clause specifies a generalized architecture and protocol for MAC Control. Specific implementations of control functions using this protocol are specified in the normative annexes to this clause. The MAC Control protocol is specified such that it can support new functions to be implemented and added to this standard in the future.

Non-realtime, or quasistatic control (e.g., configuration of MAC operational parameters) is provided by Layer Management.

Operation of the MAC Control sublayer is transparent to the CSMA/CD MAC.

The body of this clause and its associated annexes contain state diagrams, including definitions of variables, constants, and functions. Should there be a discrepancy between a state diagram and descriptive text, the state diagram shall prevail. The notation used in the state diagrams follows the conventions of 21.5.

31.2 Layer architecture

The MAC Control sublayer is a client of the CSMA/CD MAC. Figure 31–1 depicts the architectural positioning of the MAC Control sublayer with respect to the CSMA/CD MAC and the MAC Control client. MAC Control clients may include the Bridge Relay Entity, LLC, or other applications.

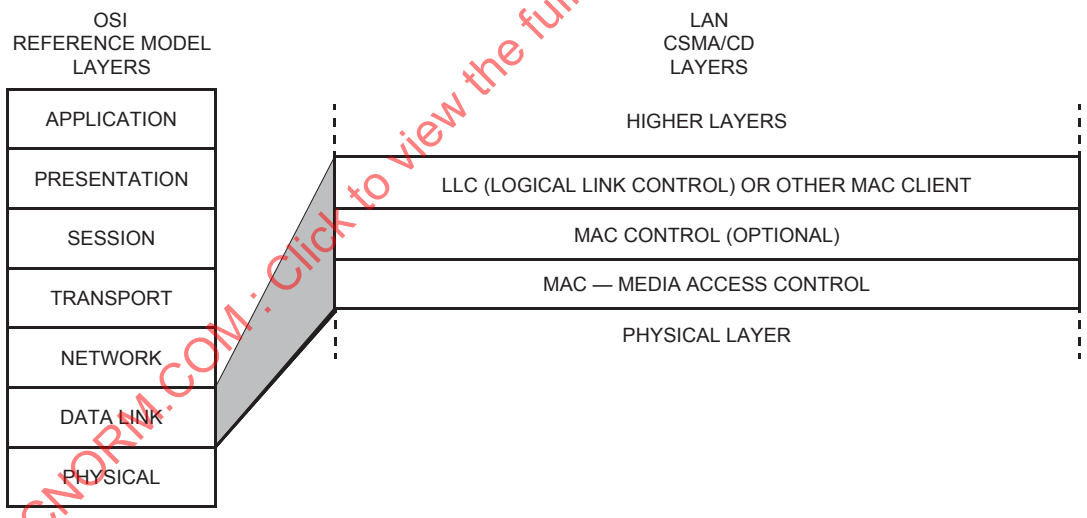

Figure 31–1—Architectural positioning of MAC Control sublayer

31.3 Support by interlayer interfaces

This subclause describes how the MAC Control sublayer uses the MAC service interface specified in Clause 2. The optional MAC Control sublayer is inserted between the MAC sublayer and its MAC client. The MAC Control sublayer uses the MAC service interface to interface to the MAC client and to the MAC.

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Figure 31–2 depicts the usage of interlayer interfaces by the MAC Control sublayer. Devices that implement the MAC Control sublayer shall support the MAC service primitives, MA_CONTROL.request and MA_-CONTROL.indication, as specified in this clause.

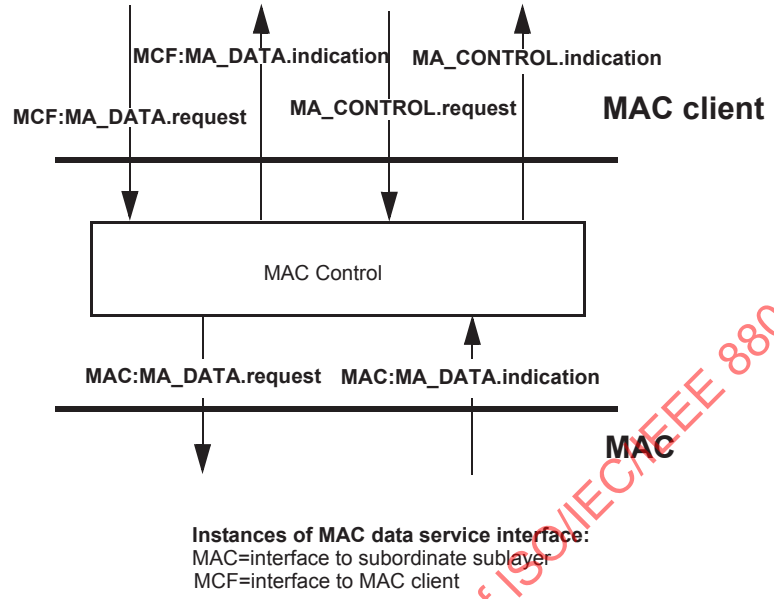

Figure 31–2—MAC Control sublayer support of interlayer service interfaces

Clients of the MAC Control sublayer may generate either MCF:MA_CONTROL.request or MCF:MA_-DATA.request primitives. MA_CONTROL.request primitives generated by MAC clients are interpreted by the MAC Control sublayer, and may result in the generation of MAC:MA_DATA.request calls to the MAC sublayer, or other actions as necessary to support the requested MAC Control sublayer function. Based upon the state of the MAC Control sublayer, MCF:MA_DATA.request primitives may cause the immediate generation of a MAC:MA_DATA.request call to the MAC sublayer, or be delayed, discarded, or modified in order to perform the requested MAC Control function.

All MAC frames validly received by the CSMA/CD MAC are passed to the MAC Control sublayer for interpretation. If the MAC frame is destined for the MAC client, the MAC Control sublayer generates an MCF:MA_DATA.indication primitive, providing complete transparency for normal data exchange between MAC clients. If the MAC frame is destined for the MAC Control sublayer entity, it is interpreted and acted on internal to the MAC Control sublayer. This may result in state changes within the MAC Control sublayer, the generation of MA_CONTROL.indication primitives, or other actions as necessary to support the MAC Control sublayer function. MAC Control sublayer functions shall always sink MAC Control frames.

In the MAC:MA_DATA.indication primitive, MAC frames destined for the MAC Control sublayer (MAC Control frames) are distinguished from MAC frames destined for MAC clients by a unique Length/Type field identifier.

The MAC Control sublayer generates MA_CONTROL.indication primitives to its client, signaling the current value of internal state variables. Each MAC Control function implemented may have its own function-specific state indications.

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31.3.1 MA_CONTROL.request

Implementation of the MA_CONTROL.request primitive is mandatory.

31.3.1.1 Function

This primitive defines the transfer of control commands from a MAC client entity to the local MAC Control sublayer entity.

31.3.1.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
MA_CONTROL.request      (
                        destination_address,
                        opcode,
                        request_operand_list
                        )
```

The destination_address parameter may specify either an individual or a group MAC entity address. It must contain sufficient information to create the DA field that is prepended to the MAC frame by the local MAC sublayer entity. The opcode specifies the control operation requested by the MAC client entity. The request_operand_list is an opcode-specific set of parameters.

The valid opcodes and their respective meanings are defined in Annex 31A.

31.3.1.3 When generated

This primitive is generated by a MAC client whenever it wishes to use the services of the optional MAC Control sublayer entity.

31.3.1.4 Effect of receipt

The effect of receipt of this primitive by the MAC Control sublayer is opcode-specific. (See Annex 31A.)

31.3.2 MA_CONTROL.indication

Implementation of the MA_CONTROL.indication primitive is mandatory.

31.3.2.1 Function

This primitive defines the transfer of control status indications from the MAC Control sublayer entity to the MAC client entity.

31.3.2.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
MA_CONTROL.indication      (
                           opcode,
                           indication_operand_list
                           )
```

The elements of the indication_operand_list are opcode-specific, and specified in Annex 31A.

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31.3.2.3 When generated

The MA_CONTROL.indication is generated by the MAC Control sublayer under conditions specific to each MAC Control operation.

31.3.2.4 Effect of receipt

The effect of receipt of this primitive by the MAC client is not specified in this clause. See the list of MAC control functions in Annex 31A.

31.4 MAC Control frames

MAC Control frames comprise MAC client data for the CSMA/CD MAC, as specified in Clause 3. They are encapsulated by the CSMA/CD MAC; that is, they are prepended by a Preamble and Start-of-Frame delimiter and appended by an FCS.

MAC Control frames are distinguished from other MAC frames only by their Length/Type field identifier.

31.4.1 MAC Control frame format

For any particular implementation of this standard, MAC Control frames are fixed length, containing minFrameSize–32 bits. The underlying MAC prepends the Preamble and Start-of-Frame delimiter fields, and appends the FCS. Figure 31–3 depicts the MAC Control frame format.

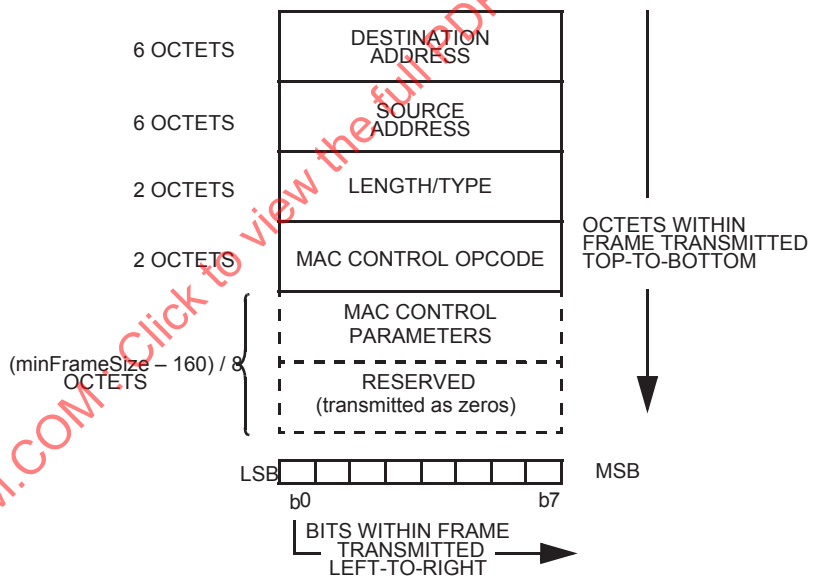

Figure 31–3—MAC Control frame format

31.4.1.1 Destination Address field

The Destination Address field of a MAC Control frame contains the 48-bit address of the station(s) for which the frame is intended. It may be an individual or multicast (including broadcast) address. Permitted values for the Destination Address field may be specified separately for each MAC Control opcode in the annexes to Clause 31.

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31.4.1.2 Source Address field

The Source Address field of a MAC Control frame contains the 48-bit individual address of the station sending the frame.

31.4.1.3 Length/Type field

The Length/Type field of a MAC Control frame is a 2-octet field that shall contain the hexadecimal value: 88-08. This value carries the Ethertype interpretation (see 3.2.6), and has been universally assigned for MAC Control of CSMA/CD LANs.

31.4.1.4 MAC Control Opcode field

The MAC Control Opcode field shall contain a 2-octet operation code indicating the MAC Control function. It defines the semantics of the MAC Control Parameters field specified in 31.4.1.5. Annex 31A contains the list of defined MAC Control opcodes and interpretations.

A MAC Control frame shall contain exactly one MAC Control opcode.

31.4.1.5 MAC Control Parameters field

The MAC Control Parameters field shall contain MAC Control opcode-specific parameters. This field may contain none, one, or more parameters as defined by the MAC Control Opcode. The opcode-specific semantics of the MAC Control Parameters field are defined in the normative annex specifying each MAC Control function.

The MAC Control Parameters field shall contain an integral number of octets. The length of the MAC Control Parameters field varies from a minimum of zero, to a maximum of minFrameSize –160 bits. See 4.2.3.3 for a discussion of minFrameSize.

31.4.1.6 Reserved field

The Reserved field is used when the MAC Control parameters do not fill the fixed length MAC Control frame. The size of the Reserved field, if any, is determined by the size of the MAC Control Parameters field supplied by MAC Control and the minimum frame size parameter of the particular implementation.

The length of Reserved field required for a MAC Control Parameters field that is n octets long is [minFrameSize – ($8 \times n$ + 160)] bits. See 4.2.3.3 for a discussion of minFrameSize. The Reserved field is transmitted as all zeros.

31.5 Opcode-independent MAC Control sublayer operation

The MAC passes to the MAC Control sublayer all valid MAC frames via the MA_DATA.indication primitive. Invalid MAC frames are not passed to the MAC Control sublayer (see 3.4).

31.5.1 Frame parsing and data frame reception

Upon receipt, the MAC Control sublayer parses the incoming MAC frame to determine whether it is destined for the MAC client (data frame) or for a specific function within the MAC Control sublayer entity itself (MAC Control frame). MAC Control frames with a length of minFrameSize and a supported opcode field are interpreted and acted upon by the MAC Control sublayer.

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A MAC frame that does not contain the unique Length/Type field specified in 31.4.1.3 is a data frame. The receipt of a data frame results in the generation of a MCF:MA_DATA.indication primitive by the MAC Control sublayer, with its parameters identical to the MAC:MA_DATA.indication primitive.

NOTE—For Length/Type field values in the range between maxBasicDataSize and minTypeValue, the behavior of the RemovePad function in the underlying MAC sublayer is unspecified. Frames with Length/Type field values in this range may or may not be passed up by the MAC sublayer.

MAC Control frames with a length greater than minFrameSize and a supported opcode field may be either discarded, or truncated to minFrameSize, interpreted, and acted upon. Unsupported MAC Control frames are discarded. Discarded frames are neither interpreted nor acted upon by the MAC Control sublayer.

31.5.2 Control frame reception

Validly received MAC Control frames are further parsed to determine the opcode. The location of the opcode within a valid MAC Control frame and its format are specified in 31.4.1.4 and Figure 31–3. If the MAC Control sublayer entity supports the function requested by the specified opcode, it interprets and acts upon the MAC Control frame in an opcode- and request_operand-specific manner. (See Annex 31A.) This action may change the state of the MAC Control sublayer, affecting its behavior with respect to data transmission requests by the MAC client, future control frame receptions, or control indications to the MAC client.

If the MAC Control sublayer entity does not support the function requested by the specified opcode, it discards the MAC Control frame. The discard of a frame in this manner may be reported to network management.

31.5.3 Opcode-independent MAC Control receive state diagram

The MAC Control sublayer shall implement the Receive state diagram specified in this subclause.

31.5.3.1 Constants

802.3_MAC_Control
: The 16-bit Length/Type field value reserved for CSMA/CD MAC Control usage, specified in 31.4.1.3.

31.5.3.2 Variables

receiveEnabled
: A Boolean set by Network Management to indicate that the station is permitted to receive from the network.
  Values: true; Receiver is enabled by management
  false; Receiver is disabled by management

DA
: The destination address field parsed from the received frame.

SA
: The source address field parsed from the received frame.

lengthOrType
: The lengthOrType field parsed from the received frame.

data
: The data payload field parsed from the received frame.

fcs
: The fcs field parsed from the received frame.

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fcsPresent
: A Boolean set by the MAC sublayer. See 4.3.2.

mac_service_data_unit
: The concatenation of lengthOrType, data.

ReceiveStatus
: Indicates the status of the received frame. See 4.3.2.

opcode
: The MAC Control opcode field parsed from the received frame.

31.5.3.3 Messages

MA_DATA.indication

The service primitive used to pass a validly received MAC frame between the MAC and the MAC Control sublayers, or between the MAC Control sublayer and the MAC client. When generated by the MAC sublayer, this message is used by the MAC Control Receive state diagram as the condition for transition between WAIT FOR RX and CHECK TYPE states. While in the PASS TO CLIENT state, the MAC Control Receive state diagram generates this message to the MAC client.

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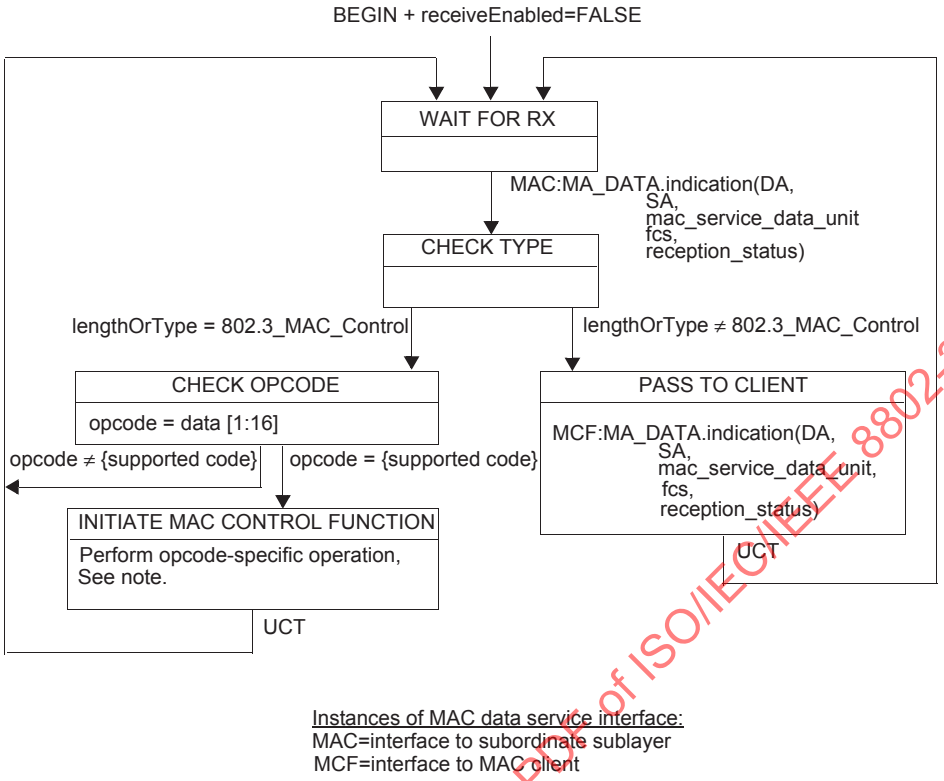
31.5.3.4 Opcode-independent MAC Control Receive state diagram



NOTE—The opcode-specific operation (see Annex 31A) is launched as a parallel process by the MAC Control sublayer, and not as a synchronous function. Progress of the generic MAC Control Receive state diagram (as shown in this figure) is not implicitly impeded by the launching of the opcode-specific function.

Figure 31–4—Generic MAC Control Receive state diagram

The functions performed in the INITIATE MAC CONTROL FUNCTION state are opcode-specific (see Annex 31A).

31.6 Compatibility requirements

An instantiation of the MAC Control sublayer is not required to implement all valid control functions specified in Annex 31A.

31.7 MAC Control client behavior

The MAC Control sublayer uses the services of the underlying connectionless-mode MAC sublayer to exchange both Data and Control frames. The MAC Control sublayer does not provide any mechanism for recovery from lost, discarded, damaged, or delayed frames. It is the responsibility of the MAC Control client to implement mechanisms for dealing with lost, discarded, damaged, and delayed frames, if necessary.

Since implementation of the MAC Control sublayer is optional, a MAC Control client cannot assume the existence of a MAC Control sublayer entity in a peer DTE.

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31.8 Protocol implementation conformance statement (PICS) proforma for Clause 31, MAC Control[12]

31.8.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 31, the optional MAC Control sublayer, shall complete the following PICS proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

31.8.2 Identification

31.8.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations, other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

31.8.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-201x, Clause 31, MAC Control
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; The answer Yes means that the implementation does not conform to IEEE Std 802.3-201x.)	

Date of Statement	

[12] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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31.8.3 PICS proforma for MAC Control frames

31.8.3.1 Support by interlayer interfaces

Item	Feature	Subclause	Value/Comment	Status	Support
SI1	Support for MAC service primitives, MA_-CONTROL.request and MA_CON-TROL.indication	31.3	Required	M	Yes [ ]

31.8.3.2 MAC Control frame format

Item	Feature	Subclause	Value/Comment	Status	Support
FF1	Length/Type field	31.4.1.3	2-octet field containing 88-08	M	Yes [ ]
FF2	MAC Control opcode	31.4.1.4	2-octet operation code	M	Yes [ ]
FF3	Number of opcodes	31.4.1.4	1	M	Yes [ ]
FF4	MAC Control parameters	31.4.1.5	MAC Control Parameter field as described	M	Yes [ ]

31.8.3.3 Opcode-independent MAC Control sublayer operation

Item	Feature	Subclause	Value/Comment	Status	Support
SD1	Generic MAC Control receive state diagram	31.5.3	Meets requirements of Figure 31–4	M	Yes [ ]
SD2	MAC Control frame action	31.3	Sink MAC Control frames	M	Yes [ ]

31.8.3.4 Control opcode assignments

Item	Feature	Subclause	Value/Comment	Status	Support
COA1	Opcode values and interpretations	31A	Reserved opcodes not used	M	Yes [ ]

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32. Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer and baseband medium, type 100BASE-T2

NOTE—This PHY is not recommended for new installations. Since September 2003, maintenance changes are no longer being considered for this clause.

32.1 Overview

The 100BASE-T2 PHY is one of the 100BASE-T family of high-speed CSMA/CD network specifications. The 100BASE-T2 Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA), and baseband medium specifications are aimed at users who want 100 Mb/s performance over basic data grade Category 3 twisted-pair cabling systems. 100BASE-T2 signaling requires two pairs of Category 3 cabling, or cabling with better transfer characteristics than Category 3, installed according to ISO/IEC 11801, as specified in 32.7. This type of cabling, and the connectors used with it, are simple to install and reconfigure.

This clause defines the type 100BASE-T2 PCS, type 100BASE-T2 PMA sublayer, and type 100BASE-T2 Medium Dependent Interface (MDI). Together, the PCS and the PMA sublayer comprise a 100BASE-T2 Physical Layer (PHY). Control actions needed for correct PHY operations are specified by the 100BASE-T2 PHY Control function. Provided in this document are full functional, electrical, and mechanical specifications for the type 100BASE-T2 PHY Control function, PCS, PMA, and MDI. This clause also specifies the baseband medium used with 100BASE-T2.

The objectives of 100BASE-T2 are as follows:

a) To support the CSMA/CD MAC;

b) To support the 100BASE-T Media Independent Interface (MII), repeater, and Auto-Negotiation;

c) To support full duplex operations (Clause 31);

d) To provide 100 Mb/s data rate at the MII;

e) To provide for operating over two pairs of Category 3, 4, or 5 balanced twisted-pair cabling systems installed in accordance with ISO/IEC 11801, as specified in 32.7, at distances up to 100 m;

f) To support operation of other applications on adjacent pairs;

g) To allow for a nominal network extent of 200 m including

   1) Balanced cabling links of 100 m to support both half duplex and full duplex operation and

   2) Two-repeater networks of approximately 200 m span;

h) To provide a communication channel with a symbol error ratio of less than one part in 10^{10} at the PMA service interface.

32.1.1 Relation of 100BASE-T2 to other standards

Relations between the 100BASE-T2 PHY and the ISO/IEC Open Systems Interconnection (OSI) Reference Model and the IEEE 802.3 CSMA/CD LAN Model are shown in Figure 32–1. The PHY layers shown in Figure 32–1 connect one Clause 4 Media Access Control (MAC) layer to a Clause 27 repeater. This clause also discusses other variations of the basic configuration shown in Figure 32–1. This whole clause builds on Clauses 1, 2, 3, 4, 21, 22, 27, 28, 29, and 30 of this standard.

32.1.2 Operation of 100BASE-T2

The 100BASE-T2 PHY employs dual-duplex baseband transmission over two wire pairs BI_DA and BI_DB, whereby the aggregate data rate of 100 Mb/s is achieved by transmission at a modulation rate of

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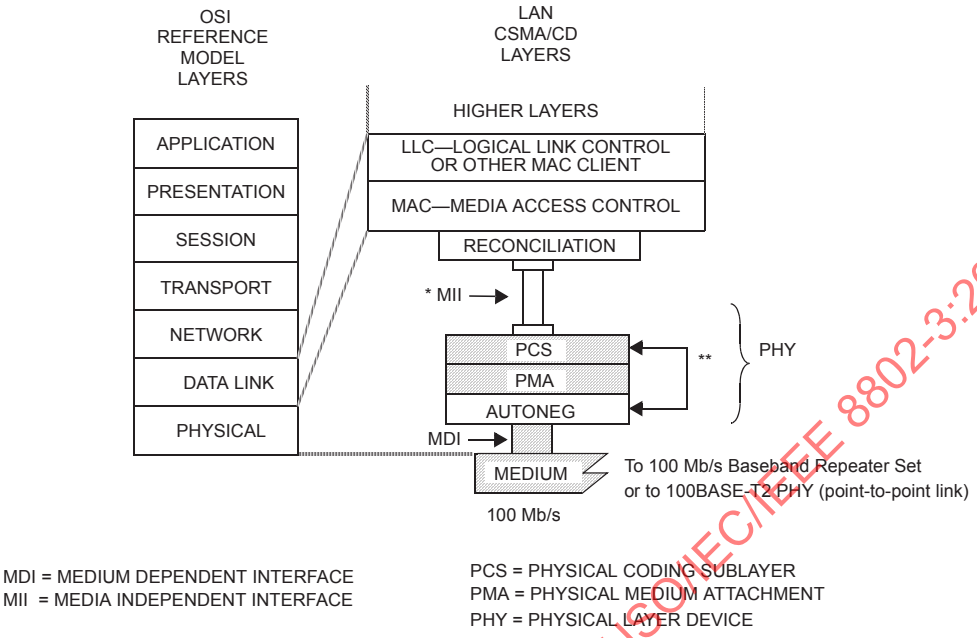

NOTE 1—* MII is optional.

NOTE 2—** AUTONEG communicates with the PMA sublayer through the PMA service interface messages PMA_LINK.request and PMA_LINK.indication.

Figure 32–1—Type 100BASE-T2 PHY relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

25 MBd over each wire pair in each direction simultaneously (full duplex transmission), as shown in Figure 32–2. Transmitted symbols are selected from the two-dimensional 5 × 5 symbol constellation illustrated in Figure 32–3. Redundancy in the 5 × 5 constellation allows specific encoding rules to be employed to represent MII data streams, an idle mode or control signals as sequences of two-dimensional symbols. Each two-dimensional symbol can be viewed as a pair (A_n, B_n) of one-dimensional quinary symbols taken from the set {–2, –1, 0, +1, +2}. Five-level Pulse Amplitude Modulation is employed for transmission over each wire pair (PAM 5 × 5). The modulation rate of 25 MBd matches the MII clock rate of 25 MHz. The corresponding symbol period is 40 ns. This specification permits the use of Category 3, 4, or 5 balanced cabling, installed according to ISO/IEC 11801, as defined in 32.7.

A 100BASE-T2 PHY can be configured either as a *master* PHY or as a *slave* PHY. The master-slave relationship between two stations sharing a link segment is established during Auto-Negotiation (see Clause 28, 32.5, Annex 28C, and 32.5.2). The master PHY uses an external clock to determine the timing of transmitter and receiver operations. The slave PHY recovers the clock from the received signal and uses it to determine the timing of transmitter operations, i.e., it performs loop timing, as illustrated in Figure 32–2. In a DTE to repeater connection, the repeater is typically set to be master and the DTE is typically set to be slave.

The following subclauses summarize the PCS, PMA, and PHY Control sections of this document. Figure 32–4 shows the division of responsibilities between the PCS, the PMA sublayer, and the PHY Control function.

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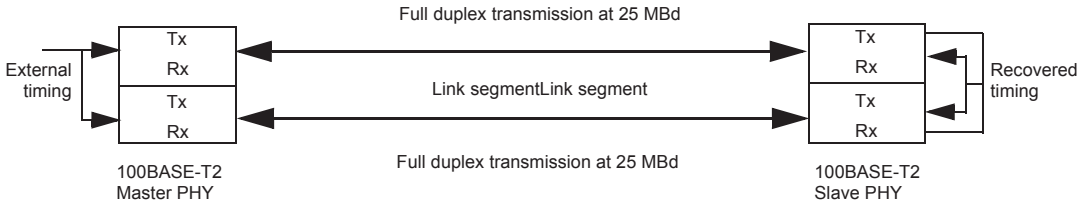

Figure 32–2—100BASE-T2 topology

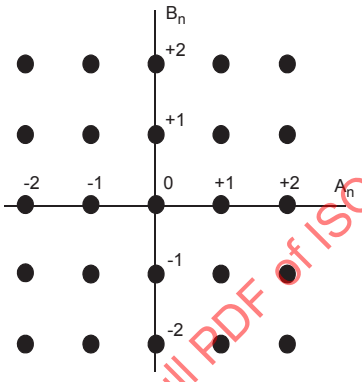

Figure 32–3—PAM5×5 symbol constellation

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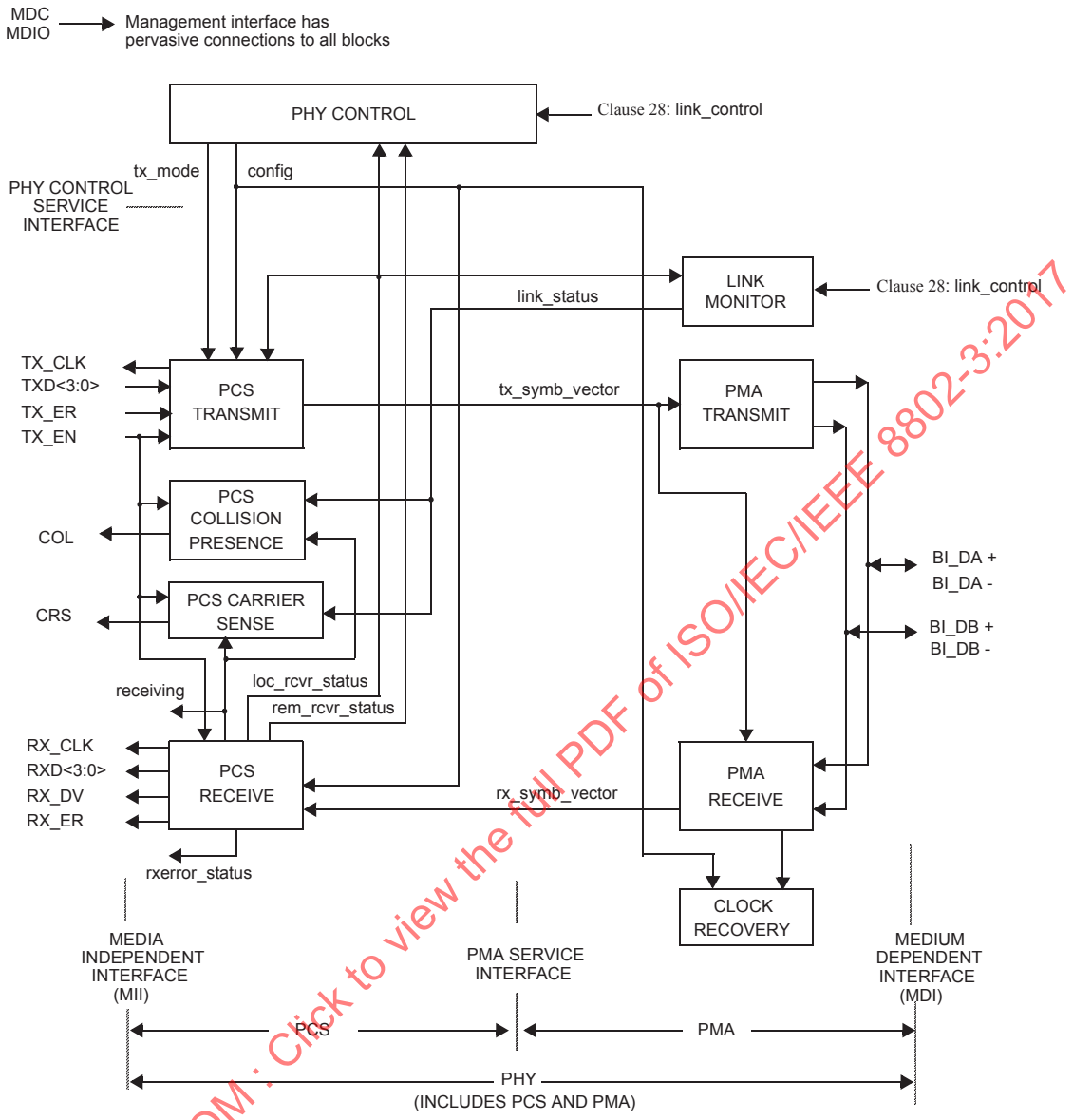

Figure 32–4—Division of responsibilities between 100BASE-T2 PCS, PMA, and PHY Control

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32.1.2.1 Physical coding sublayer (PCS)

The 100BASE-T2 PCS couples an MII, as described in Clause 22, to a PMA sublayer.

The functions performed by the PCS comprise the generation of continuous quinary symbol sequences to be transmitted over each wire pair. During *data mode*, i.e., when a data stream from the MII is transmitted, the four bits representing the TXD<3:0> data nibble are scrambled by a side-stream scrambler and encoded into a pair of quinary symbols. During *idle mode*, i.e., between transmission of consecutive data streams, the sequences of quinary symbols are generated with an encoding rule that differs from the encoding rule used in data mode. Through this technique, sequences of arbitrary quinary symbols that represent data can easily be distinguished from sequences that represent the idle mode. Furthermore, idle mode encoding takes into account the information of whether the local PHY is operating reliably or not and allows conveying this information to the remote station. A transition from the idle to the data mode is signaled by inserting a Start-of-Stream delimiter that consists of a pattern of two consecutive pairs of quinary symbols. Similarly, the end of a data stream transmission is signaled by inserting an End-of-Stream delimiter that also consists of a pattern of two consecutive pairs of quinary symbols. Further patterns are reserved for signaling a transmit error during transmission of a data stream.

PCS Receive processes pairs of quinary symbols provided by the PMA. It detects the beginning and the end of streams of data and, during the reception of a data stream, descrambles and decodes the received quinary symbol pairs into nibbles RXD<3:0> that are passed to the MII. PCS Receive also detects errors in the received sequences and signals them to the MII. Furthermore, the PCS contains a PCS Carrier Sense function, a PCS Collision Presence function, and a management interface.

The PCS functions and state diagrams are specified in 32.3. The signals provided by the PCS at the MII conform to the interface requirements of Clause 22. The PCS interfaces to PHY Control and to the PMA are abstract message-passing interfaces specified in 32.2 and 32.4, respectively.

32.1.2.2 PMA sublayer

The PMA couples messages from the PMA service interface onto the balanced cabling physical medium. The PMA provides dual-duplex communications at 25 MBd over two pairs of balanced cabling up to 100 m in length.

The PMA Transmit function comprises two independent transmitters to generate five-level pulse-amplitude modulated signals on each of the two pairs BI_DA and BI_DB, as described in 32.4.1.1.2.

The PMA Receive function comprises two independent receivers for five-level pulse-amplitude modulated signals on each of the two pairs BI_DA and BI_DB, as described in 32.4.1.1.3. The receivers are responsible for acquiring clock, and providing quinary symbol pairs to the PCS as defined by the PMA_UNITDATA.indication message. The PMA also contains functions for Link Monitor.

PMA functions and state diagrams are specified in 32.4. PMA electrical specifications are given in 32.6.

32.1.2.3 PHY Control function

PCS and PMA sublayer operations are controlled via signals generated by the PHY Control function. PHY Control does not itself represent a sublayer but rather a logical grouping of the control functions necessary for proper operations of a 100BASE-T2 transceiver.

PHY Control determines whether the PHY should operate in a normal state, where packets can be exchanged over the link segment, or whether the PHY should be forced to send quinary symbol sequences that represent the idle mode. The latter occurs when either one of the PHYs, or both PHYs, that share a link segment are not operating reliably.

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The PHY Control function and state diagram are specified in 32.2, prior to introducing the PCS and PMA functional specifications. The PHY Control interface to the PCS and PMA sublayer is an abstract message-passing interface also specified in 32.2.

32.1.3 Application of 100BASE-T2

32.1.3.1 Compatibility considerations

All implementations of the balanced cabling link shall be compatible at the MDI. The PCS, PMA, and the medium are defined to provide compatibility among devices designed by different manufacturers. Designers are free to implement circuitry within the PCS and PMA in an application-dependent manner provided the MDI and MII specifications are met.

32.1.3.2 Incorporating the 100BASE-T2 PHY into a DTE

When the PHY is incorporated within the physical bounds of a DTE, conformance to the MII is optional, provided that the observable behavior of the resulting system is identical to that of a system with a full MII implementation. For example, an integrated PHY may incorporate an interface between PCS and MAC that is logically equivalent to the MII, but does not have the full output current drive capability called for in the MII specification.

32.1.3.3 Use of 100BASE-T2 PHY for point-to-point communication

The 100BASE-T2 PHY, in conjunction with the MAC specified in Clause 1 through Clause 4 (including parameterized values in 4.4.2 to support 100 Mb/s operation) may be used at both ends of a link for point-to-point applications between two DTEs. Such a configuration does not require a repeater. In this case each PHY may connect through an MII to its respective DTE. Optionally, either PHY (or both PHYs) may be incorporated into the DTEs without an exposed MII.

32.1.3.4 Auto-Negotiation requirement

Full Auto-Negotiation, as specified in Clause 28, shall be included in all compliant implementations.

32.1.4 State diagram conventions

The body of this clause and its associated annexes contain state diagrams, including definitions of variables, constants and functions. Should there be a discrepancy between a state diagram and descriptive text, the state diagram shall prevail. The notation used in the state diagrams follows the conventions of 21.5.

32.2 PHY Control functional specifications and service interface

32.2.1 PHY Control function

PHY Control generates the control actions that are needed to bring the PHY in a mode of operation during which packets can be exchanged with the link partner. PHY Control shall comply with the state diagram description given in Figure 32–5.

During Auto-Negotiation, PHY Control ensures that the transmitter is disabled. When the Auto-Negotiation process asserts link_control=ENABLE, PHY Control enters the TRAINING state. During training, PHY Control enforces transmission in the idle mode by setting tx_mode=SEND_I and the PHY transmits sequences of quinary symbols encoded with the parameter loc_rcvr_status=NOT_OK. When the PHY achieves successful training and establishes proper receiver operations, PCS Receive asserts the parameter loc_rcvr_status=OK, and PCS Transmit conveys this information to the link partner via idle transmission.

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The criterion for assertion of the parameter loc_rcvr_status is left to the implementer. It can be based, for example, on observing the mean-square error at the decision point of the receiver or detecting errors during reception of symbol streams that represent the idle mode. Upon observation that the remote PHY also operates reliably (rem_rcvr_status=OK), the normal mode of operation is entered where transmission of packets over the link segment can take place.

The normal mode of operation corresponds to the SEND IDLE OR DATA state, where PHY Control asserts tx_mode=SEND_N. In this state, when no packets have to be sent, idle mode transmission takes place. Encoding of quinary symbols is realized with the parameter loc_rcvr_status = OK.

If during the normal mode of operation unsatisfactory receiver operations is detected (loc_rcvr_status=NOT_OK), transmission of the current packet, if any, is completed and PHY Control enters the TRAINING state.

Whenever a PHY that operates reliably detects unsatisfactory operation of the remote PHY (rem_rcvr_status=NOT_OK), it enters the SEND IDLE state where tx_mode=SEND_I is asserted and idle transmission takes place. In this state, encoding is performed with the parameter loc_rcvr_status=OK. As soon as the remote PHY signals satisfactory receiver operation (rem_rcvr_status=OK), the SEND IDLE OR DATA state is entered. Note that if in the SEND IDLE state loc_rcvr_status takes the value NOT_OK transition to the TRAINING state occurs.

PHY Control may force the transmit scrambler state to be initialized to a random value by requesting the execution of the PCS Reset function defined in 32.3.1.1.

32.2.2 PHY Control Service interface

The following specifies the services provided by PHY Control. These services are described in an abstract manner and do not imply any particular implementation.

The following primitives are defined:

PHYC_CONFIG.indication
PHYC_TXMODE.indication
PHYC_RXSTATUS.request
PHYC_REMRXSTATUS.request

The parameter link_control is identical to the link_control parameter defined for the PMA Service interface in 32.4.2.4.

32.2.2.1 PHYC_CONFIG.indication

Each PHY in a 100BASE-T2 link is configured as a master PHY or as a slave PHY. Master/slave configuration is determined during Auto-Negotiation (see 32.5). The result of this negotiation is provided to PHY Control.

32.2.2.1.1 Semantics of the primitive

PHYC_CONFIG.indication (config)

PHYC_CONFIG.indication specifies to PCS and PMA Clock Recovery via the parameter config whether the PHY must operate as a master PHY or as a slave PHY. The parameter config can take on one of two values of the form:

MASTER This value is continuously asserted when the PHY must operate as a master PHY.

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SLAVE This value is continuously asserted when the PHY must operate as a slave PHY.

32.2.2.1.2 When generated

PHY Control shall generate PHYC_CONFIG.indication messages synchronously with every MII TX_CLK cycle.

32.2.2.1.3 Effect of receipt

Upon reception of this primitive, PCS and PMA Clock Recovery shall perform their functions in master or slave configuration according to the value assumed by the parameter config.

32.2.2.2 PHYC_TXMODE.indication

The transmitter in a 100BASE-T2 link normally sends over the two pairs quinary symbols that can represent an MII data stream or the idle mode.

32.2.2.2.1 Semantics of the primitive

PHYC_TXMODE.indication (tx_mode)

PHYC_TXMODE.indication specifies to PCS Transmit via the parameter tx_mode what sequence of quinary symbols the PCS should be transmitting. The parameter tx_mode can take on one of two values of the form:

SEND_N This value is continuously asserted when transmission of sequences of quinary symbols representing an MII data stream or the idle mode is to take place.

SEND_I This value is continuously asserted in case transmission of sequences of quinary symbols representing the idle mode is to take place.

32.2.2.2.2 When generated

PHY Control shall generate PHYC_TXMODE.indication messages synchronously with every MII TX_CLK cycle.

32.2.2.2.3 Effect of receipt

Upon receipt of this primitive, the PCS shall perform its Transmit function as described in 32.3.1.2.

32.2.2.3 PHYC_RXSTATUS.request

This primitive is generated by PCS Receive to communicate the status of the receive link for the local PHY. The parameter loc_rcvr_status conveys to PHY Control and Link Monitor the information on whether the status of the overall receive link is satisfactory or not. Note that loc_rcvr_status is used by PCS Transmit encoding functions.

32.2.2.3.1 Semantics of the primitive

PHYC_RXSTATUS.request (loc_rcvr_status)

The loc_rcvr_status parameter can take on one of two values of the form:

OK This value is asserted and remains true during reliable operation of the receive link for

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the local PHY.

NOT_OK — This value is asserted whenever operation of the receive link for the local PHY is unreliable.

32.2.2.3.2 When generated

PCS Receive shall generate PHYC_RXSTATUS.request messages synchronously with signals received at the MDI. It shall prevent that the value of the parameter loc_rcvr_status is modified while TX_EN=1 in order to avoid that a transition from data to idle mode or from idle to data mode occurs while a packet is being presented to the PCS at the MII.

32.2.2.3.3 Effect of receipt

The effect of receipt of this primitive is specified in 32.2.5 and 32.4.1.3.3.

32.2.2.4 PHYC_REMRXSTATUS.request

This primitive is generated by PCS Receive to indicate the status of the receive link as communicated by the remote PHY. The parameter rem_rcvr_status conveys to PHY Control the information on whether reliable operation of the remote PHY is detected or not.

32.2.2.4.1 Semantics of the primitive

PHYC_REMRXSTATUS.request (rem_rcvr_status)

The rem_rcvr_status parameter can take on one of two values of the form:

OK — The receive link for the remote PHY is operating reliably.

NOT_OK — Reliable operation of the receive link for the remote PHY is not detected.

32.2.2.4.2 When generated

The PCS shall generate PHYC_REMRXSTATUS.request messages synchronously with signals received at the MDI.

32.2.2.4.3 Effect of receipt

The effect of receipt of this primitive is specified in 32.2.5.

32.2.3 State diagram variables

link_control
: See 32.4.1.3.1.

link_status
: See 32.4.1.3.1.

loc_rcvr_status
: Variable set by the PCS Receive function to indicate correct or incorrect operation of the receive link for the local PHY.

  Values: OK: the receive link for the local PHY is operating reliably,
  NOT_OK: operation of the receive link for the local PHY is not reliable.

pma_reset
: Allows reset of all PMA functions.

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Values: ON and OFF

Set by: PMA Reset

rem_rcvr_status

Variable set by the PCS Receive function to indicate whether correct operation of the receive link for the remote PHY is detected or not.

Values: OK: the receive link for the remote PHY is operating reliably,
NOT_OK: reliable operation of the receive link for the remote PHY is not detected.

tx_mode

PCS Transmit shall send quinary symbols according to the value assumed by this variable.

Values: SEND_N: transmission of sequences of quinary symbols representing an MII data stream, the idle mode, or control signals shall take place,
SEND_I: transmission of sequences of quinary symbols representing the idle mode shall take place.

32.2.4 State diagram timers

All timers operate in the manner described in 14.2.3.2 with the following addition. A timer is reset and stops counting upon entering a state where “stop x_timer” is asserted.

maxwait_timer

A timer used to measure the amount of time during which a receiver dwells in the TRAINING state. The timer shall expire 2500 ms to 3000 ms after entering the TRAINING state.

minwait_timer

A timer used to measure the amount of time during which a receiver waits in the SEND IDLE OR DATA, the TRAINING, or the SEND IDLE state before being allowed to leave the current state. The timer shall expire 128T = 5.12 µs after being started.

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32.2.5 PHY Control state diagram

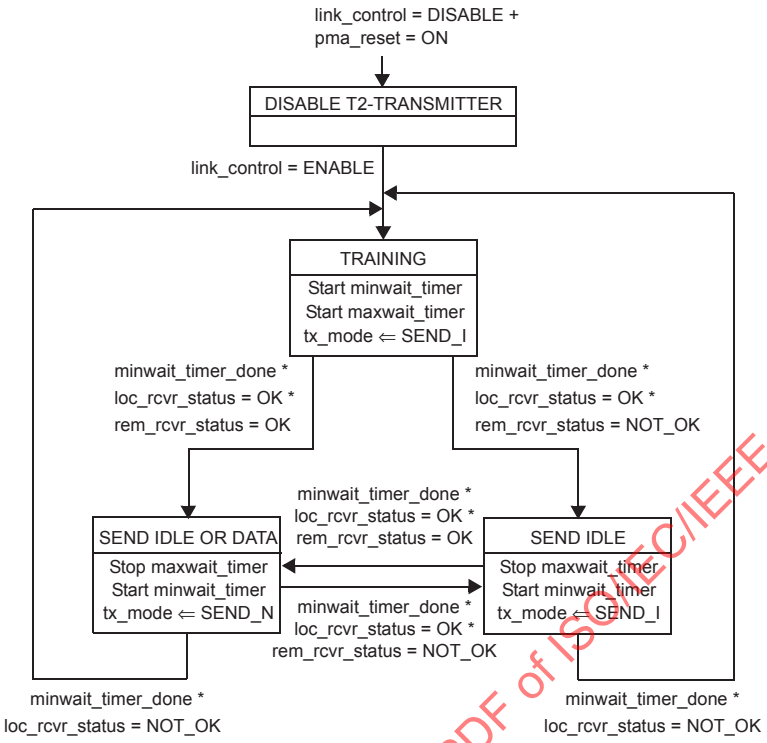

Figure 32–5—PHY Control state diagram

32.3 PCS functional specifications

The PCS comprises one PCS Reset function and four simultaneous and asynchronous operating functions. The PCS operating functions are: PCS Transmit, PCS Receive, PCS Carrier Sense, and PCS Collision Presence. All operating functions start immediately after the successful completion of the PCS Reset function.

The PCS reference diagram, Figure 32–5, shows how the four operating functions relate to the messages of the PCS-PMA and the PCS-PHY Control interfaces. Connections from the management interface (signals MDC and MDIO) to other layers are pervasive, and are not shown in Figure 32–5. The management functions are specified in Clause 30. See also Figure 32–7, which presents a block diagram helpful for understanding the definitions of PCS Transmit function variables, and Figure 32–11, which defines the structure of frames passed from PCS to PMA.

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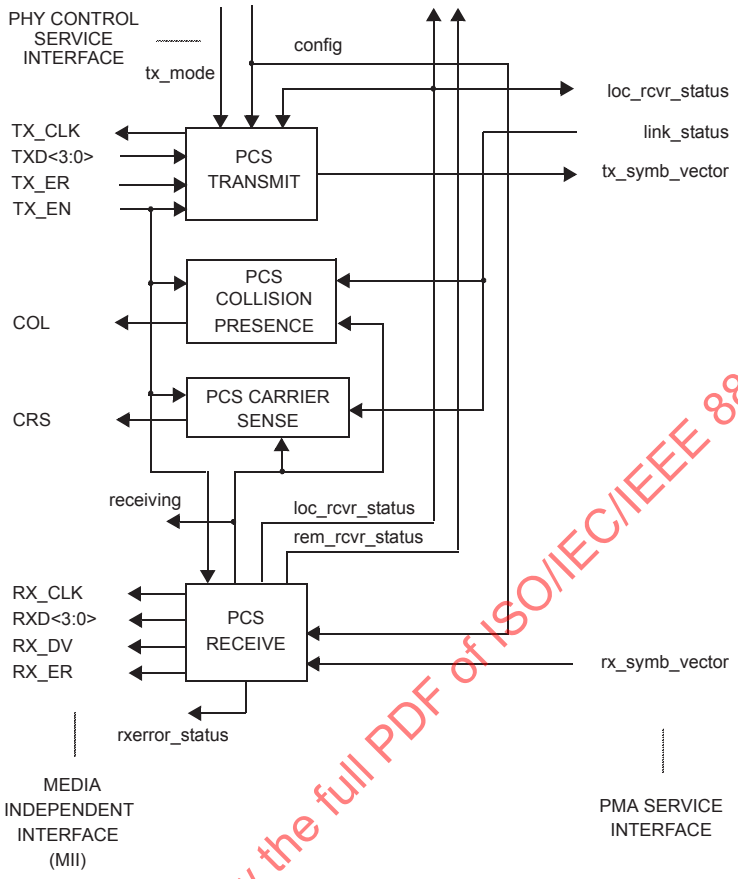

Figure 32-6—PCS reference diagram

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32.3.1 PCS functions

32.3.1.1 PCS Reset function

The PCS Reset function shall be executed any time one of three conditions occurs. These three conditions are "power on," the receipt of a request for reset from the management entity, and the receipt of a request for reset from PHY Control. PCS Reset initializes all PCS functions. PCS Reset sets pcs_reset = ON for the duration of its Reset function. All state diagrams take the open-ended pcs_reset branch upon execution of PCS Reset. The reference diagrams do not explicitly show the PCS Reset function.

32.3.1.2 PCS Transmit function

The PCS Transmit function shall conform to the PCS Transmit state diagram in Figure 32–12.

In normal mode of operation, the tx_mode parameter, which is transferred from PHY Control to the PCS via the PHYC_TXMODE.indication message, assumes the value tx_mode=SEND_N, and the PCS Transmit function generates at each symbol period pairs of quinary symbols that represent data or the idle mode. A symbol period T is equal to 40 ns. A time index n, where n is an integer, is introduced to establish a temporal relationship between different symbol periods. The tx_symb_vector parameter at time n is a two-element vector of quinary symbols (A_n, B_n) that is transferred to the PMA via PMA_UNITDATA.request. The PMA shall transmit symbols A_n and B_n over wire pairs BI_DA and BI_DB, respectively. During transmission of data, the four bits representing the TXD<3:0> data nibble are scrambled by the OCS using a side-stream scrambler then encoded into a pair of quinary symbols and transferred to the PMA. The idle mode is signaled by a sequence of pairs of quinary symbols that are also generated using the side-stream transmit scrambler. However, the encoding rules by which the quinary symbols are obtained are different for the data and the idle modes. This allows, at the receiver, sequences of quinary symbol pairs that represent data to be distinguished from sequences of quinary symbol pairs that represent the idle mode. A transition from the idle mode to the data mode is signalled by inserting a Start-of-Stream delimiter that consists of a pattern of two consecutive pairs of quinary symbols. Similarly, the end of transmission of data is signalled by an End-of-Stream delimiter that also consists of a pattern of two consecutive pairs of quinary symbols. Further patterns are reserved for signaling the assertion of TX_ER within a stream of data.

If tx_mode = SEND_I is asserted, PCS Transmit generates sequences of symbol pairs (A_n, B_n) according to the encoding rule in idle mode. Idle mode encoding takes into account the value of the parameter loc_rcvr_status. By this mechanism, a PHY indicates during idle transmission the status of its own receiver to the link partner.

The PCS Transmit reference diagram is shown in Figure 32–7. PCS encoding involves the generation of the three-bit words Sa_n[2:0], Sb_n[2:0], Ta_n[2:0], and Tb_n[2:0], from which the pairs of quinary symbols (A_n, B_n) are obtained. The three-bit words Sa_n[2:0] and Sb_n[2:0] are determined first, as explained in 32.3.1.2.2, from sequences of random binary symbols derived from the transmit side-stream scrambler. The generation of Ta_n[2:0] and Tb_n[2:0] and the quinary symbols A_n and B_n is given in 32.3.1.2.3. The physical structure represented in Figure 32–7 is not required. Implementers are free to construct any logical devices having functionality identical to that described by the following specifications and the PCS Transmit state diagram.

32.3.1.2.1 Side-stream scrambler polynomials

The PCS Transmit function employs side-stream scrambling. If the parameter config provided to the PCS by the PHY Control function via the PHYC_CONFIG.indication message assumes the value MASTER, PCS Transmit shall employ

$$g_M(x) = 1 + x^{13} + x^{33}$$

as transmitter side-stream scrambler generator polynomial. If config = SLAVE, PCS Transmit shall employ

$$g_S(x) = 1 + x^{20} + x^{33}$$

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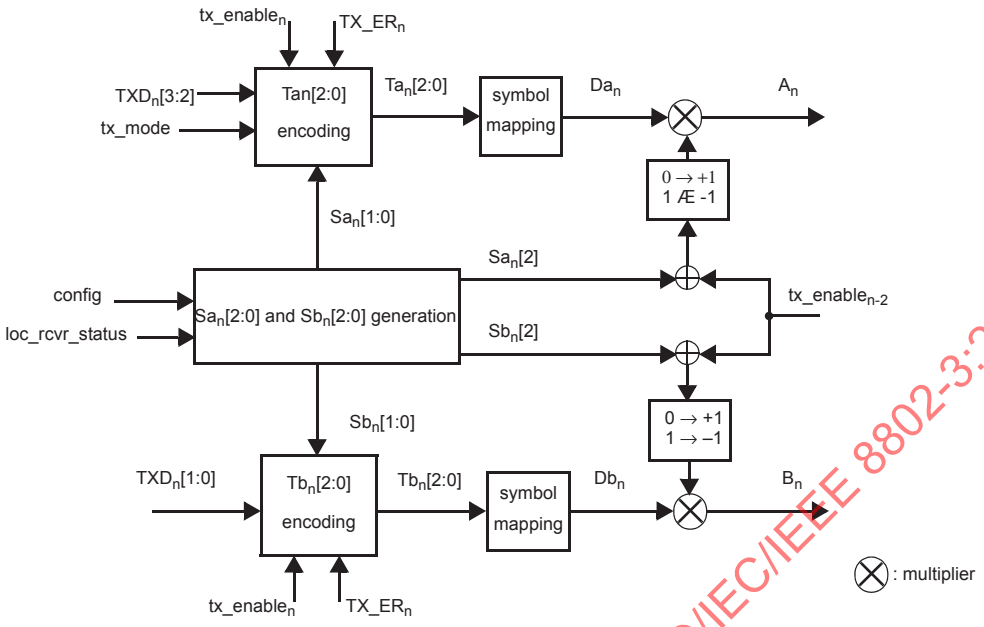
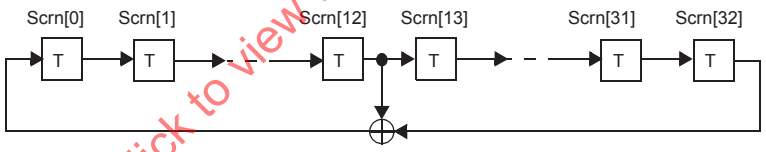
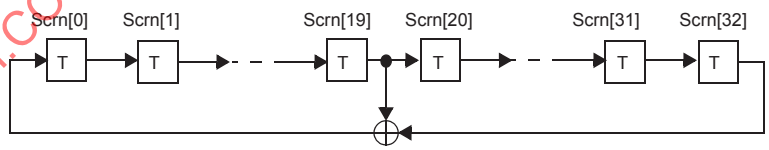


Figure 32–7—PCS Transmit reference diagram

as transmitter side-stream scrambler generator polynomial. The implementation of master and slave PHY side-stream scramblers by linear-feedback shift registers is shown in Figure 32–8. The bits stored in the shift register delay line at time n are denoted by Scr$_n$[32:0]. At each symbol period, the shift register is advanced by one bit and one new bit represented by Scr$_n$[0] is generated. The transmitter side-stream scrambler is reset upon execution of the PCS Reset function. If PCS Reset is executed, all bits of the 33-bit vector representing the side-stream scrambler state are randomly set. The generation of the random bits is left to the implementer.



a) Side-stream scrambler employed by the master PHY



b) Side-stream scrambler employed by the slave PHY

Figure 32–8—Realization of side-stream scramblers by linear feedback shift registers

32.3.1.2.2 Generation of bits Sa$_n$[2:0] and Sb$_n$[2:0]

PCS Transmit encoding rules are based on the generation, at time n, of the four bits Sx$_n$, Sy$_n$, Sa$_n$[2], and Sb$_n$[2]. These four bits are mutually uncorrelated and also uncorrelated with the bit Scr$_n$[0] in data and idle

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modes. For both master and slave PHYs, they are obtained by the same linear combinations of bits stored in the transmit scrambler shift register delay line. The four bits are elements of the same maximum-length shift register sequence of length $2^{33} - 1$ as $Scr_n[0]$, but shifted in time. The associated delays are all large and different, such that there is no apparent correlation among the five bits $Scr_n[0]$, Sx_n, Sy_n, $Sa_n[2]$, and $Sb_n[2]$. The bits Sx_n and Sy_n are given by

$$Sx_n = Scr_n[3] \oplus Scr_n[8]$$

$$Sy_n = Scr_n[4] \oplus Scr_n[6]$$

where ⊕ denotes the XOR logic operator. Four bits $X_n[1:0]$ and $Y_n[1:0]$ are obtained by

$$X_n[0] = \begin{cases} Sx_n & \text{if } \{n - n_0 = 0 \pmod 2 \text{ or loc_rcvr_status = OK}\} \\ Sx_n \oplus 1 & \text{else} \end{cases}$$

$$X_n[1] = X_n[0] \oplus 1$$

$$Y_n[0] = \begin{cases} Sy_n & \text{if } n - n_0 = 0 \pmod 2 \\ Sy_{n-1} \oplus 1 & \text{else} \end{cases}$$

$$Y_n[1] = Y_n[0]$$

where n_0 denotes the time index of the last transmitter side-stream scrambler reset.

The bits San[2:0] and Sbn[2:0] are given by

$$Sa_n[2] = Scr_n[1] \oplus Scr_n[5]$$

$$Sa_n[1:0] = \begin{cases} X_n[1:0] & \text{if } Scr_n[0] = 1 \\ Y_n[1:0] & \text{else} \end{cases}$$

$$Sb_n[2] = Scr_n[2] \oplus Scr_n[12]$$

$$Sb_n[1:0] = \begin{cases} Y_n[1:0] & \text{if } Scr_n[0] = 1 \\ X_n[1:0] & \text{else} \end{cases}$$

32.3.1.2.3 Generation of sequences A_n and B_n

If tx_mode = SEND_N, the PCS Transmit function generates sequences A_n and B_n that represent either a stream of data or an idle mode. If tx_mode = SEND_I, idle transmission is enforced. The encoding rule is determined by the value of the signal tx_enable_n, given by

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$$\text{tx_enable}_n = \begin{cases} TX_EN_n & \text{if tx_mode = SEND_N} \\ 0 & \text{else} \end{cases}$$

where TX_EN_n represents the MII signal TX_EN at time n. If $tx_enable_n = 1$, transmission of a stream of data takes place. As illustrated in Figure 32–11, the definition of a Start-of-Stream Delimiter ("SSD") is related to the condition $SSD_n = (tx_enable_n) * (! tx_enable_{n-2}) = 1$, where "*" and "!" denote the logic AND and NOT operators, respectively. For the generation of "SSD", PCS Transmit replaces the first two nibbles of the preamble in a data stream with the symbols defined below. Similarly, the definition of an End-of-Stream Delimiter (ESD) is related to the condition $ESD_n = (! tx_enable) * (tn_enable_{n-2}) = 1$. This occurs during the first two symbol periods after transmission of the last nibble of a data stream.

The symbols A_n and B_n are obtained from the three-bit words $Ta_n[2:0]$ and $Tb_n[2:0]$ whose definitions in the data and the idle modes are given below.

Data mode (tx_enable_n=1):

Definition of "SSD":

$Ta_n[2:0] = [1, 0, 0]$

$Tb_n[2:0] = [!tx_enable_{n-1}, tx_enable_{n-2}, tx_enable_{n-2}]$

A most significant bit $Ta_n[2]$=1 or $Tb_n[2]$=1 results in the transmission of a symbol that can be interpreted as an ESC symbol.

Encoding of data nibbles:

$$Ta_n[2:0] = [0, (Sa_n[1] \oplus TXD_n[3]), (Sa_n[0] \oplus TXD_n[2] \oplus 1)]$$

$$Tb_n[2:0] = [0, (Sb_n[1] \oplus TXD_n[1]), (Sb_n[0] \oplus TXD_n[0] \oplus 1)]$$

where $TXD_n[3:0]$ denotes the data nibble TXD[3:0] at time n.

Encoding of error indication:

If TX_ER_n=1 is asserted, where TX_ER_n denotes the value of the signal TX_ER at time n, error indication is signaled by means of the ESC and 0 symbols. The encoding rule is given by

$$Ta_n[2:0] = [(Sa_n[1] \oplus Sa_n[0]), 0, 0]$$

$$Tb_n[2:0] = [(Sb_n[1] \oplus Sb_n[0]), 0, 0]$$

Idle mode (tx_enable_n=0):

Definition of "ESD":

$Ta_n[2:0] = [1, 0, 0]$

$Tb_n[2:0] = [tx_enable_{n-1}, !tx_enable_{n-2}, !tx_enable_{n-2}]$

Encoding in the idle mode:

$$Ta_n[2:0] = [0, Sa_n[1], Sa_n[0]]$$

$$Tb_n[2:0] = [0, Sb_n[1], Sb_n[0]]$$

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The mapping of $Ta_n[2:0]$ and $Tb_n[2:0]$ into quinary symbols Da_n and Db_n is given in Figure 32–9. This mapping ensures that the symbols representing data are Gray coded. The quinary symbols A_n and B_n are obtained from Da_n and Db_n by

Symbol mapping	
Ta/Tb	Da/Db
000	0
001	+1
010	-1
011	-2
100 (ESC)	+2

Idle or data	
Da_n:	0, +1, -1, or -2
Db_n:	0, +1, -1, or -2

Data stream delimiters		
Da_n: ESC		Dan+1: ESC
Db_n: ESC		Dbn+1: 0

Error indication		
Da_n: ESC		Da_n: 0
Db_n: 0	or	Db_n: ESC

Figure 32–9—Symbol mapping and encoding rule summary

$$A_n = \begin{cases} Da_n & \text{if } Sa_n[2] \oplus tx_enable_{n-2} = 0 \\ -Da_n & \text{else} \end{cases}$$

$$B_n = \begin{cases} Db_n & \text{if } Sb_n[2] \oplus tx_enable_{n-2} = 0 \\ -Db_n & \text{else} \end{cases}$$

With the rules defined in this subclause, if in idle mode a transmitted symbol on one wire pair belongs to the set {–2,0,+2}, the symbol on the other wire pair belongs to the set {–1,+1}. Moreover, one of the quinary symbols that are transmitted at time $2(n–n_0)$ and $2(n–n_0)+1$ is guaranteed to be either +2 or –2. Both in data and idle modes, the symbol sequences on each wire pair can be modeled as sequences of independent and identically distributed quinary symbols. The symbol constellations and symbol probabilities for these two modes are shown in Figure 32–10. The average symbol energy is the same in data and idle modes.

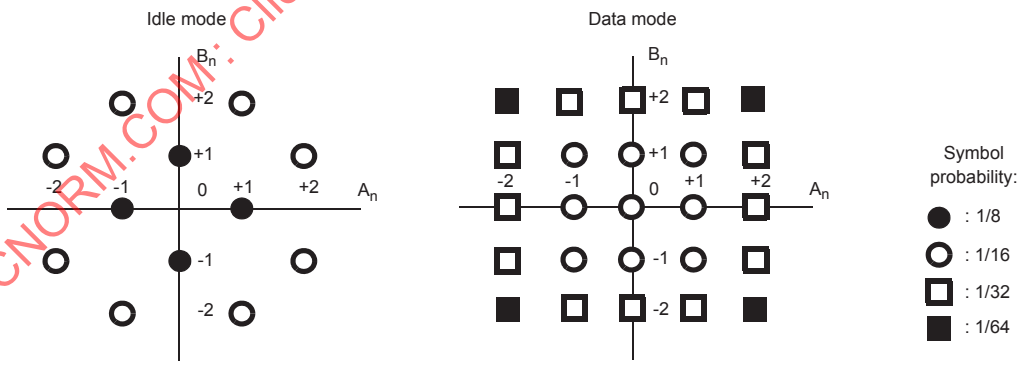

Figure 32–10—Symbol constellations in idle and data modes

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32.3.1.3 PCS Receive function

The PCS Receive function shall conform to the PCS Receive state diagram in Figure 32–13.

The PCS Receive function accepts pairs of detected quinary symbols provided by the PMA Receive function via the parameter rx_symb_vector. To achieve correct operation, PCS Receive uses the knowledge of the encoding rules that are employed in the idle mode. For example, the property that in the idle mode if A_n belongs to the set {–2,0,+2} then B_n belongs to the set {–1,+1}, and vice versa, can be used to acquire the correct state for the receiver side-stream descrambler, and to determine which detected quinary symbol was transmitted on wire pair BI_DA and which on wire pair BI_DB. Also, correct polarity of the detected quinary symbols can reliably be obtained by ensuring in the idle mode that the encoding rule holds whenever a –2 symbol is received. PCS Receive generates the sequence of vectors of two quinary symbols (RA_n, RB_n) and indicates the reliability of receiver operations by setting the parameter loc_rcvr_status to OK (logic high) or NOT_OK (logic low). The sequence (RA_n, RB_n) is processed to generate the signals RXD<3:0>, RX_DV, and RX_ER, which are presented to the MII. PCS Receive detects the transmission of a stream of data from the remote station and conveys this information to the PCS Carrier Sense and PCS Collision Presence functions via the parameter receiving.

32.3.1.3.1 Receiver descrambler polynomials

For side-stream descrambling, the master PHY shall employ the receiver descrambler generator polynomial $g'_M(x) = 1 + x^{20} + x^{33}$, and the slave PHY shall employ the receiver descrambler generator polynomial $g'_S(x) = 1 + x^{13} + x^{33}$.

32.3.1.3.2 Decoding of quinary symbols

At the beginning of a stream of data, PCS Receive detects "SSD" and asserts the signal RX_DV. Detection of "SSD" is achieved by processing two consecutive vectors (RA_{n-1}, RB_{n-1}) and (RA_n, RB_n) at each time n. Upon detection of "SSD," PCS Receive also assigns the value TRUE to the parameter receiving that is provided to the PCS Carrier Sense and Collision Presence functions.

Table 32–1 shows the mapping of symbols RA_n and RB_n into two-bit words $Qa_n[1:0]$ and $Qb_n[1:0]$ that are descrambled and decoded to generate nibbles of data RXD[3:0].

Table 32–1—Inverse quinary symbol mapping

RA_n/RB_n	$Qa_n[1:0]/Qb_n[1:0]$
0	00
+1	01 or 10
–1	01 or 10
± 2	11

The mapping shown in Table 32–1 corresponds to the inverse of the encoding function employed by PCS Transmit. For example, a symbol $A_n = +1$ is generated by $Ta_n[1:0]$ being equal to "01" or "10." Hence, in the above table the value of $Qa_n[1:0]$ for $RA_n = +1$ is specified as being equal to "01 or 10." Similarly for other entries in the table.

During reception of a stream of data, PCS Receive checks that the symbols RA_n and RB_n follow the encoding rule defined in 32.3.1.2 whenever they assume values ± 2. PCS Receive processes two consecutive vectors at each time n to detect "ESD." Upon detection of "ESD," PCS Receive deasserts the signal RX_DV, and assigns the value FALSE to the parameter receiving. If a violation of the encoding rules is detected, PCS

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Receive asserts the signal RX_ER for at least one symbol period. During reception of an idle sequence, PCS Receive checks that the symbols RA_n and RB_n follow the encoding rule defined in 32.3.1.2.

32.3.1.4 PCS Carrier Sense function

The PCS Carrier Sense function shall conform to the PCS Carrier Sense state diagram in Figure 32–14.

The PCS Carrier Sense function controls the MII signal CRS according to the rules presented in this clause. While link_status = OK, CRS is asserted whenever receiving=TRUE or TX_EN=1.

32.3.1.5 PCS Collision Presence function

A PCS collision is defined as the simultaneous occurrence of TX_EN=1 and the assertion of the parameter receiving=TRUE while link_status=OK. While a PCS collision is detected, the MII signal COL shall be asserted. At other times COL shall remain deasserted.

32.3.2 PCS interfaces

32.3.2.1 PCS–MII interface signals

The signals in Table 32–2 are formally defined in 22.2.2. Jabber detection as specified in 22.2.4.2.12 is not required by this standard.

Table 32–2—MII interface signals

Signal name	Meaning	Subclause
TX_CLK	Transmit clock	22.2.2.1
RX_CLK	Receive clock	22.2.2.2
TX_EN	Frames transmit data	22.2.2.3
TXD<3:0>	Transmit data	22.2.2.4
TX_ER	Forces transmission of illegal code	22.2.2.5
RX_DV	Frames receive SFD and DATA	22.2.2.7
RXD<3:0>	Receive data	22.2.2.8
RX_ER	Receive error indication	22.2.2.10
CRS	Non-idle medium indication	22.2.2.11
COL	Collision indication	22.2.2.12
MDC	Management data clock	22.2.2.13
MDIO	Management data	22.2.2.14

32.3.2.2 PCS–management entity signals

The management interface has pervasive connections to all functions. Operation of the management control lines MDC and MDIO, and requirements for managed objects inside the PCS and PMA, are specified in Clause 22 and Clause 30, respectively.

No spurious signals shall be emitted onto the MDI when the PHY is held in power down mode as defined in 22.2.4.1.5, independently of the value of TX_EN, or when released from power down mode, or when external power is first applied to the PHY.

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32.3.3 Frame structure

Frames passed from the PCS to the PMA sublayer shall have the structure shown in Figure 32–11. This figure shows the temporal relationship between the signals tx_enable$_n$, and TXD[3:0] and the sequences of quinary symbol pairs (A_n, B_n) in correspondence of transitions from the idle mode to transmission of data and vice versa. Time proceeds from left to right in the figure.

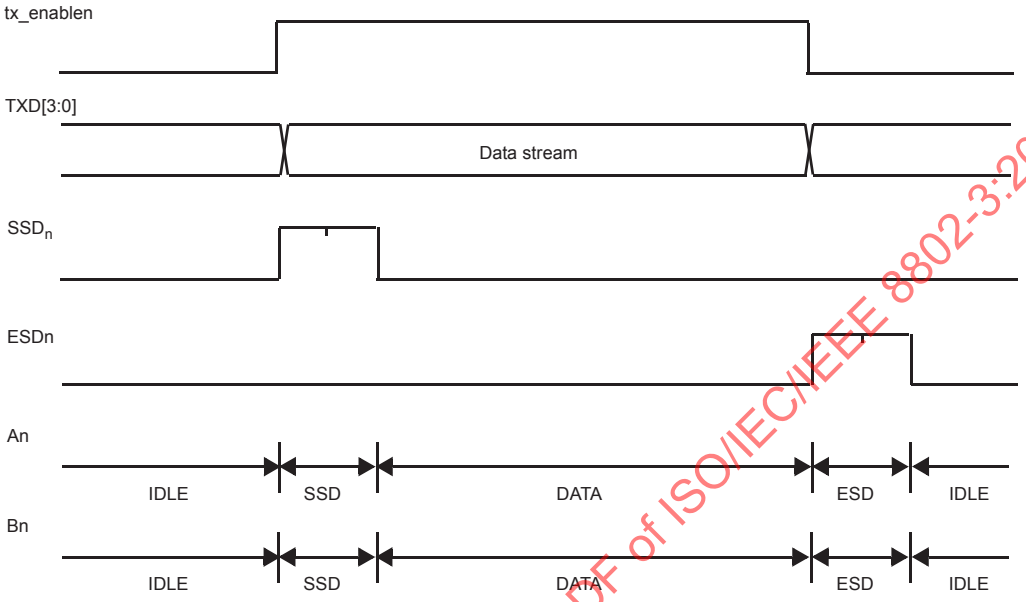

Figure 32–11—PCS sublayer to PMA sublayer frame structure

32.3.4 State variables

32.3.4.1 Variables

COL

The COL signal of the MII as specified in Clause 22.

config

The config parameter set by PHY Control and passed to the PCS via the PHYC_CONFIG.indication primitive.
Values: MASTER and SLAVE.

CRS

The CRS signal of the MII as specified in Clause 22.

DATA

A sequence of vectors of two quinary symbols corresponding to valid data, as specified in 32.3.1.2.

ESD

Two consecutive vectors of two quinary symbols corresponding to the End-of-Stream delimiter, as specified in 32.3.1.2.

IDLE

A sequence of vectors of two quinary symbols generated in idle mode, as specified in 32.3.1.2.

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link_status

The link_status parameter set by PMA Link Monitor and passed to the PCS via the PMA_LINK.indication primitive.
Values: OK, READY, and FAIL

loc_rcvr_status

The loc_rcvr_status parameter generated by PCS Receive.
Values: OK and NOT_OK

pcs_reset

The pcs_reset parameter set by the PCS Reset function.
Values: ON and OFF

(RA_n, RB_n)

The vector of the two correctly aligned most recently received quinary symbols generated by PCS Receive.

receiving

The receiving parameter generated by the PCS Receive function.
Values: TRUE and FALSE

rxerror_status

The rxerror_status parameter set by the PCS Receive function. Although this variable is set by PCS Receive, it achieves the same function as the variable rxerror_status of Clause 24 that is set by PMA and communicated through the PMA_RXERROR.indication primitive.
Values: ERROR and NO_ERROR

RX_DV

The RX_DV signal of the MII as specified in Clause 22.

RX_ER

The RX_ER signal of the MII as specified in Clause 22.

rx_symb_vector

A vector of two quinary symbols received by the PMA and passed to the PCS via the PMA_UNITDATA.indication primitive.
Value: SYMB_PAIR

RXD[3:0]

The RXD<3:0> signal of the MII as specified in Clause 22.

SSD

Two consecutive vectors of two quinary symbols corresponding to the Start-of-Stream delimiter, as specified in 32.3.1.2.

tx_enable

The tx_enable parameter generated by PCS Transmit as specified in 32.3.1.2.3.

TX_ER

The TX_ER signal of the MII as specified in Clause 22.

tx_mode

The tx_mode parameter set by PHY Control and passed to the PCS via the

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PHYC_TXMODE.indication primitive.
Values: SEND_N and SEND_I

tx_symb_vector

A vector of two quinary symbols generated by the PCS Transmit function and passed to the PMA via the PMA_UNITDATA.request primitive.
Value: SYMB_PAIR

32.3.4.2 Timer

symb_timer

A continuous free-running timer. The condition symb_timer_done becomes true upon timer expiration.

Restart time: Immediately after expiration; timer restart resets the condition symb_timer_done.

Duration: 40 ns nominal.

TX_CLK shall be generated synchronously with symb_timer (see tolerance required for TX_CLK in 32.6.1.2.6). In the PCS Transmit state diagram, the message PMA_UNITDATA.request is issued concurrently with symb_timer_done.

32.3.4.3 Messages

PMA_UNITDATA.indication (rx_symb_vector)
A signal sent by PMA Receive indicating that a vector of two quinary symbols is available in rx_symb_vector.

PMA_UNITDATA.request (tx_symb_vector)
A signal sent to PMA Transmit indicating that a vector of two quinary symbols is available in tx_symb_vector.

32.3.5 State diagrams

32.3.5.1 PCS Transmit

PCS Transmit sends vectors of two quinary symbols to the PMA via the tx_symb_vector parameter. In normal mode of operation, between streams indicated by the parameter tx_enable, PCS Transmit generates sequences of vectors using the encoding rules defined for the idle mode. Upon assertion of tx_enable, PCS Transmit passes an "SSD" of two consecutive vectors of two quinary symbols to the PMA replacing the preamble bits of a stream of data during these two symbol periods. Following the "SSD," each TXD<3:0> nibble is encoded into a vector of two quinary symbols until tx_enable is deasserted. If, while tx_enable is asserted, the TX_ER signal is also asserted, PCS Transmit passes to the PMA vectors indicating a transmit error. Note that if the signal TX_ER is asserted while "SSD" is being sent, the transmission of the error condition is delayed until transmission of "SSD" has been completed. Following the deassertion of tx_enable, an "ESD" of two consecutive vectors of two quinary symbols is generated, after which the transmission of a sequence indicating the idle mode is resumed.

Collision detection is implemented by noting the occurrence of carrier receptions during transmissions, following the model of 10BASE-T. The PCS shall implement the Transmit process as depicted in Figure 32–12 including compliance with the associated state variables as specified in 32.3.4.

32.3.5.2 PCS Receive

PCS Receive accepts vectors of two quinary symbols from the PMA via the rx_symb_vector parameter. After correct receiver operation has been achieved, the loc_rcvr_status parameter assumes the value OK, and PCS

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Receive continuously checks that the received sequence satisfies the encoding rule used in idle mode. As soon as a violation is detected, PCS Receive asserts the parameter receiving and determines whether the violation is due to reception of "SSD" or to a receiver error by examining the last two received vectors (RA_{n-1}, RB_{n-1}) and (RA_n, RB_n). In the first case, during the two symbol periods corresponding to "SSD," PCS Receive replaces "SSD" by preamble bits. Following "SSD," the signal RX_DV is asserted and each received vector is decoded into a data nibble RXD<3:0> until "ESD" is detected. Deassertion of RX_DV and transition to the IDLE state take place upon detection of "ESD". The signal RX_ER is asserted if a receiver error occurs before proper stream termination. In the second case, the signal RX_ER is asserted and the parameter rxerror_status assumes the value ERROR. Deassertion of RX_DV and transition to the IDLE state (rxerror_status=NO_ERROR) takes place upon detection of a sequence generated in idle mode.

A premature stream termination is caused by the detection of four consecutive vectors satisfying the encoding rule used in idle mode prior to the detection of "ESD", provided that the first vector is not a valid data vector. Note that RX_DV remains asserted during the symbol periods corresponding to the first three idle vectors, while RX_ER=TRUE is signaled on the MII. The signal RX_ER is also asserted in the LINK FAILED state, which ensures that RX_ER remains asserted for at least one symbol period. The PCS shall implement the Receive process as depicted in Figure 32–13 including compliance with the associated state variables as specified in 32.3.4.

The parameters receiving and rxerror_status are communicated to the PCS's clients by the following primitives:

PCS_CARRIER.indication (carrier_status)
: A signal generated by PCS Receive to indicate reception of non-idle quinary symbols. The purpose of this primitive is to give clients indication of activity on the underlying continuous-signaling channel.

PCS_RXERROR.indication (rxerror_status)
: A signal generated by PCS Receive to indicate a reception of non-idle symbols that does not start with "SSD."

32.3.5.3 PCS Carrier Sense

The PCS Carrier Sense process generates the signal CRS on the MII, which the MAC uses via the Reconciliation sublayer for frame receptions and for deferral. The process operates by performing logical operations on TX_EN and receiving. The PCS shall implement the Carrier Sense process as depicted in Figure 32–14 including compliance with the associated state variables as specified in 32.3.4.

32.3.6 PCS electrical specifications

The interface between PCS, PMA and PHY Control is an abstract message-passing interface, having no specified electrical properties. Electrical characteristics of the signals passing between the PCS and MII may be found in Clause 22.

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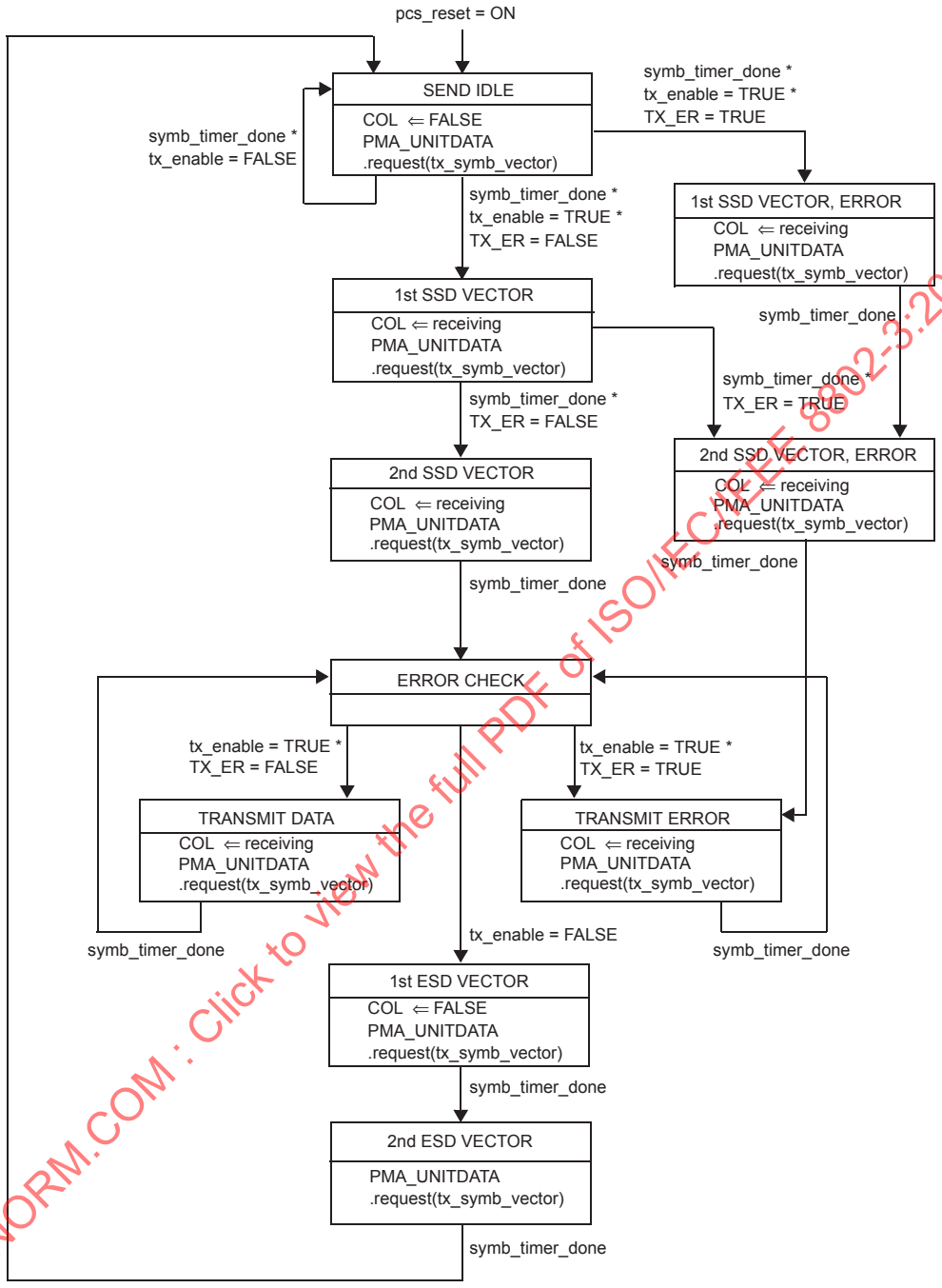

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NOTE—The generation of PMA_UNITDATA.request(tx_symb_vector) depends on the parameters config, tx_mode, and loc_rcvr_status as defined in 32.3.1.2 and is not shown explicitly in the state diagram.

Figure 32–12—PCS Transmit state diagram

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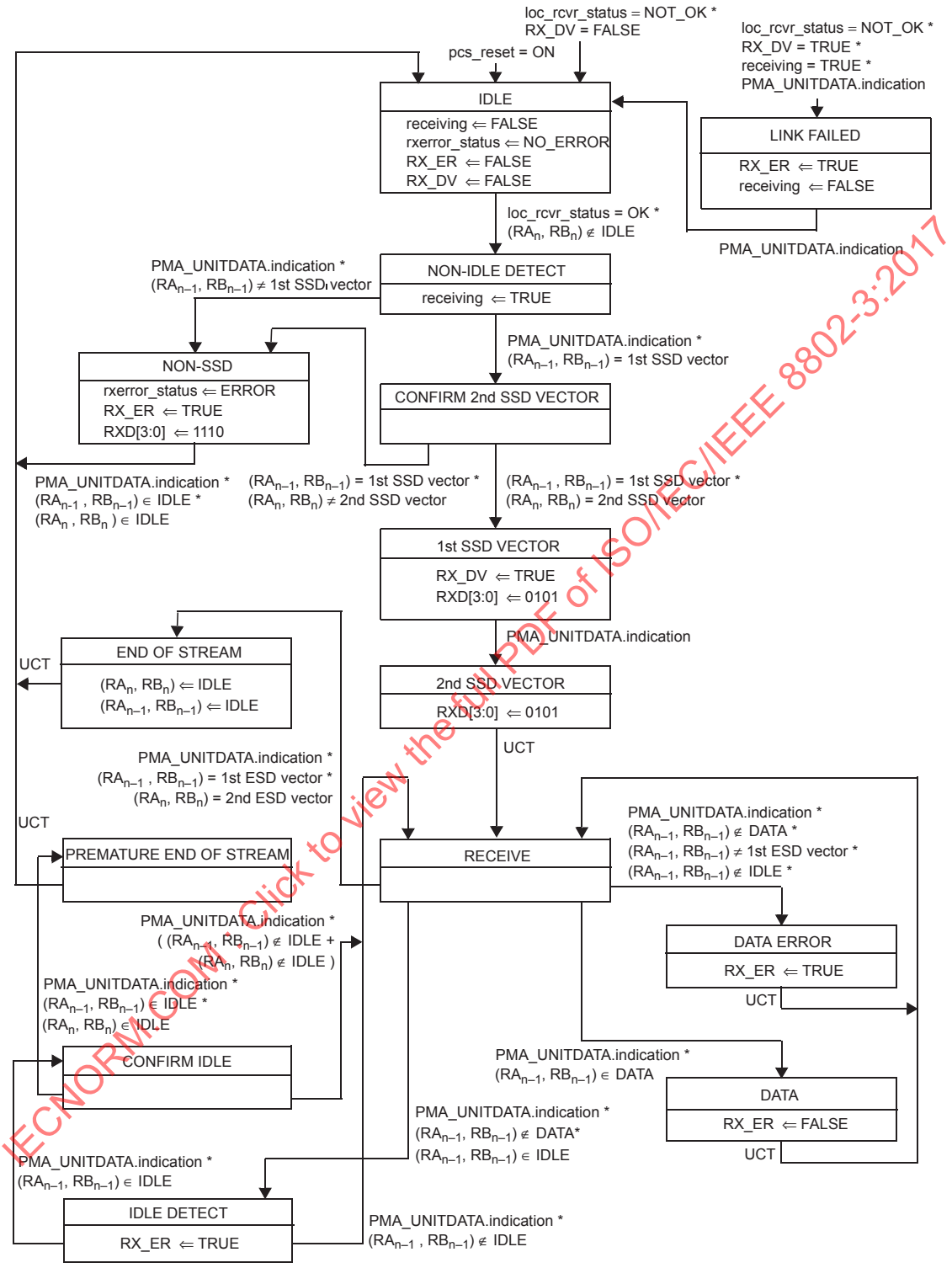

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Figure 32–13—PCS Receive state diagram

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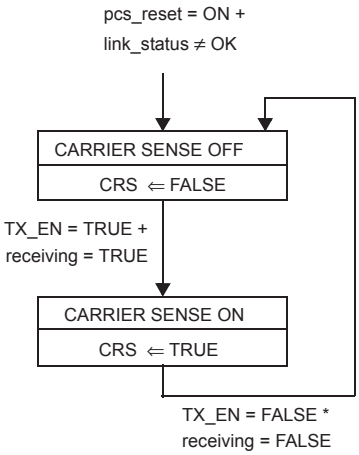

Figure 32–14—PCS Carrier Sense state diagram

32.4 PMA functional specifications and service interface

32.4.1 PMA functional specifications

The PMA couples messages from a PMA service interface specified in 32.4.2 to the 100BASE-T2 baseband medium, specified in 32.7. The interface between PMA and the baseband medium is the Medium Dependent Interface (MDI), specified in 32.8.

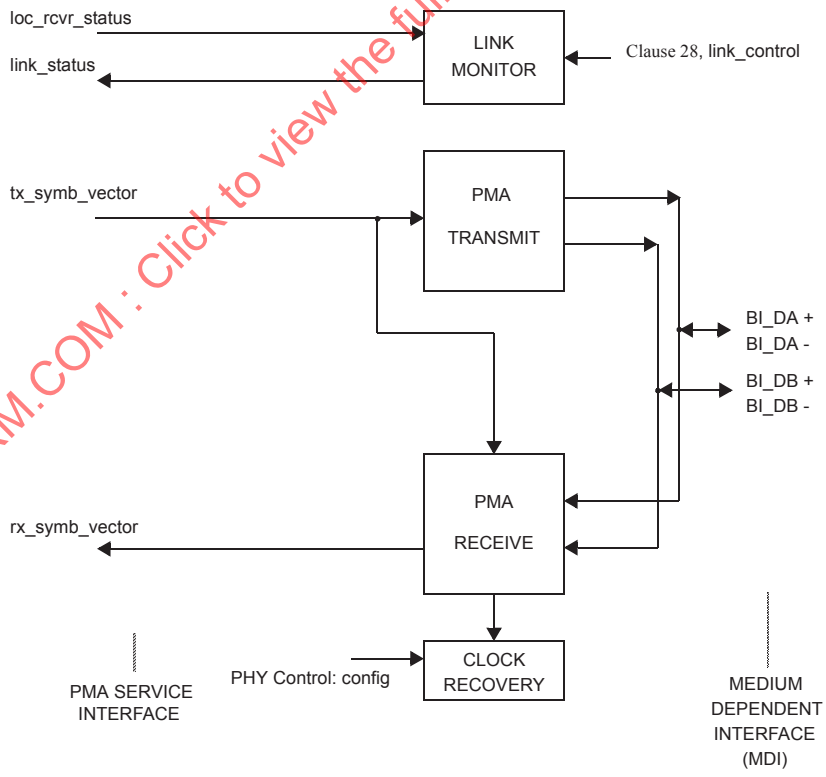

Figure 32–15—PMA reference diagram

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32.4.1.1 PMA functions

The PMA sublayer comprises one PMA Reset function and four simultaneous and asynchronous operating functions. The PMA operating functions are PMA Transmit, PMA Receive, Link Monitor, and Clock Recovery. All operating functions are started immediately after the successful completion of the PMA Reset function. The Reset function may be shared between PMA and PCS sublayers.

The PMA reference diagram, Figure 32–15, shows how the operating functions relate to the messages of the PMA Service interface, PHY Control Service interface, and the signals of the MDI. Connections from the management interface, comprising the signals MDC and MDIO, to other layers are pervasive, and are not shown in Figure 32–15. The management interface and its functions are specified in Clause 22.

32.4.1.1.1 PMA Reset function

The PMA Reset function shall be executed any time either of two conditions occurs. These two conditions are "power on" and the receipt of a reset request from the management entity. The PMA Reset function initializes all PMA functions and forces Auto-Negotiation to be executed. The PMA Reset function sets pma_reset = ON for the duration of its reset function. All state diagrams take the open ended pma_reset branch upon execution of the PMA Reset function. The reference diagrams do not explicitly show the PMA Reset function.

32.4.1.1.2 PMA Transmit function

The PMA Transmit function comprises two independent transmitters to generate five-level pulse-amplitude modulated signals on each of the two pairs BI_DA and BI_DB. PMA Transmit shall continuously transmit onto the MDI pulses modulated by the quinary symbols given by tx_symb_vector[BI_DA] and tx_symb_vector[BI_DB], respectively. The two transmitters shall be driven by the same transmit clock. The signals generated by PMA Transmit will follow the mathematical description given in 32.4.1.2.1, and shall comply with the electrical specifications given in 32.6.

32.4.1.1.3 PMA Receive function

The PMA Receive function comprises two independent receivers for quinary pulse-amplitude modulated signals on each of the two pairs BI_DA and BI_DB. PMA Receive contains the circuits necessary to detect quinary symbol sequences from the signals received at the MDI over receive pairs BI_DA and BI_DB and present these sequences to the PCS Receive function. The signals received at the MDI are described mathematically in 32.4.1.2.2. The PHY shall translate the signals received on pairs BI_DA and BI_DB into the PMA_UNITDATA.indication parameter rx_symb_vector with a symbol error ratio of less than one part in 10^{10}.

To achieve the indicated performance, it is highly recommended that PMA Receive include the functions of signal equalization, suppression of cyclo-stationary interference signals created by alien near-end crosstalk sources, and echo and self near-end crosstalk cancellation. The sequence of quinary transmitted symbols tx_symb_vector is needed to perform echo and self near-end crosstalk cancellation.

32.4.1.1.4 Link Monitor function

Link Monitor determines the status of the underlying receive channel. Failure of the underlying receive channel typically causes the PMA's clients to suspend normal operation.

The Auto-Negotiation process notifies Link Monitor whether the device connected to the far end is of type 100BASE-T2. Based on this and other information, Link Monitor sets two important internal variables:

a) The pma_type variable that indicates whether the remote station is of type 100BASE-T2 or not,
b) The link_status variable that is sent across the PMA Service interface.

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The Link Monitor function shall comply with the state diagram of Figure 32-16.

Upon power-on, reset, or release from power-down, the Auto-Negotiation algorithm sets link_control=SCAN_FOR_CARRIER and sends during this period fast link pulses to signal its presence to a remote station. If the presence of a remote station is sensed through reception of fast link pulses, the Auto-Negotiation algorithm sets link_control=DISABLE and exchanges Auto-Negotiation information with the remote station. During this period, link_status=FAIL is asserted. If the presence of a remote 100BASE-T2 station is established, the Auto-Negotiation algorithm permits full operation by setting link_control=ENABLE. As soon as reliable transmission is achieved, the variable link_status=OK is asserted, upon which further PHY operations can take place.

32.4.1.1.5 Clock Recovery function

The Clock Recovery function couples to both receive pairs. It provides a synchronous clock for sampling the signals on the two pairs.

The Clock Recovery function shall provide a clock suitable for synchronous signal sampling on each line so that the symbol error ratio indicated in 32.4.1.1.3 is achieved. The received clock signal must be stable and ready for use when training has been completed (loc_rcvr_status=OK).

32.4.1.2 PMA interface messages

The messages between the PMA, PCS, and PHY Control are defined in 32.4.2, PMA Service Interface. Communication through the MDI is summarized below.

32.4.1.2.1 MDI signals transmitted by the PHY

The quinary symbols to be transmitted by the PMA on the two pairs BI_DA and BI_DB are denoted by tx_symb_vector[BI_DA] and tx_symb_vector[BI_DB], respectively. Five-level Pulse Amplitude Modulation over each pair (PAM5×5) is the modulation scheme employed in 100BASE-T2. It is the function of PMA Transmit to generate on each pair a pulse-amplitude modulated signal of the form

$$s(t) = \sum_k a_k h_1(t - kT)$$

where a_k represents the quinary symbol from the set {–2, –1, 0, +1, +2} to be transmitted at time kT, and $h_1(t)$ denotes the system symbol response at the MDI. This symbol response shall comply with the electrical specifications given in 32.6.

32.4.1.2.2 Signals received at the MDI

Signals received at the MDI can be expressed for each pair as pulse-amplitude modulated signals that are corrupted by noise:

$$r(t) = \sum_k a_k h_2(t - kT) + w(t)$$

In this equation, $h_2(t)$ denotes the impulse response of the overall channel from the transmit side up to the MDI at the receive side, and $w(t)$ is a term that includes the contribution of various noise sources. The two signals received on pair BI_DA and BI_DB shall be processed within the PMA Receive function to yield the quinary received symbols rx_symb_vector[BI_DA] and rx_symb_vector[BI_DB].

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32.4.1.3 PMA state diagram

32.4.1.3.1 State diagram variables

link_control
: The link_control parameter as communicated by the PMA_LINK.request primitive.
Values: See 32.4.2.4.

link_status
: The link_status parameter as communicated by the Link Monitor function through the PMA_LINK.indication primitive.
Values: See 32.4.2.5.

loc_rcvr_status
: The loc_rcvr_status parameter as communicated by the PMA_RXSTATUS.request primitive.
Values: See 32.2.2.3.1.

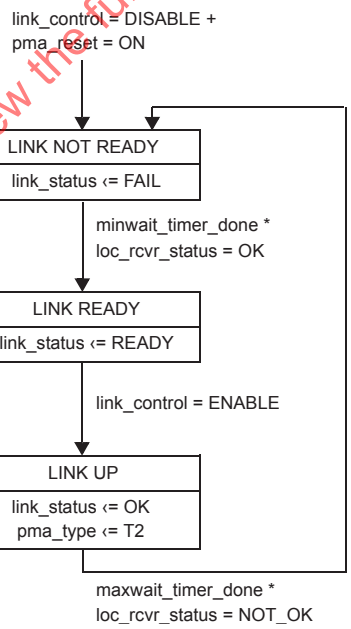
pma_reset
: Allows reset of all PMA functions.
Values: ON and OFF
Set by: PMA Reset

32.4.1.3.2 Timers

maxwait_timer
Values: See 32.2.4.

minwait_timer
Values: See 32.2.4.

32.4.1.3.3 Link Monitor state diagram



NOTE—The variables link_control and link_status are designated as link_control_[T2] and link_status_[T2], respectively, by the Auto-Negotiation Arbitration state diagram (Figure 28–18).

Figure 32-16—Link Monitor state diagram

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32.4.2 PMA service interface

This subclause specifies the services provided by the PMA. These services are described in an abstract manner and do not imply any particular implementation. The PMA Service Interface supports the exchange of symbol vectors, status indications, and control signals between the PMA, the PCS, and PHY Control. The following primitives are defined:

PMA_TYPE.indication
PMA_UNITDATA.request
PMA_UNITDATA.indication
PMA_LINK.request
PMA_LINK.indication
PMA_CARRIER.indication
PMA_RXERROR.indication

The parameter config is passed from PHY Control to the PMA via the primitive PHYC_CONFIG.indication. The definition of this parameter is given for the PHY Control Service interface in 32.2.2.1 and is not repeated here for the PMA Service interface.

32.4.2.1 PMA_TYPE.indication

This primitive is generated by the PMA to indicate the nature of the PMA instantiation. Its purpose is to allow clients to support connections to the various types of 100BASE-T PMA entities in a generalized manner.

32.4.2.1.1 Semantics of the service primitive

PMA_TYPE.indication (pma_type)

The pma_type parameter for use with the 100BASE-T2 PMA is T2.

32.4.2.1.2 When generated

The PMA shall continuously generate this primitive to indicate the value of pma_type.

32.4.2.1.3 Effect of receipt

The client uses the value of pma_type to define the semantics of the primitives defined at the PMA service interface.

32.4.2.2 PMA_UNITDATA.request

This primitive defines the transfer of pairs of quinary symbols in the form of the tx_symb_vector parameter from the PCS to the PMA. The quinary symbols are obtained in the PCS Transmit function using the encoding rules defined in 32.3.1.2 to represent MII data streams, an idle mode, or other sequences.

32.4.2.2.1 Semantics of the service primitive

PMA_UNITDATA.request (tx_symb_vector)

During transmission using 100BASE-T2 signaling, the PMA_UNITDATA.request simultaneously conveys to the PMA via the parameter tx_symb_vector the value of the symbols to be sent over each of the two transmit pairs BI_DA and BI_DB. The tx_symb_vector parameter takes on the form:

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SYMB_PAIR	A vector of two quinary symbols, one for each of the two transmit pairs BI_DA and BI_DB. Each quinary symbol may take on one of the values –2, –1, 0, +1 or +2.

The quinary symbols that are elements of tx_symb_vector are called, according to the pair on which each will be transmitted, tx_symb_vector[BI_DA] and tx_symb_vector[BI_DB].

32.4.2.2.2 When generated

The PCS generates PMA_UNITDATA.request (SYMB_PAIR) synchronously with every MII TX_CLK cycle.

32.4.2.2.3 Effect of receipt

Upon receipt of this primitive, the PMA transmits on the MDI the signals corresponding to the indicated quinary symbols. The parameter tx_symb_vector is also used by the PMA Receive function to process the signals received on pairs BI_DA and BI_DB.

32.4.2.3 PMA_UNITDATA.indication

This primitive defines the transfer of pairs of quinary symbols in the form of the rx_symb_vector parameter from the PMA to the PCS.

32.4.2.3.1 Semantics of the service primitive

PMA_UNITDATA.indication (rx_symb_vector)

During reception of PAM5×5 signals using 100BASE-T2 signaling, the PMA_UNITDATA.indication simultaneously conveys to the PCS via the parameter rx_symb_vector the values of the symbols detected on each of the two receive pairs BI_DA and BI_DB. The rx_symbol_vector parameter takes on the form:

SYMB_PAIR	A vector of two quinary symbols, one for each of the two receive pairs BI_DA and BI_DB. Each quinary symbol may take on one of the values –2, –1, 0, +1 or +2.

The quinary symbols that are elements of rx_symb_vector are called, according to the pair upon which each symbol was received, rx_symbol_vector[BI_DA] and rx_symb_vector[BI_DB].

32.4.2.3.2 When generated

The PMA shall generate PMA_UNITDATA.indication (SYMB_PAIR) messages synchronously with signals received at the MDI.

32.4.2.3.3 Effect of receipt

The effect of receipt of this primitive is unspecified.

32.4.2.4 PMA_LINK.request

This primitive allows the Auto-Negotiation algorithm to enable and disable operation of the PMA.

32.4.2.4.1 Semantics of the service primitive

PMA_LINK.request (link_control)

The link_control parameter can take on one of three values: SCAN_FOR_CARRIER, DISABLE, or ENABLE.

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SCAN_FOR_CARRIER	Used by the Auto-Negotiation algorithm prior to receiving any fast link pulses. During this mode the PMA reports link_status=FAIL. PHY processes are disabled.
DISABLE	Set by the Auto-Negotiation algorithm in the event fast link pulses are detected. *PHY processes are disabled.* This allows the Auto-Negotiation algorithm to determine how to configure the link.
ENABLE	Used by Auto-Negotiation to turn control over to the PHY for data processing functions.

32.4.2.4.2 When generated

Upon power on, reset, or release from power down, the Auto-Negotiation algorithm issues the message PMA_LINK.request (SCAN_FOR_CARRIER).

32.4.2.4.3 Effect of receipt

While link_control=SCAN_FOR_CARRIER or link_control=DISABLE, the PMA shall report link_status=FAIL. While link_control=ENABLE, PHY Control determines the operations to be performed by the PHY.

32.4.2.5 PMA_LINK.indication

This primitive is generated by the PMA to indicate the status of the underlying medium. This primitive informs the PCS, PHY Control and the Auto-Negotiation algorithm about the status of the underlying link.

32.4.2.5.1 Semantics of the service primitive

PMA_LINK.indication (link_status)

The link_status parameter can take on one of three values: FAIL, READY, or OK.

FAIL	No valid link established.
READY	Training completed after Auto-Negotiation.
OK	The Link Monitor function indicates that a valid 100BASE-T2 link is established. Reliable reception of signals transmitted from the remote PHY is possible.

32.4.2.5.2 When generated

The PMA shall generate this primitive to indicate the value of link_status in compliance with the state diagrams given in Figure 32-16.

32.4.2.5.3 Effect of receipt

The effect of receipt of this primitive is specified in 32.2 and 32.3.

32.4.2.6 PMA_CARRIER.indication

This primitive is identical to PCS_CARRIER.indication defined in 32.3.5.2. It is not explicitly shown in the PMA reference diagram.

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32.4.2.7 PMA_RXERROR.indication

This primitive is identical to PCS_RXERROR.indication defined in 32.3.5.2. It is not explicitly shown in the PMA reference diagram.

32.4.2.8 PMA_RXSTATUS.request

This primitive allows the Link Monitor to determine via the parameter loc_rcvr_status generated by the PCS Receive function whether reliable receiver operations are established. The parameter loc_rcvr_status is also passed from the PCS Receive function to the PHY Control Service interface via the primitive PHYC_RXSTATUS.request. The definition of this parameter is given for the PHY Control Service interface in 32.2.2.3 and is not repeated here for the PMA Service interface.

32.5 Management functions

100BASE-T2 makes extensive use of the management functions provided by the Media Independent Interface (Clause 22) and the communication and self-configuration functions provided by Auto-Negotiation (Clause 28.)

In addition to the provision of MII Registers 0, 1, 4, 5, 6, and 7, it is required that implementations that support 100BASE-T2 also provide equivalents to MII Registers 8, 9, and 10 (Clause 22). Register 8 is used to provide the Auto-Negotiation Link Partner NEXT Page Register, Register 9 is used to provide the MASTER-SLAVE Control Register, and Register 10 is used to provide the MASTER-SLAVE Status Register. These registers are used to configure PHYs for testing, to manually configure PHYs for MASTER-SLAVE negotiation, to store the contents of Next Pages during the Auto-Negotiation process, and to store information reporting the results of the master/slave configuration process as described in the next subclause.

32.5.1 100BASE-T2 Use of Auto-Negotiation and MII Registers 8, 9, and 10

On power-up, before Auto-Negotiation starts, the Auto-Negotiation Advertisement register shall have the following configuration: The Selector Field (4.4:0) is set to an appropriate code as specified in Annex 28A. The Acknowledge bit (4.14) is set to logic zero. The Technology Ability Field (4:9:5) is set based on the values set in the MII Status Register (Register 1) (1.15:11) or equivalent and (4.11:10) is set based on the values set in the MII Status Register (Register 1) (1.10:9) or equivalent.

When Auto-Negotiation begins, 100BASE-T2 implementations send an Auto-Negotiation Base Page with bit D15 set to logical one to indicate that a Next Page follows (see 28.2.1.2.)

The Base Page is followed by a formatted Next Page containing the 100BASE-T2 Technology Ability Message Code (7), which indicates that two Unformatted Next Pages containing the 100BASE-T2 Technology Ability fields follow (see Table 28C–1.)

Two Unformatted Next Pages are sent using the 100BASE-T2 Technology Ability fields shown in Table 32–6 Register 8 will be used to store the transmitted information while it is being processed as described below.

Bit U0 of page 1 shall be copied from MII Register 4.10 to indicate 100BASE-T2FD advertised ability.

Bit U1 of page 1 shall be copied from MII Register 4.11 to indicate 100BASE-T2HD advertised ability.

Bit U2 of page 1 shall be copied from MASTER-SLAVE control register 9.10 to indicate that the PHY device is a repeater port or DTE for 100BASE-T2.

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Bits U3 and U4 shall be copied from MASTER-SLAVE control register (bits 9.12 and 9.11) for use by the MASTER-SLAVE negotiation process as described below.

Bits U5-U10 of page 1 and U0-U9 of page 2 shall be used to define the seed used for the MASTER-SLAVE negotiation process described as follows.

Using the information described above, the PHY performs a MASTER-SLAVE configuration process as defined in 32.5.4.3. This process is conducted at the entrance to the FLP LINK GOOD CHECK state shown Auto-Negotiation Arbitration State Diagram (Figure 28–18.)

If the local device detects that both the local device and the remote device are of the same type (either repeater or DTE) and that both have generated the same random seed, it sets the Ack2 bit of Register 8 to logical zero and generates and transmits a new random seed for MASTER-SLAVE negotiation.

The MASTER-SLAVE configuration process returns one of the three following outcomes.

Successful: Bit 10:15 of the MASTER-SLAVE Status Register is set to logical zero and bit 10.14 is set to logical one. 100BASE-T2 returns control to Auto-Negotiation (at the entrance to the FLP LINK GOOD CHECK state in Figure 28–18) and passes the value of MASTER or SLAVE to PHYC_CONFIG.indication (see 32.2.2.)

Unsuccessful: link_status_T2 is set to FAIL and Auto-Negotiation restarts (see Figure 28–18.)

Fault detected: (This happens when both end stations are set for manual configuration and both are set to MASTER or both are set to SLAVE.) Bit 10.15 of the MASTER-SLAVE Status Register is set to logical one to indicate that a manual configuration fault has been detected and bit 10.14 is set to logical one to indicate that MASTER-SLAVE resolution completed with a fault. Because the MASTER-SLAVE relationship was not established, link_status_T2 is set to FAIL, causing Auto-Negotiation to restart.

32.5.2 Management functions

The management interface specified in Clause 22 provides a simple, two-wire, serial interface to connect a management entity and a managed PHY for the purposes of controlling the PHY and gathering status from the PHY. This interface is referred to as the MII Management Interface. The register definition specifies a basic register set with an extension mechanism.

100BASE-T2 requires the basic register set that consists of two registers referred to as the Control Register (Register 0) and the Status Register (Register 1) and of some PHY-specific registers. The detailed definitions of these registers are given in 22.2.4.

The full set of management registers is listed in Table 22–6 and 100BASE-T2 PHY specific registers are given in Table 32–3.

Table 32–3—100BASE-T2 Control and Status registers

Register address	Register name	Basic/Extended
9	MASTER-SLAVE Control register	E
10	MASTER-SLAVE Status register	E

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32.5.3 PHY specific registers for 100BASE-T2

Some of the extended registers (registers with addresses 2 to 15) are used as PHY specific registers as described in 22.2.4.3. A 100BASE-T2 PHY shall use register addresses 9 and 10 for its control and status functions. The bits in the 100BASE-T2 Control register are used to place the PHY into several possible test modes and to determine the MASTER-SLAVE relationship during Auto-Negotiation. The bits in the 100BASE-T2 Status register are used to report the MASTER-SLAVE relationship determined during Auto-Negotiation, the local and remote receiver status, and provide an idle error counter.

32.5.3.1 100BASE-T2 Control register (Register 9)

Register 9 shall provide the following values for 100BASE-T2. The assignment of bits in the register is shown in Table 32–4. The default value for each bit of the register should be chosen so that the initial state of the PHY upon power up or reset is a normal operational state without management intervention.

Table 32–4—100BASE-T2 Control register (MII management Register 9) bit definition

Bit(s)	Name	Description	R/W
9.15:14	Transmitter test mode	Default bit values are “00”	R/W
9.13	Receiver test mode	Default bit value is “0”	R/W
9.12	MASTER-SLAVE Manual Configuration Enable	1 = Enable MASTER-SLAVE Manual Configuration value 0 = Disable MASTER-SLAVE Manual Configuration value (default)	R/W
9.11	MASTER-SLAVE Manual Configuration Value	1 = Configure PHY as MASTER during MASTER-SLAVE negotiation, only when 9.12 is set to logical one. 0 = Configure PHY as SLAVE during MASTER-SLAVE negotiation, only when 9.12 is set to logical one.	R/W
9.10	T2_Repeater/DTE bit	1 = Repeater device port 0 = DTE device	R/W
9.9:0	Reserved		

32.5.3.1.1 Transmitter test mode

For a PHY with 100BASE-T2 capability, the PHY shall be placed in transmitter test mode 1 operation (described in 32.6.1.2.1) when bit 9.15 is set to logical zero and bit 9.14 is set to logical one. When bit 9.15 is set to logical one and bit 9.14 is set to logical zero, the PHY shall be placed in transmitter test mode 2 operation as described in 32.6.1.2.1. When bit 9.15 is set to logical one and bit 9.14 is set to logical one, the PHY shall be placed in the transmitter test mode 3 operation as described in 32.6.1.2.1.

The default value for bits 9.15:14 are all zero.

32.5.3.1.2 Receive test mode

The PHY shall be placed in the receiver test mode as described in 32.6.1.3.2 when the bit 9.13 is set to logical one.

The default value for bit 9.13 is zero.

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32.5.3.1.3 MASTER-SLAVE Manual Configuration Enable

The MASTER-SLAVE relationship is established during Auto-Negotiation via either automatic MASTER-SLAVE configuration or manual configuration. If bit 9.12 is set to logical zero, then the MASTER-SLAVE configuration negotiation function will determine the PHY configuration. If bit 9.12 is set to logical one, then manual MASTER-SLAVE configuration is enabled, using 9.11 to specify the value. (Usage of this bit is further described in 32.5.3.1.)

The default value of bit 9.12 is zero.

32.5.3.1.4 MASTER-SLAVE Manual Configuration Value

MASTER-SLAVE Manual configuration is enabled by setting bit 9.12 to logical one. When manual configuration mode is enabled, setting bit 9.11 to logical one configures the PHY as MASTER, and setting bit 9.11 to logic zero configures the PHY as SLAVE during MASTER-SLAVE negotiation process and shall be used to report the result of the MASTER-SLAVE configuration resolution for that PHY. Detailed description of the use of this bit in MASTER-SLAVE configuration resolution is provided in 32.5.3.1.

The default value of bit 9.11 is zero.

32.5.3.1.5 T2_Repeater/DTE Bit

Bit 9.10 shall be set to logical zero if the PHY is a DTE device and shall be set to a logical one if the PHY is a repeater device port (usage of this bit is described in 32.5.2.)

32.5.3.1.6 Reserved bits

Bits 9.9:0 are reserved for future standardization. They shall be written as zero and shall be ignored when read; however, a PHY shall return the value zero in these bits.

32.5.3.2 100BASE-T2 Status register (Register 10)

Register 10 shall provide the following values for 100BASE-T2. The assignment of bits in the register is shown in Table 32–5. The default value for each bit of the register should be chosen so that the initial state of the PHY upon power up or reset is a normal operational state without management intervention.

Table 32–5—100BASE-T2 Status register (MII management Register 10) bit definition

Bit(s)	Name	Description	R/W[a]
10.15	MASTER-SLAVE manual configuration fault	1 = MASTER-SLAVE manual configuration fault detected 0 = No MASTER-SLAVE manual configuration fault detected	RO/SC
10.14	MASTER-SLAVE configuration resolution complete	1 = MASTER-SLAVE configuration resolution has completed 0 = MASTER-SLAVE configuration resolution has not completed	RO
10.13	Local Receiver Status	1 = Local Receiver OK 0 = Local Receiver not OK	RO
10.12	Remote Receiver Status	1 = Remote Receiver OK 0 = Remote Receiver not OK	RO
10.11:8	Reserved		
10.7:0	Idle Error Count	Idle Error count	RO/SC

[a]R/W = Read/Write, SC = Self Clearing, RO = Read Only

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32.5.3.2.1 MASTER-SLAVE Manual Configuration Fault

When read as a logical one, bit 10.15 indicates that a MASTER-SLAVE Manual Configuration Fault condition has been detected. The type of fault as well as the criteria and method of fault detection is PHY specific. The MASTER-SLAVE Manual Configuration Fault bit shall be implemented with a latching function, such that the occurrence of a MASTER-SLAVE Manual Configuration Fault will cause the MASTER-SLAVE Manual Configuration Fault bit to be set and remain set until it is cleared. The MASTER-SLAVE Manual Configuration Fault bit shall be cleared each time Register 10 is read via the management interface and shall also be cleared by a 100BASE-T2 PMA reset.

For 100BASE-T2, this fault condition will occur when both PHYs are forced to be MASTER or SLAVE at the same time using bits 9.12 and 9.11. Bit 10.15 should be set via the MASTER-SLAVE Configuration Resolution function described in 32.5.4.

32.5.3.2.2 MASTER-SLAVE Configuration Resolution Complete

When read as a logical one, bit 10.14 indicates that the MASTER-SLAVE Resolution process has been completed and that the contents of Registers 9 and 10 related to MASTER-SLAVE are valid. When read as a logic zero, bit 10.14 indicates that the MASTER-SLAVE Configuration Resolution process has not been completed and that the contents of Registers 9 and 10 which are related to MASTER-SLAVE resolution are invalid. Bit 10.14 should be set via the MASTER-SLAVE Configuration Resolution function described in 32.5.4.

32.5.3.2.3 Local Receiver Status

Bit 10.13 indicates the status of the local receiver. Local receiver status is defined by the value of the loc_rcvr_status variable described in 32.2.3.

32.5.3.2.4 Remote Receiver Status

Bit 10.12 indicates the status of the remote receiver. Remote receiver status is defined by the value of the rem_rcvr_status variable described in 32.2.3.

32.5.3.2.5 Reserved bits

Bit 10.11:8 are reserved for future standardization. They shall be written as zero and shall be ignored when read; however, a PHY shall return the value zero in these bits.

32.5.3.2.6 Idle Error count

Bits 10.7:0 indicate the Idle Error count, where 10.7 is the most significant bit. During normal operation these bits contain a cumulative count of the errors detected when the receiver is receiving idles and the PHY Control parameter tx_mode is equal to SEND_N (indicating that both local and remote receiver status have been detected to be OK). When the PHY has receiver test mode (bit 9.13) enabled, these bits contain a cumulative count of the errors detected at all times when the local receiver status is OK. These bits are reset to all zeros when the error count is read by the management function or upon execution of the PCS Reset function and they are held at all ones in case of overflow (see 30.5.1.1.13).

32.5.4 Changes and additions to Auto-Negotiation (Clause 28)

32.5.4.1 Change to 28.2.4.1.3 (Auto-Negotiation Advertisement register)

For implementations which support 100BASE-T2, the Technology Ability Field (4:9:5) is set based on the values set in the MII Status Register (Register 1) (1.15:11) or equivalent and (4.11:10) is set based on the

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values set in the MII Status Register (Register 1) (1.10:9) or equivalent. Use of Register 4 is defined in 28.2.4.1.3.

32.5.4.2 Use of Auto-Negotiation Next Page codes for 100BASE-T2 PHYs

For a PHY capable of 100BASE-T2 transmission, during Auto-Negotiation the Base Page will be followed by a Next Page with a message code containing the 100BASE-T2 Technology Ability Message Code (7) as shown in Table 28C–1. This Message Next Page indicates that two Unformatted Message Next Pages will follow which contain the 100BASE-T2 Technology Ability Fields as described in Table 32–6.

Table 32–6—Bit assignments for Unformatted Next Pages containing 100BASE-T2 Technology Ability Field

Bit	Technology	MII register bit/source
PAGE 1		
U0	100BASE-T2 Half Duplex (1 = Half Duplex and 0 = no Half Duplex)	MII Register 4.10
U1	100BASE-T2 Full Duplex (1=Full Duplex and 0 = no Full Duplex)	MII Register 4.11
U2	100BASE-T2 Repeater/DTE bit (1 = Repeater and 0 = DTE)	MII Register 9.10 (MASTER-SLAVE Control register)
U3	100BASE-T2 MASTER-SLAVE Manual Configuration Enable (1 = Manual Configuration Enable); intended to be used for manual selection in a particular MASTER-SLAVE mode. To be used in conjunction with bit U4	MII Register 9.12 (MASTER-SLAVE Control register)
U4	100BASE-T2 MASTER-SLAVE Manual Configuration value 1 = MASTER and 0 = SLAVE. This bit is ignored if U3 = 0.	MII Register 9.11 (MASTER-SLAVE Control register)
U5	100BASE-T2 MASTER-SLAVE Seed Bit 0 (SB0) (LSB)	MASTER-SLAVE seed value (15.0)
U6	100BASE-T2 MASTER-SLAVE Seed Bit 1 (SB1)	
U7	100BASE-T2 MASTER-SLAVE Seed Bit 2 (SB2)	
U8	100BASE-T2 MASTER-SLAVE Seed Bit 3 (SB3)	
U9	100BASE-T2 MASTER-SLAVE Seed Bit 4 (SB4)	
U10	100BASE-T2 MASTER-SLAVE Seed Bit 5 (SB5)	
PAGE 2		
U0	100BASE-T2 MASTER-SLAVE Seed Bit 6 (SB6)	
U1	100BASE-T2 MASTER-SLAVE Seed Bit 7 (SB7)	
U2	100BASE-T2 MASTER-SLAVE Seed Bit 8 (SB8)	
U3	100BASE-T2 MASTER-SLAVE Seed Bit 9 (SB9)	
U4	100BASE-T2 MASTER-SLAVE Seed Bit 10 (SB10)	
U5	100BASE-T2 MASTER-SLAVE Seed Bit 11 (SB11)	
U6	100BASE-T2 MASTER-SLAVE Seed Bit 12 (SB12)	
U7	100BASE-T2 MASTER-SLAVE Seed Bit 13 (SB13)	
U8	100BASE-T2 MASTER-SLAVE Seed Bit 14 (SB14)	
U9	100BASE-T2 MASTER-SLAVE Seed Bit 15 (SB15)	
U10	unused	

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32.5.4.3 MASTER-SLAVE Configuration Resolution

Since both PHYs that share a link segment are capable of being MASTER or SLAVE, a prioritization scheme exists to ensure that the correct mode is chosen. The MASTER-SLAVE relationship shall be determined during Auto-Negotiation using Table 32–7 with the 100BASE-T2 Technology Ability Next Page bit values specified in Table 32–7 and information received from the link partner.

Table 32–7—100BASE-T2 MASTER-SLAVE Configuration Resolution table

Local Device Type	Remote Link Partner Type	Resolution Function result	
		Local Device	Remote Link Partner
DTE (U2=0 & U3=0) or Manual SLAVE (U3=1 & U4=0)	Repeater (U2=1 & U3=0) or Manual MASTER (U3=1 & U4=1)	SLAVE	MASTER
Repeater (U2=1 & U3=0)	Manual MASTER (U3=1 & U4=1)		
Manual SLAVE (U3=1 & U4=0)	DTE (U2=0 & U3=0)		
Repeater (U2=1 & U3=0) or Manual MASTER (U3=1 & U4=1)	DTE (U2=0 & U3=0) or Manual SLAVE (U3=1 & U4=0)	MASTER	SLAVE
DTE (U2=0 & U3=0)	Manual Slave (U3=1 & U4=0)		
Manual Master (U3=1 & U4=1)	Repeater (U2=1 & U3=0)		
Repeater (U2=1 & U3=0)	Repeater (U2=1 & U3=0)	PHY with higher seed value is the MASTER. If the seeds are equal, the MASTER-SLAVE resolution is unsuccessful, set link_status_T2=FAIL, causing Auto-Negotiation to restart.	
DTE (U2=0 & U3=0)	DTE (U2=0 & U3=0)		
Manual SLAVE (U3=1 & U4=0)	Manual SLAVE (U3=1 & U4=0)	Fault detected Set link_status_T2=FAIL, forcing Auto-Negotiation to restart.	
Manual MASTER (U3=1 & U4=1)	Manual MASTER (U3=1 & U4=1)		

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The rationale for this hierarchy is straightforward. A 100BASE-T2 repeater has higher priority than a DTE to become the MASTER. In the case where both devices are of the same type, e.g., both devices are Repeaters, the device with the higher MASTER-SLAVE seed bits (SB0..SB15), where SB15 is the MSB, becomes the MASTER and the device with the lower seed value becomes the SLAVE. In case both devices have the same seed value, both should assert link_status_T2=FAIL (as defined in 28.3.1) and restart Auto-Negotiation. Successful completion of the MASTER-SLAVE resolution shall be treated as MASTER-SLAVE configuration resolution complete and the 100BASE-T2 Status Register bit 10.14 shall be set to logical one.

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The method of generating a random seed is left to the implementer. The generated random seeds should belong to a sequence of independent, identically distributed integer numbers with a uniform distribution in the range of 0 to 65535. The algorithm used to generate the integer should be designed to minimize the correlation between the number generated by any two devices at any given time. A seed counter shall be provided to track the number of seed attempts. The seed counter shall be set to zero at start-up and shall be incremented each time a seed is generated. A MASTER-SLAVE resolution fault shall be declared if resolution is not reached after the generation of seven seeds.

The MASTER-SLAVE Manual Configuration Enable bit (control register bit 9.12) is used to manually set a device to become the MASTER or the SLAVE. In case both devices are manually set to become the MASTER or the SLAVE, this condition shall be flagged as a MASTER-SLAVE Manual Configuration fault condition, thus the MASTER-SLAVE Manual Configuration fault bit (status register bit 10.15) shall be set to logical one. The MASTER-SLAVE Manual Configuration fault condition shall be treated as MASTER-SLAVE configuration resolution complete and status register bit 10.14 shall be set to logical one. In this case, link_status_T2 will be set to FAIL, because the MASTER-SLAVE relationship was not resolved. This will force Auto-Negotiation to restart after the link_fail_inhibit_timer has expired. Determination of MASTER-SLAVE values occur on the entrance to the FLP LINK GOOD CHECK state (Figure 28–18) when the highest common denominator (HCD) technology is 100BASE-T2. The resulting MASTER-SLAVE value is used by the 100BASE-T2 PHY control (32.2.2.1).

32.6 PMA electrical specifications

This clause defines the electrical characteristics of the PHY at the MDI.

The ground reference point for all common-mode tests is the MII ground circuit. Implementations without an MII use the chassis ground. The values of all components in test circuits shall be accurate to within ±1% unless otherwise stated.

32.6.1 PMA-to-MDI interface characteristics

32.6.1.1 Isolation requirement

The PHY shall provide electrical isolation between the DTE or repeater circuits, including frame ground and all MDI leads. This electrical separation shall withstand at least one of the following electrical strength tests:

a) 1500 V rms at 50–60 Hz for 60 s, applied as specified in Section 5.3.2 of IEC 60950
b) 2250 Vdc for 60 s, applied as specified in Section 5.3.2 of IEC 60950
c) A sequence of ten 2400 V impulses of alternating polarity, applied at intervals of not less than 1 s. The shape of the impulses shall be 1.2/50 µs (1.2 µs virtual front time, 50 µs virtual time or half value), as defined in IEC 60060.

There shall be no insulation breakdown, as defined in Section 5.3.2 of IEC 60950, during the test. The resistance after the test shall be at least 2 MΩ, measured at 500 Vdc.

32.6.1.2 Transmitter electrical specifications

The PMA shall provide the Transmit function specified in 32.4.1.1.2 in accordance with the electrical specifications of this clause.

Where a load is not specified, the transmitter shall meet requirements of this clause with a 100 Ω resistive differential load connected to each transmitter output.

The tolerance on the poles of the test filters used in this clause shall be ±1%.

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32.6.1.2.1 Transmitter test modes

Since the 100BASE-T2 PCS employs scrambling, synchronization of data at the MII to the scrambled state is virtually impossible. Therefore a special transmit test mode shall be required to allow for testing of the transmitter waveform. Additionally, a test mode for measuring transmitter output jitter is also required.

For a PHY with a MII interface, these modes shall be enabled by setting bits 9.14 and 9.15 (MASTER-SLAVE Control Register) of the MII Management register set as shown in Table 32–8. These test modes shall only change the data symbols provided to the transmitter circuitry and may not alter the electrical characteristics of the transmitter. A PHY without an MII shall provide a means to provide these functions. The vendor shall provide a means to enable these modes for conformance testing.

Table 32–8—MII management register set

Bit 9.15	Bit 9.14	Mode
0	0	Normal operation
0	1	TX Test mode 1—waveform test
1	0	TX Test mode 2—jitter test
1	1	TX Test mode 3—idle

When transmit test mode 1 is enabled, the PHY shall transmit the following sequence of data symbols (A_n and B_n of 32.3.1.2.3) continually from both transmitters:

{{+2 followed by 127 0 symbols}, {-2 followed by 127 0 symbols},{+1 followed by 127 0 symbols}, {–1 followed by 127 0 symbols}, {16 +2 symbols, 16 –2 symbols followed by 224 0 symbols}}

This sequence is repeated continually without breaks between the repetitions when the transmit test mode is enabled. A typical transmitter output is shown below in Figure 32–17. The transmitter shall time the transmitted symbols from a 25.000 MHz ± 0.01% clock.

When transmit test mode 2 is enabled, the PHY shall transmit the data symbol sequence {+2,–2} repeatedly on both channels. The transmitter shall time the transmitted symbols from a 25.000 MHz ± 0.01% clock.

When transmit test mode 3 is enabled, the PHY shall transmit idle data compliant with the idle signaling specified in 32.3 with loc_rcvr_status=OK.

32.6.1.2.2 Peak differential output voltage and level distortion

When in transmit test mode 1 and observing the differential signal output at the MDI terminated in 100 Ω, preprocessed by the high pass filter defined below, for each pair, with no intervening cable, the absolute value of the peak of the waveform at points A and B as defined in Figure 32–17 shall fall within 1.71 V to 1.91 V (1.81 V ± 0.5 dB).

The absolute value of the peak of the waveforms at points A and B shall differ by less than 1%.

The absolute value of the peak of the waveform at points C and D as defined in Figure 32–17 shall differ from 0.5 times the average of the absolute values of the peaks of the waveform at points A and B by less than 2%.

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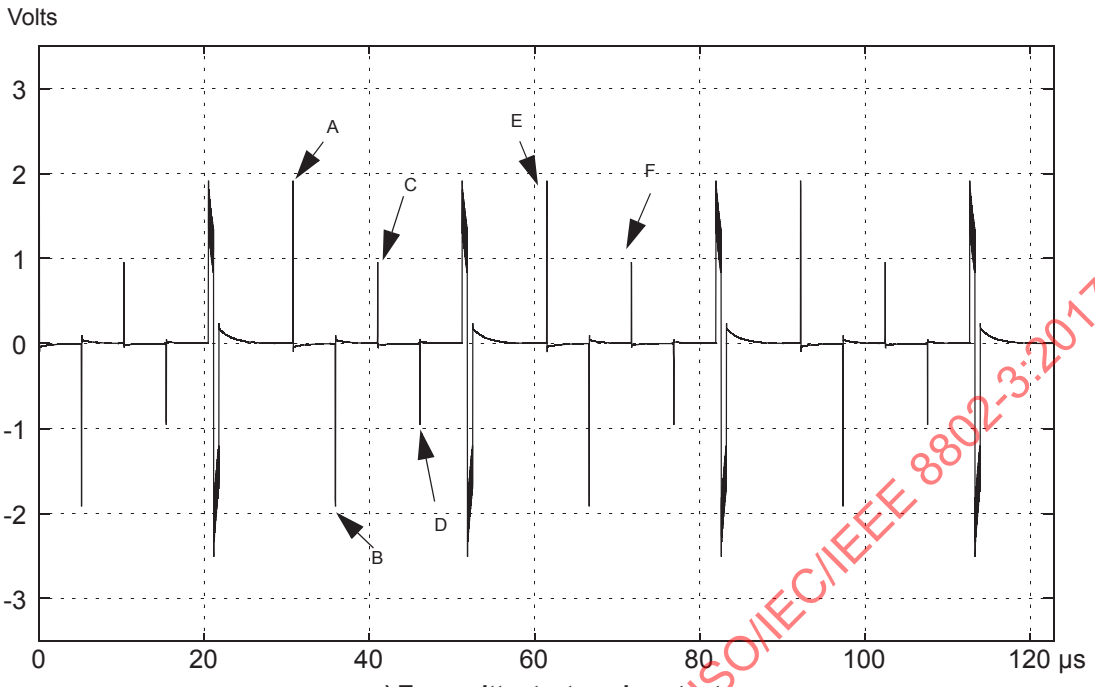
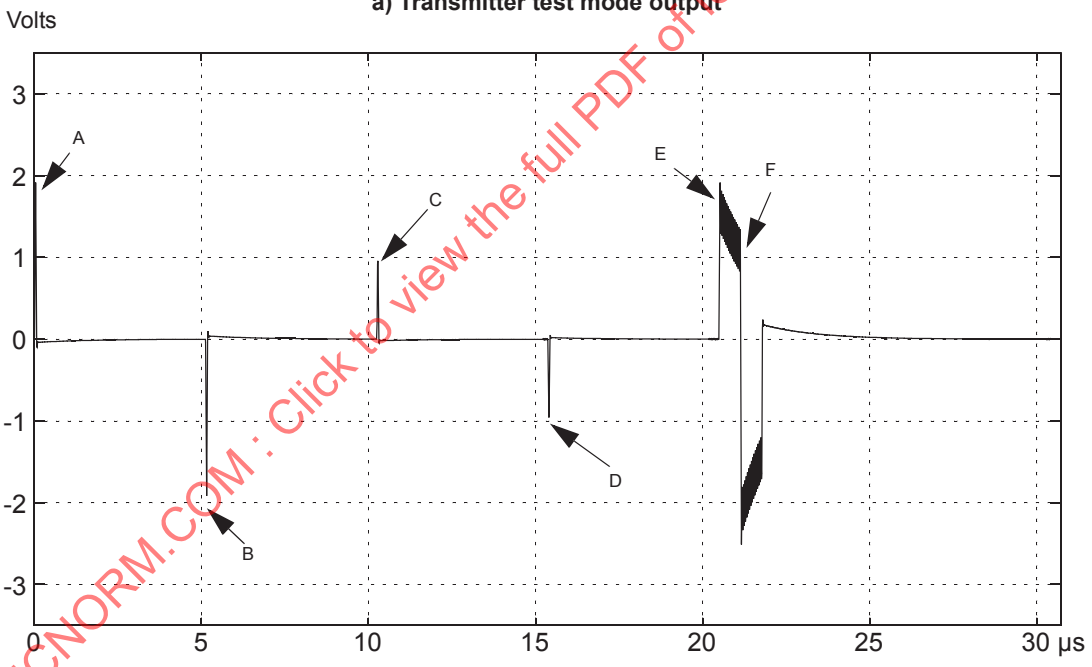


a) Transmitter test mode output



b) Expanded view of partial cycle of transmitter test mode output

Figure 32–17—Example transmitter test mode transmitter

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The preprocessing filter shall have the following transfer function:[13]

$$H_{\text{preprocess}}(f) = \frac{\mathrm{j}f}{\mathrm{j}f + 200 \times 10^3} \quad f \text{ in Hz}$$

32.6.1.2.3 Maximum output droop

When in transmit test mode 1 and observing the differential signal output at the MDI, for either pair, with no intervening cable, the peak value of the waveform at point F as defined in Figure 32–17 shall be greater than 70.5% of the peak value of the waveform at point E. A preprocessing filter is not used for this measurement.

32.6.1.2.4 Differential output templates

The transmitter differential output voltage shall be measured at the output of the high pass preprocessing filter defined in 32.6.1.2.2, with no intervening cables. The voltage waveforms A, B, C and D defined in Figure 32–17, after normalization by their respective peak values, shall lie within the time domain template defined in Figure 32–18 and the piecewise linear interpolation between the points in Table 32–9. The waveforms may be shifted in time as appropriate to fit within the template.

Additionally, the magnitude in dB of the Fourier transform of the preprocessed waveforms A, B, C and D shall lie within the frequency domain template defined in Figure 32–18 and the piecewise linear interpolation between the points in Table 32–9. The time span of the waveforms so processed shall be –80 ns to +2000 ns with the 0 ns point of the waveform aligned as for the time domain mask shown in Figure 32–18 and the magnitude of the Fourier transform should be normalized so that the maximum value is at 0 dB.[14]

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[13] "j" denotes the positive square root of –1.

[14] A sampling rate of 100 MHz is adequate to generate the frequency domain mask.

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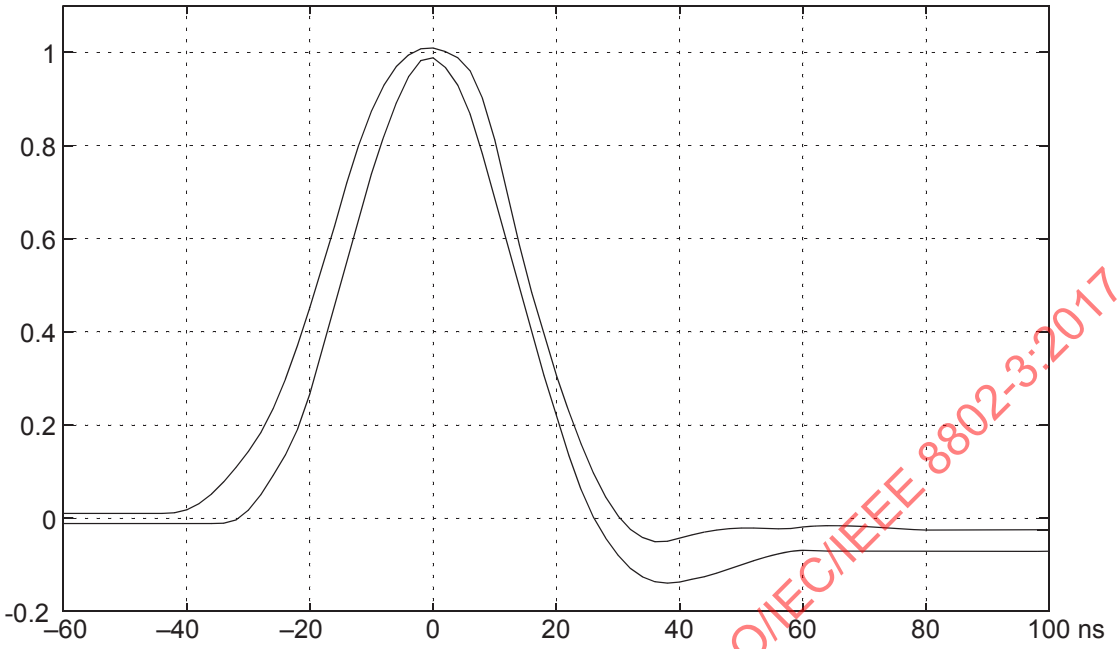
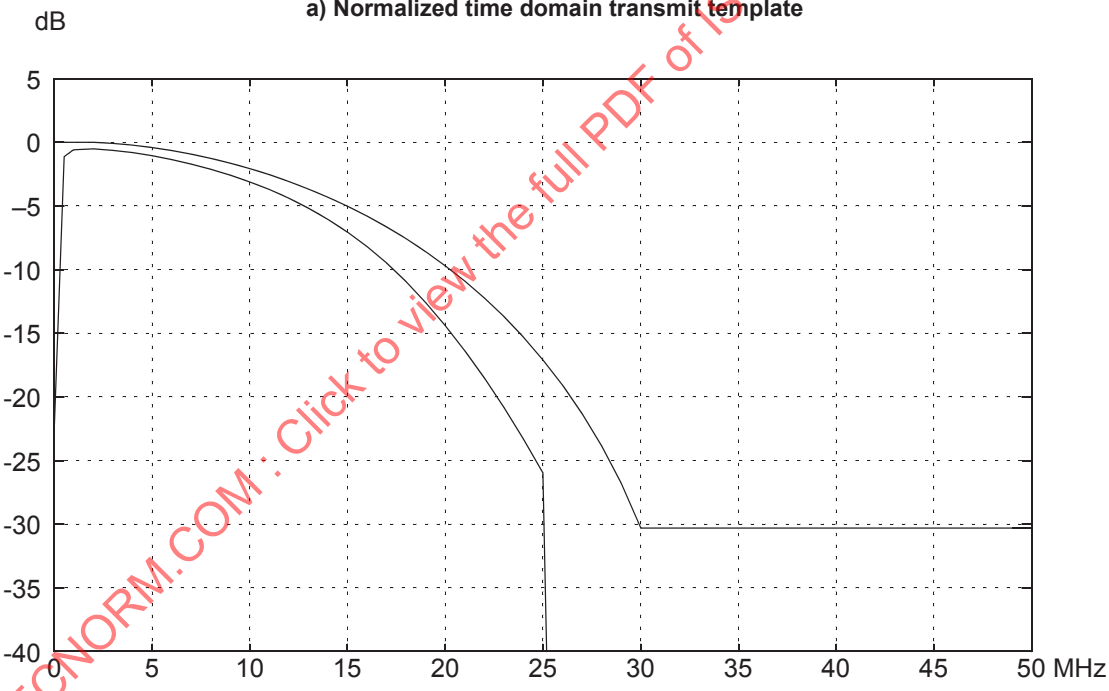


a) Normalized time domain transmit template



b) Normalized frequency domain transmit template

NOTE—The frequency domain transmit template is not intended to address electromagnetic radiation limits.

Figure 32–18—Normalized transmit templates as measured at MDI through preprocessing filter

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Table 32–9—Normalized time domain voltage template

Time, ns	Normalized transmit time domain template, upper limit	Normalized transmit time domain template, lower limit	Time, ns	Normalized transmit time domain template, upper limit	Normalized transmit time domain template, lower limit
–60	0.010	–0.011	22	0.230	0.136
–58	0.010	–0.011	24	0.160	0.062
–56	0.010	–0.011	26	0.097	0.002
–54	0.010	–0.011	28	0.045	–0.042
–52	0.010	–0.011	30	0.005	–0.079
–50	0.010	–0.011	32	–0.024	–0.108
–48	0.010	–0.011	34	–0.042	–0.126
–46	0.010	–0.011	36	–0.051	–0.136
–44	0.010	–0.011	38	–0.050	–0.139
–42	0.012	–0.011	40	–0.043	–0.137
–40	0.018	–0.011	42	–0.036	–0.131
–38	0.031	–0.011	44	–0.030	–0.126
–36	0.052	–0.011	46	–0.025	–0.118
–34	0.078	–0.011	48	–0.023	–0.109
–32	0.109	–0.004	50	–0.021	–0.100
–30	0.143	0.017	52	–0.021	–0.091
–28	0.184	0.050	54	–0.022	–0.084
–26	0.235	0.092	56	–0.023	–0.077
–24	0.298	0.136	58	–0.022	–0.071
–22	0.372	0.192	60	–0.019	–0.069
–20	0.453	0.268	62	–0.017	–0.070
–18	0.538	0.360	64	–0.016	–0.070
–16	0.627	0.461	66	–0.016	–0.071
–14	0.720	0.558	68	–0.017	–0.071
–12	0.804	0.650	70	–0.018	–0.071
–10	0.874	0.739	72	–0.020	–0.071
–8	0.930	0.820	74	–0.021	–0.071
–6	0.969	0.891	76	–0.023	–0.071
–4	0.995	0.948	78	–0.024	–0.070
–2	1.008	0.982	80	–0.026	–0.070
0	1.009	0.988	82	–0.025	–0.070

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Table 32–9—Normalized time domain voltage template *(continued)*

Time, ns	Normalized transmit time domain template, upper limit	Normalized transmit time domain template, lower limit	Time, ns	Normalized transmit time domain template, upper limit	Normalized transmit time domain template, lower limit
2	1.002	0.967	84	–0.025	–0.070
4	0.989	0.930	86	–0.025	–0.071
6	0.961	0.868	88	–0.025	–0.071
8	0.902	0.782	90	–0.025	–0.072
10	0.812	0.685	92	–0.025	–0.072
12	0.703	0.585	94	–0.025	–0.072
14	0.587	0.489	96	–0.025	–0.071
16	0.485	0.396	98	–0.025	–0.071
18	0.394	0.306	100	–0.025	–0.071
20	0.307	0.221			

Table 32–10—Normalized frequency domain amplitude spectrum template

Frequency, MHz	Normalized transmit frequency domain template, upper limit, dB	Normalized transmit frequency domain template, lower limit, dB	Frequency, MHz	Normalized transmit frequency domain template, upper limit, dB	Normalized transmit frequency domain template, lower limit, dB
0.1	0.00	–17.88	22	–12.24	–18.52
0.2	0.00	–13.49	23	–13.70	–20.84
0.3	0.00	–9.09	24	–15.31	–23.32
0.4	0.00	–4.70	25	–17.09	–25.97
0.5	0.00	–1.13	26	–19.08	
0.6	0.00	–1.01	27	–21.31	
0.7	0.00	–0.90	28	–23.84	
0.8	0.00	–0.78	29	–26.78	
0.9	0.00	–0.66	30	–30.29	
1	0.00	–0.59	31	–30.29	
2	–0.00	–0.52	32	–30.29	
3	–0.08	–0.63	33	–30.29	
4	–0.23	–0.82	34	–30.29	

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Table 32–10—Normalized frequency domain amplitude spectrum template *(continued)*

Frequency, MHz	Normalized transmit frequency domain template, upper limit, dB	Normalized transmit frequency domain template, lower limit, dB	Frequency, MHz	Normalized transmit frequency domain template, upper limit, dB	Normalized transmit frequency domain template, lower limit, dB
5	–0.42	–1.06	35	–30.29	
6	–0.65	–1.36	36	–30.29	
7	–0.93	–1.71	37	–30.29	
8	–1.26	–2.12	38	–30.29	
9	–1.64	–2.59	39	–30.29	
10	–2.07	–3.12	40	–30.29	
11	–2.55	–3.72	41	–30.29	
12	–3.08	–4.40	42	–30.29	
13	–3.67	–5.17	43	–30.29	
14	–4.31	–6.05	44	–30.29	
15	–5.03	–7.06	45	–30.29	
16	–5.80	–8.20	46	–30.29	
17	–6.65	–9.50	47	–30.29	
18	–7.58	–10.96	48	–30.29	
19	–8.59	–12.59	49	–30.29	
20	–9.70	–14.39	50	–30.29	
21	–10.91	–16.37			

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32.6.1.2.5 Transmitter timing jitter

When in transmit test mode 2, the peak-to-peak jitter of the zero crossings of the differential signal output at the MDI shall be less than 0.5 ns.

32.6.1.2.6 Transmit clock frequency

The quinary symbol transmission rate on each pair shall be 25.000 MHz ± 0.01%.

32.6.1.3 Receiver electrical specifications

The PMA shall provide the Receive function specified in 32.4.1.1.3 in accordance with the electrical specifications of this clause. The patch cabling and interconnecting hardware used in test configurations shall meet or exceed ISO/IEC 11801, Category 3 specifications.

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32.6.1.3.1 Test channel

To perform the Receiver Alien NEXT Tolerance test and Receiver timing jitter test described in this clause, a test channel including transmitter, cabling and NEXT models is required. This test channel is shown conceptually in Figure 32–19.

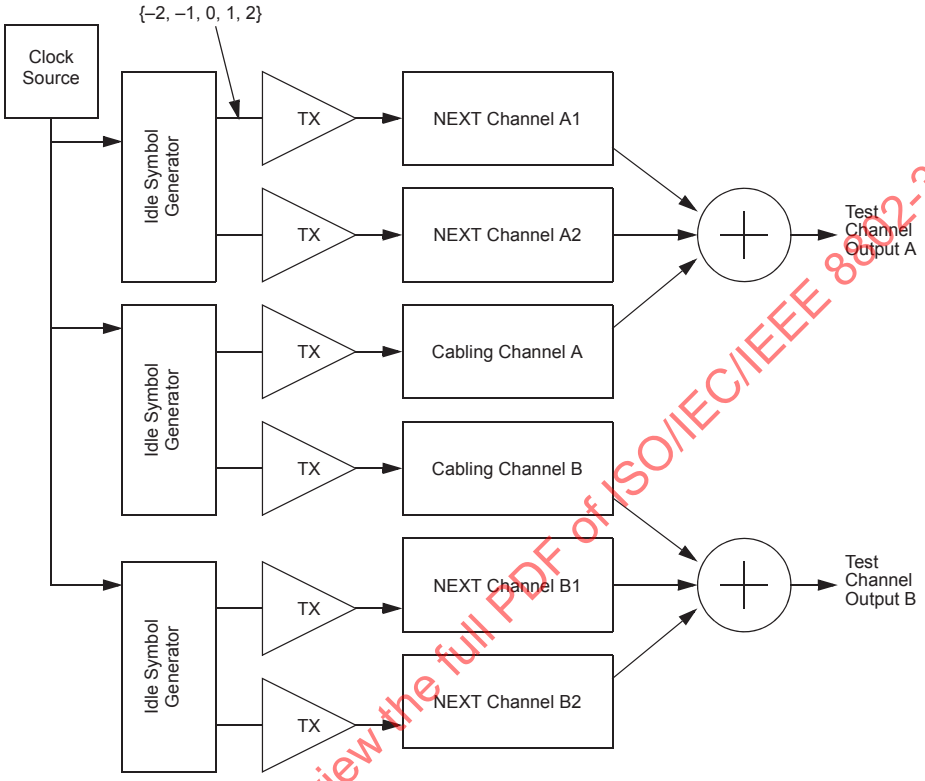

Figure 32–19—Conceptual diagram of test channel

The combined responses of the TX block and NEXT or cabling channel blocks shall be those defined in Table 32–8. The responses of Table 32–10 are shown in Figure 32–20. The responses represent the response of the test channel to isolated "1" symbols in a stream of "0" symbols at the input to the transmitter blocks. The test channel may also include a first order high pass filter with 3 dB cutoff frequency of less than 100 kHz in addition to the tabulated responses. The output impedance of the test channel shall be consistent with 32.6.1.4.1. The idle symbol generator outputs shall be conformant with the idle signaling specified in 32.3 with loc_rcvr_status=OK. The clock source shall result in a quinary symbol transmission rate conformant with 32.6.1.2.6. The peak-to-peak jitter on the clock source shall be less than 0.2 ns.

The test channel may be implemented in any fashion consistent with the above specifications and with the further constraint that the ratio of the squared error between the implemented NEXT channel symbol responses and the specified NEXT channel symbol responses to the energy in the specified NEXT channel symbol responses shall be less than 5% and the energy of the implemented NEXT channel symbol responses and the energy of the specified NEXT channel symbol responses shall differ by less than ± 0.25 dB. If digital filters are used to generate the channel characteristics, care must be taken to ensure that the signal to quantization noise at the channel output is greater than 35 dB.

The NEXT channel impulse responses defined in Table 32–11 have been developed to simulate the attenuation and phase characteristics of worst case 100BASE-T2 alien NEXT.

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The cabling attenuation and group delay characteristics used to derive the cable symbol responses specified in Table 32–8 at 0 m and 100 m are obtained from the following worst-case model of the cabling attenuation. The model includes 1.2 dB of flat loss simulating three worst-case Category 3 connectors. The group delay of the model is relative and does not include the fixed delay associated with 100 m of Category 3 cabling. An additional 570 ns of fixed delay should be added in order to obtain the absolute group delay; however, it is not necessary to add this fixed delay to the test channel.

$$\gamma(f) = -(1.537\times10^{-6}\sqrt{\pi f} + j1.537\times10^{-6}\sqrt{\pi f} + 44.5\times10^{-12}2\pi f)$$

$$H(f, l) = e^{\gamma(f)l}10^{-1.2/20}$$

f in Hz

Table 32–11—Coefficients for worst-case channel and T2 Alien NEXT model

Time (µs)	Cable 0 m	Cable 100 m	Alien NEXT 1	Alien NEXT 2	Alien NEXT 3	Alien NEXT 4
0.000	4.23e-06	1.48e-03	1.62e-05	1.19e-05	–5.05e-06	3.70e-05
0.004	–4.87e-06	1.55e-03	–5.97e-05	1.67e-05	6.71e-05	2.02e-05
0.008	–6.84e-06	1.62e-03	–8.19e-05	1.15e-05	9.78e-05	1.20e-05
0.012	–1.28e-05	1.69e-03	–3.79e-05	7.58e-06	6.43e-05	1.50e-05
0.016	3.56e-06	1.77e-03	4.53e-05	–1.47e-05	1.52e-06	6.51e-06
0.020	6.97e-06	1.86e-03	1.40e-04	–1.73e-05	–9.59e-05	–8.16e-06
0.024	1.68e-05	1.96e-03	1.86e-04	3.46e-05	–2.01e-04	–3.64e-05
0.028	8.73e-06	2.07e-03	1.07e-04	1.67e-04	–2.67e-04	–8.81e-05
0.032	–1.98e-05	2.19e-03	–2.56e-04	3.80e-04	–1.52e-04	–2.18e-04
0.036	–2.24e-05	2.33e-03	–1.10e-03	5.84e-04	3.94e-04	–5.53e-04
0.040	–2.95e-05	2.48e-03	–2.53e-03	7.54e-04	1.49e-03	–1.14e-03
0.044	3.65e-05	2.64e-03	–4.46e-03	8.74e-04	3.09e-03	–1.95e-03
0.048	7.11e-05	2.83e-03	–6.54e-03	9.73e-04	4.89e-03	–2.83e-03
0.052	6.30e-05	3.04e-03	–8.29e-03	1.13e-03	6.41e-03	–3.56e-03
0.056	–1.42e-04	3.27e-03	–9.25e-03	1.38e-03	7.24e-03	–3.97e-03
0.060	–4.49e-04	3.53e-03	–9.04e-03	1.93e-03	6.96e-03	–3.84e-03
0.064	–2.89e-04	3.87e-03	–7.53e-03	2.90e-03	5.37e-03	–3.06e-03
0.068	–2.72e-04	4.22e-03	–4.73e-03	4.32e-03	2.51e-03	–1.69e-03
0.072	–3.87e-04	4.55e-03	–9.82e-04	5.95e-03	–1.15e-03	–5.29e-05
0.076	–1.39e-04	5.09e-03	3.14e-03	7.23e-03	–4.72e-03	1.19e-03
0.080	4.92e-04	5.83e-03	6.98e-03	7.68e-03	–7.33e-03	1.50e-03
0.084	1.50e-03	6.70e-03	9.98e-03	6.90e-03	–8.27e-03	5.20e-04
0.088	9.97e-04	7.69e-03	1.19e-02	4.74e-03	–7.36e-03	–1.68e-03

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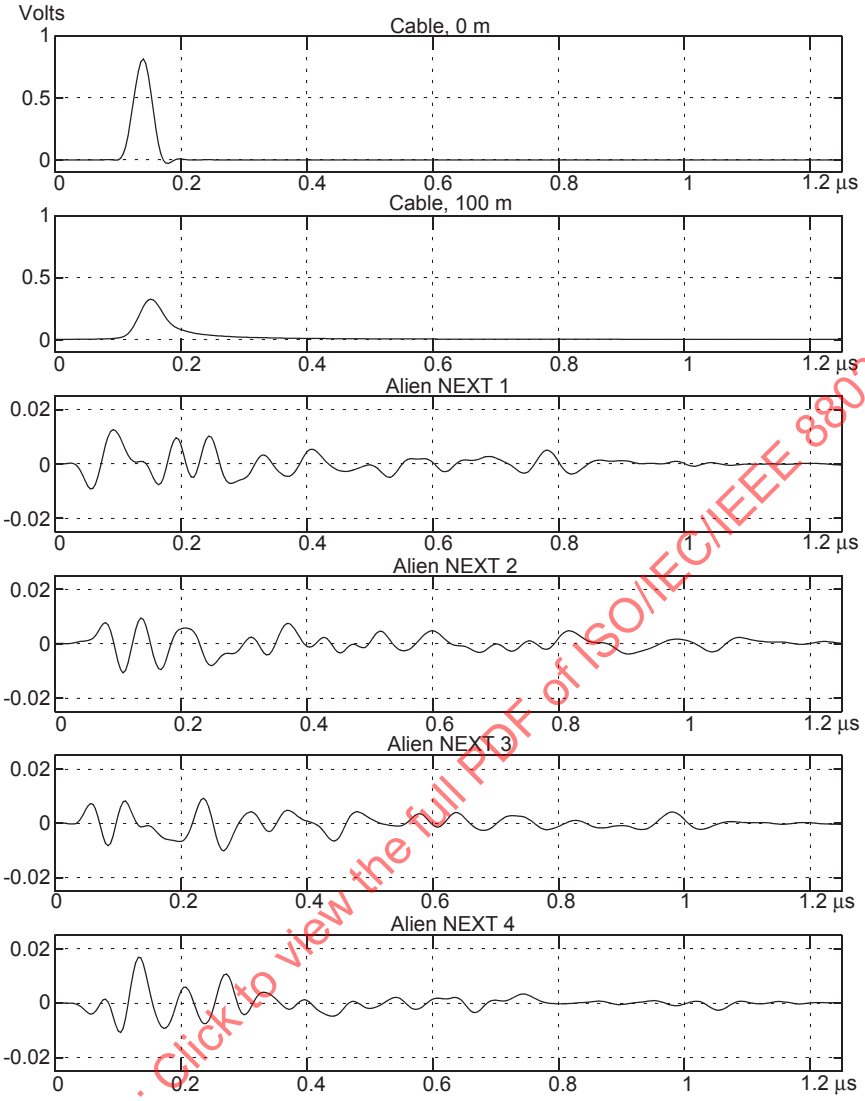

Figure 32–20—Test channel responses

Table 32–11—Coefficients for worst-case channel and T2 Alien NEXT model *(continued)*

Time (µs)	Cable 0 m	Cable 100 m	Alien NEXT 1	Alien NEXT 2	Alien NEXT 3	Alien NEXT 4
0.092	–1.45e-03	8.81e-03	1.26e-02	1.43e-03	–4.82e-03	–4.65e-03
0.096	–3.84e-03	1.04e-02	1.22e-02	–2.63e-03	–1.17e-03	–7.77e-03
0.100	–1.58e-03	1.27e-02	1.10e-02	–6.60e-03	2.75e-03	–1.01e-02
0.104	1.30e-02	1.64e-02	9.20e-03	–9.57e-03	6.05e-03	–1.08e-02
0.108	4.64e-02	2.27e-02	7.06e-03	–1.08e-02	7.97e-03	–9.32e-03
0.112	1.05e-01	3.30e-02	4.91e-03	–9.84e-03	8.20e-03	–5.54e-03

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Table 32–11—Coefficients for worst-case channel and T2 Alien NEXT model *(continued)*

Time (µs)	Cable 0 m	Cable 100 m	Alien NEXT 1	Alien NEXT 2	Alien NEXT 3	Alien NEXT 4
0.116	1.95e-01	4.93e-02	3.07e-03	–7.06e-03	7.00e-03	–2.20e-04
0.120	3.14e-01	7.28e-02	1.72e-03	–3.05e-03	4.92e-03	5.68e-03
0.124	4.54e-01	1.04e-01	9.15e-04	1.34e-03	2.63e-03	1.10e-02
0.128	5.95e-01	1.42e-01	6.23e-04	5.31e-03	6.32e-04	1.50e-02
0.132	7.15e-01	1.84e-01	6.67e-04	8.16e-03	–7.36e-04	1.69e-02
0.136	7.93e-01	2.28e-01	8.34e-04	9.39e-03	–1.30e-03	1.66e-02
0.140	8.15e-01	2.68e-01	7.62e-04	8.84e-03	–1.25e-03	1.44e-02
0.144	7.77e-01	3.01e-01	1.20e-04	6.66e-03	–9.31e-04	1.08e-02
0.148	6.83e-01	3.21e-01	–1.23e-03	3.32e-03	–8.01e-04	6.60e-03
0.152	5.49e-01	3.27e-01	–3.18e-03	–5.48e-04	–1.13e-03	2.50e-03
0.156	3.96e-01	3.20e-01	–5.26e-03	–4.29e-03	–1.86e-03	–1.22e-03
0.160	2.50e-01	3.01e-01	–6.94e-03	–7.31e-03	–2.84e-03	–4.34e-03
0.164	1.30e-01	2.73e-01	–7.68e-03	–9.17e-03	–3.84e-03	–6.80e-03
0.168	4.47e-02	2.40e-01	–7.12e-03	–9.59e-03	–4.72e-03	–8.47e-03
0.172	–5.75e-03	2.06e-01	–5.15e-03	–8.55e-03	–5.39e-03	–9.25e-03
0.176	–2.72e-02	1.75e-01	–1.95e-03	–6.26e-03	–5.80e-03	–9.17e-03
0.180	–2.85e-02	1.49e-01	1.90e-03	–3.26e-03	–6.01e-03	–8.19e-03
0.184	–1.82e-02	1.28e-01	5.60e-03	–1.83e-04	–6.13e-03	–6.35e-03
0.188	–5.94e-03	1.11e-01	8.37e-03	2.37e-03	–6.29e-03	–3.77e-03
0.192	2.81e-03	9.82e-02	9.58e-03	4.08e-03	–6.50e-03	–7.34e-04
0.196	6.25e-03	8.84e-02	9.06e-03	5.05e-03	–6.67e-03	2.21e-03
0.200	5.54e-03	8.06e-02	6.92e-03	5.49e-03	–6.65e-03	4.54e-03
0.204	3.70e-03	7.39e-02	3.66e-03	5.66e-03	–6.24e-03	5.81e-03
0.208	1.64e-03	6.80e-02	6.86e-05	5.68e-03	–5.26e-03	5.91e-03
0.212	5.59e-05	6.26e-02	–3.01e-03	5.52e-03	–3.62e-03	4.88e-03
0.216	–1.02e-03	5.77e-02	–4.83e-03	5.16e-03	–1.33e-03	2.95e-03
0.220	–1.53e-03	5.34e-02	–4.97e-03	4.40e-03	1.42e-03	4.48e-04
0.224	–9.73e-04	4.96e-02	–3.46e-03	3.07e-03	4.28e-03	–2.25e-03
0.228	–3.20e-04	4.63e-02	–6.22e-04	1.04e-03	6.85e-03	–4.71e-03
0.232	2.89e-05	4.33e-02	2.90e-03	–1.55e-03	8.65e-03	–6.56e-03
0.236	1.73e-04	4.06e-02	6.35e-03	–4.20e-03	9.24e-03	–7.53e-03
0.240	1.33e-04	3.83e-02	8.95e-03	–6.40e-03	8.35e-03	–7.48e-03
0.244	1.39e-04	3.62e-02	1.02e-02	–7.73e-03	5.99e-03	–6.40e-03

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Table 32–11—Coefficients for worst-case channel and T2 Alien NEXT model *(continued)*

Time (µs)	Cable 0 m	Cable 100 m	Alien NEXT 1	Alien NEXT 2	Alien NEXT 3	Alien NEXT 4
0.248	9.80e-05	3.42e-02	9.77e-03	–8.11e-03	2.56e-03	–4.30e-03
0.252	4.22e-05	3.25e-02	7.90e-03	–7.70e-03	–1.34e-03	–1.35e-03
0.256	–2.56e-06	3.08e-02	4.95e-03	–6.76e-03	–5.02e-03	2.14e-03
0.260	–3.84e-05	2.93e-02	1.50e-03	–5.62e-03	–7.91e-03	5.67e-03
0.264	–2.83e-05	2.80e-02	–1.85e-03	–4.58e-03	–9.67e-03	8.59e-03
0.268	–2.41e-05	2.67e-02	–4.54e-03	-3.89e-03	–1.01e-02	1.04e-02
0.272	–8.46e-06	2.55e-02	–6.29e-03	–3.61e-03	–9.30e-03	1.08e-02
0.276	4.04e-07	2.44e-02	–7.13e-03	–3.62e-03	–7.62e-03	9.78e-03
0.280	4.91e-06	2.34e-02	–7.25e-03	–3.70e-03	–5.51e-03	7.51e-03
0.284	1.01e-05	2.24e-02	–6.97e-03	–3.61e-03	–3.40e-03	4.44e-03
0.288	3.79e-06	2.15e-02	–6.54e-03	–3.18e-03	–1.47e-03	1.18e-03
0.292	2.18e-06	2.07e-02	–6.11e-03	–2.37e-03	2.01e-04	–1.65e-03
0.296	–2.23e-06	1.99e-02	–5.78e-03	–1.23e-03	1.62e-03	–3.54e-03
0.300	–1.74e-06	1.92e-02	–5.43e-03	6.10e-05	2.78e-03	–4.28e-03
0.304	4.33e-07	1.85e-02	–4.87e-03	1.26e-03	3.62e-03	–3.93e-03
0.308	2.19e-07	1.79e-02	–3.88e-03	2.10e-03	4.14e-03	–2.74e-03
0.312	1.40e-06	1.73e-02	–2.42e-03	2.37e-03	4.25e-03	–1.08e-03
0.316	–5.61e-07	1.67e-02	–7.17e-04	1.97e-03	3.87e-03	6.99e-04
0.320	–4.40e-07	1.62e-02	9.57e-04	9.16e-04	2.95e-03	2.25e-03
0.324	–4.37e-07	1.56e-02	2.28e-03	–5.89e-04	1.53e-03	3.34e-03
0.328	–3.68e-08	1.51e-02	3.07e-03	–2.20e-03	–8.99e-05	3.92e-03
0.332	9.92e-07	1.47e-02	3.23e-03	–3.52e-03	–1.59e-03	4.04e-03
0.336	5.29e-07	1.43e-02	2.74e-03	–4.19e-03	–2.63e-03	3.85e-03
0.340	5.69e-07	1.38e-02	1.73e-03	–4.00e-03	–3.00e-03	3.44e-03
0.344	–1.87e-07	1.34e-02	4.38e-04	–2.97e-03	–2.62e-03	2.85e-03
0.348	–3.47e-07	1.31e-02	–8.80e-04	–1.22e-03	–1.53e-03	2.11e-03
0.352	–9.04e-08	1.27e-02	–2.04e-03	9.56e-04	5.06e-05	1.27e-03
0.356	8.10e-08	1.24e-02	–3.01e-03	3.22e-03	1.79e-03	3.65e-04
0.360	5.29e-07	1.20e-02	–3.78e-03	5.22e-03	3.32e-03	–5.53e-04
0.364	3.23e-07	1.17e-02	–4.36e-03	6.64e-03	4.36e-03	–1.41e-03
0.368	1.82e-07	1.14e-02	–4.67e-03	7.34e-03	4.82e-03	–2.03e-03
0.372	–6.93e-08	1.11e-02	–4.60e-03	7.31e-03	4.75e-03	–2.26e-03
0.376	–1.46e-07	1.09e-02	–4.11e-03	6.65e-03	4.31e-03	–1.98e-03

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Table 32–11—Coefficients for worst-case channel and T2 Alien NEXT model *(continued)*

Time (µs)	Cable 0 m	Cable 100 m	Alien NEXT 1	Alien NEXT 2	Alien NEXT 3	Alien NEXT 4
0.380	6.66e-08	1.06e-02	–3.17e-03	5.50e-03	3.64e-03	–1.29e-03
0.384	1.71e-07	1.03e-02	–1.84e-03	4.02e-03	2.88e-03	–3.97e-04
0.388	3.12e-07	1.01e-02	–2.24e-04	2.44e-03	2.18e-03	4.68e-04
0.392	1.95e-07	9.86e-03	1.51e-03	9.58e-04	1.59e-03	1.07e-03
0.396	5.86e-08	9.64e-03	3.13e-03	–2.37e-04	1.17e-03	1.30e-03
0.400	–2.48e-08	9.43e-03	4.40e-03	–1.02e-03	8.60e-04	1.08e-03
0.404	–3.03e-08	9.22e-03	5.16e-03	–1.34e-03	5.83e-04	4.43e-04
0.408	1.02e-07	9.02e-03	5.37e-03	–1.16e-03	2.87e-04	–4.57e-04
0.412	1.68e-07	8.83e-03	5.08e-03	–5.37e-04	-8.75e-05	–1.43e-03
0.416	1.93e-07	8.64e-03	4.41e-03	4.06e-04	–5.80e-04	–2.27e-03
0.420	1.20e-07	8.46e-03	3.49e-03	1.39e-03	–1.26e-03	–2.94e-03
0.424	3.01e-08	8.29e-03	2.45e-03	2.10e-03	–2.18e-03	–3.47e-03
0.428	5.52e-09	8.12e-03	1.40e-03	2.28e-03	–3.31e-03	–3.92e-03
0.432	2.95e-08	7.96e-03	4.39e-04	1.83e-03	–4.53e-03	–4.33e-03
0.436	1.05e-07	7.80e-03	–4.02e-04	8.46e-04	–5.62e-03	–4.64e-03
0.440	1.40e-07	7.65e-03	–1.11e-03	–4.79e-04	–6.34e-03	–4.79e-03
0.444	1.27e-07	7.51e-03	–1.71e-03	–1.86e-03	–6.51e-03	–4.72e-03
0.448	7.69e-08	7.37e-03	–2.18e-03	–2.95e-03	–6.01e-03	–4.34e-03
0.452	2.73e-08	7.23e-03	–2.53e-03	–3.49e-03	–4.88e-03	–3.66e-03
0.456	2.59e-08	7.10e-03	–2.75e-03	–3.31e-03	–3.20e-03	–2.68e-03
0.460	5.54e-08	6.97e-03	–2.83e-03	–2.57e-03	–1.24e-03	–1.56e-03
0.464	9.74e-08	6.85e-03	–2.80e-03	–1.60e-03	7.13e-04	–5.10e-04
0.468	1.11e-07	6.73e-03	–2.65e-03	–7.72e-04	2.36e-03	2.70e-04
0.472	8.93e-08	6.61e-03	–2.40e-03	–3.48e-04	3.50e-03	6.40e-04
0.476	5.48e-08	6.49e-03	–2.08e-03	–3.49e-04	4.12e-03	6.10e-04
0.480	3.08e-08	6.39e-03	–1.72e-03	–6.97e-04	4.26e-03	2.42e-04
0.484	3.87e-08	6.28e-03	–1.36e-03	–1.18e-03	4.05e-03	–3.37e-04
0.488	6.37e-08	6.17e-03	–1.02e-03	–1.52e-03	3.61e-03	–9.74e-04
0.492	8.60e-08	6.07e-03	–7.22e-04	–1.45e-03	3.03e-03	–1.52e-03
0.496	8.68e-08	5.98e-03	–5.08e-04	–7.85e-04	2.45e-03	–1.85e-03
0.500	6.64e-08	5.88e-03	–4.43e-04	4.01e-04	1.89e-03	–1.94e-03
0.504	4.41e-08	5.79e-03	–6.03e-04	1.84e-03	1.38e-03	–1.81e-03
0.508	3.47e-08	5.70e-03	–1.02e-03	3.19e-03	9.06e-04	–1.54e-03

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Table 32–11—Coefficients for worst-case channel and T2 Alien NEXT model *(continued)*

Time (µs)	Cable 0 m	Cable 100 m	Alien NEXT 1	Alien NEXT 2	Alien NEXT 3	Alien NEXT 4
0.512	4.54e-08	5.61e-03	–1.69e-03	4.14e-03	4.56e-04	–1.20e-03
0.516	6.35e-08	5.52e-03	–2.55e-03	4.57e-03	6.45e-05	–7.70e-04
0.520	7.41e-08	5.44e-03	–3.47e-03	4.40e-03	–2.43e-04	–2.64e-04
0.524	6.88e-08	5.36e-03	–4.30e-03	3.69e-03	–4.49e-04	3.11e-04
0.528	5.25e-08	5.28e-03	–4.86e-03	2.59e-03	–5.97e-04	9.07e-04
0.532	3.91e-08	5.20e-03	–4.98e-03	1.30e-03	–7.31e-04	1.46e-03
0.536	3.76e-08	5.13e-03	–4.57e-03	4.15e-05	–8.65e-04	1.90e-03
0.540	4.78e-08	5.05e-03	–3.67e-03	–1.04e-03	–9.88e-04	2.14e-03
0.544	5.97e-08	4.98e-03	–2.47e-03	–1.87e-03	–1.04e-03	2.11e-03
0.548	6.32e-08	4.91e-03	–1.16e-03	–2.42e-03	–9.79e-04	1.74e-03
0.552	5.59e-08	4.84e-03	4.24e-05	–2.70e-03	–7.35e-04	1.07e-03
0.556	4.40e-08	4.78e-03	9.93e-04	–2.70e-03	–2.60e-04	2.15e-04
0.560	3.68e-08	4.71e-03	1.60e-03	–2.43e-03	4.47e-04	–6.81e-04
0.564	3.90e-08	4.65e-03	1.85e-03	–1.93e-03	1.33e-03	–1.46e-03
0.568	4.74e-08	4.59e-03	1.86e-03	–1.22e-03	2.25e-03	–2.02e-03
0.572	5.44e-08	4.53e-03	1.78e-03	–3.47e-04	3.03e-03	–2.28e-03
0.576	5.40e-08	4.47e-03	1.74e-03	6.36e-04	3.49e-03	–2.22e-03
0.580	4.68e-08	4.41e-03	1.79e-03	1.66e-03	3.55e-03	–1.86e-03
0.584	3.86e-08	4.36e-03	1.86e-03	2.66e-03	3.17e-03	–1.27e-03
0.588	3.55e-08	4.30e-03	1.85e-03	3.54e-03	2.41e-03	–5.17e-04
0.592	3.92e-08	4.25e-03	1.67e-03	4.23e-03	1.41e-03	2.65e-04
0.596	4.55e-08	4.19e-03	1.23e-03	4.64e-03	3.37e-04	9.51e-04
0.600	4.89e-08	4.14e-03	5.18e-04	4.74e-03	-6.03e-04	1.45e-03
0.604	4.65e-08	4.09e-03	–4.25e-04	4.50e-03	–1.23e-03	1.72e-03
0.608	4.03e-08	4.04e-03	–1.43e-03	3.96e-03	–1.42e-03	1.79e-03
0.612	3.52e-08	3.99e-03	–2.30e-03	3.21e-03	–1.13e-03	1.73e-03
0.616	3.46e-08	3.95e-03	–2.85e-03	2.33e-03	–4.11e-04	1.62e-03
0.620	3.84e-08	3.90e-03	–2.96e-03	1.44e-03	6.15e-04	1.56e-03
0.624	4.26e-08	3.86e-03	–2.66e-03	6.40e-04	1.76e-03	1.61e-03
0.628	4.37e-08	3.81e-03	–2.01e-03	1.25e-05	2.81e-03	1.78e-03
0.632	4.06e-08	3.77e-03	–1.16e-03	–4.14e-04	3.60e-03	2.01e-03
0.636	3.58e-08	3.72e-03	–2.62e-04	–6.60e-04	4.00e-03	2.11e-03
0.640	3.29e-08	3.68e-03	5.11e-04	–7.79e-04	3.95e-03	1.94e-03

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Table 32–11—Coefficients for worst-case channel and T2 Alien NEXT model *(continued)*

Time (µs)	Cable 0 m	Cable 100 m	Alien NEXT 1	Alien NEXT 2	Alien NEXT 3	Alien NEXT 4
0.644	3.37e-08	3.64e-03	1.04e-03	–8.48e-04	3.47e-03	1.38e-03
0.648	3.69e-08	3.60e-03	1.32e-03	–9.56e-04	2.68e-03	4.76e-04
0.652	3.95e-08	3.56e-03	1.38e-03	–1.17e-03	1.71e-03	–6.44e-04
0.656	3.91e-08	3.52e-03	1.32e-03	–1.52e-03	7.06e-04	–1.80e-03
0.660	3.60e-08	3.48e-03	1.24e-03	–1.97e-03	–2.19e-04	–2.78e-03
0.664	3.25e-08	3.45e-03	1.22e-03	–2.47e-03	–1.02e-03	–3.39e-03
0.668	3.12e-08	3.41e-03	1.34e-03	–2.93e-03	–1.66e-03	–3.51e-03
0.672	3.26e-08	3.38e-03	1.58e-03	–3.22e-03	–2.14e-03	–3.12e-03
0.676	3.51e-08	3.34e-03	1.92e-03	–3.27e-03	–2.45e-03	–2.36e-03
0.680	3.64e-08	3.31e-03	2.26e-03	–3.01e-03	–2.58e-03	–1.40e-03
0.684	3.52e-08	3.27e-03	2.53e-03	–2.48e-03	–2.54e-03	–4.72e-04
0.688	3.24e-08	3.24e-03	2.67e-03	–1.77e-03	–2.30e-03	2.96e-04
0.692	3.01e-08	3.21e-03	2.66e-03	–1.04e-03	–1.85e-03	8.20e-04
0.696	2.98e-08	3.17e-03	2.47e-03	–4.69e-04	–1.20e-03	1.07e-03
0.700	3.13e-08	3.14e-03	2.17e-03	–1.76e-04	–4.09e-04	1.10e-03
0.704	3.31e-08	3.11e-03	1.78e-03	–2.25e-04	4.27e-04	9.85e-04
0.708	3.34e-08	3.08e-03	1.38e-03	–6.12e-04	1.21e-03	8.49e-04
0.712	3.19e-08	3.05e-03	9.74e-04	–1.24e-03	1.87e-03	7.97e-04
0.716	2.96e-08	3.02e-03	5.40e-04	–1.94e-03	2.35e-03	8.91e-04
0.720	2.83e-08	2.99e-03	4.50e-05	–2.52e-03	2.66e-03	1.15e-03
0.724	2.86e-08	2.96e-03	–5.39e-04	–2.82e-03	2.80e-03	1.56e-03
0.728	2.99e-08	2.94e-03	–1.21e-03	–2.76e-03	2.82e-03	2.06e-03
0.732	3.10e-08	2.91e-03	–1.93e-03	–2.34e-03	2.78e-03	2.56e-03
0.736	3.07e-08	2.88e-03	–2.63e-03	–1.64e-03	2.70e-03	2.99e-03
0.740	2.91e-08	2.86e-03	–3.19e-03	–8.03e-04	2.59e-03	3.27e-03
0.744	2.75e-08	2.83e-03	–3.49e-03	2.08e-05	2.40e-03	3.36e-03
0.748	2.68e-08	2.80e-03	–3.41e-03	6.61e-04	2.08e-03	3.25e-03
0.752	2.74e-08	2.78e-03	–2.90e-03	9.96e-04	1.62e-03	2.96e-03
0.756	2.85e-08	2.75e-03	–1.98e-03	9.72e-04	1.01e-03	2.54e-03
0.760	2.89e-08	2.73e-03	–7.19e-04	6.06e-04	3.03e-04	2.04e-03
0.764	2.83e-08	2.71e-03	7.27e-04	–1.29e-05	–4.51e-04	1.55e-03
0.768	2.69e-08	2.68e-03	2.19e-03	–7.52e-04	–1.17e-03	1.09e-03
0.772	2.57e-08	2.66e-03	3.49e-03	–1.45e-03	–1.76e-03	6.97e-04

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Table 32–11—Coefficients for worst-case channel and T2 Alien NEXT model *(continued)*

Time (µs)	Cable 0 m	Cable 100 m	Alien NEXT 1	Alien NEXT 2	Alien NEXT 3	Alien NEXT 4
0.776	2.55e-08	2.64e-03	4.45e-03	–1.95e-03	–2.16e-03	3.84e-04
0.780	2.62e-08	2.61e-03	4.96e-03	–2.13e-03	–2.35e-03	1.50e-04
0.784	2.70e-08	2.59e-03	4.94e-03	–1.91e-03	–2.33e-03	–9.21e-06
0.788	2.70e-08	2.57e-03	4.41e-03	–1.30e-03	–2.16e-03	–1.09e-04
0.792	2.62e-08	2.55e-03	3.43e-03	–3.53e-04	–1.88e-03	–1.67e-04
0.796	2.50e-08	2.53e-03	2.14e-03	7.94e-04	–1.52e-03	–1.97e-04
0.800	2.43e-08	2.51e-03	6.97e-04	1.99e-03	–1.11e-03	–2.12e-04
0.804	2.44e-08	2.48e-03	–7.29e-04	3.07e-03	–6.76e-04	–2.16e-04
0.808	2.50e-08	2.46e-03	–1.98e-03	3.92e-03	–2.42e-04	–2.11e-04
0.812	2.55e-08	2.44e-03	–2.95e-03	4.47e-03	1.71e-04	–1.93e-04
0.816	2.52e-08	2.43e-03	–3.56e-03	4.69e-03	5.47e-04	–1.58e-04
0.820	2.44e-08	2.41e-03	–3.79e-03	4.59e-03	8.49e-04	–1.06e-04
0.824	2.35e-08	2.39e-03	–3.68e-03	4.24e-03	1.04e-03	–4.15e-05
0.828	2.31e-08	2.37e-03	–3.29e-03	3.71e-03	1.09e-03	3.17e-05
0.832	2.34e-08	2.35e-03	–2.72e-03	3.10e-03	9.78e-04	1.09e-04
0.836	2.38e-08	2.33e-03	–2.02e-03	2.46e-03	7.26e-04	1.89e-04
0.840	2.40e-08	2.31e-03	–1.28e-03	1.85e-03	3.61e-04	2.70e-04
0.844	2.36e-08	2.29e-03	–5.54e-04	1.30e-03	–7.48e-05	3.50e-04
0.848	2.29e-08	2.28e-03	9.66e-05	8.67e-04	–5.29e-04	4.35e-04
0.852	2.22e-08	2.26e-03	6.28e-04	5.63e-04	–9.51e-04	5.28e-04
0.856	2.21e-08	2.24e-03	1.02e-03	3.91e-04	–1.30e-03	6.25e-04
0.860	2.24e-08	2.23e-03	1.26e-03	3.27e-04	–1.54e-03	7.05e-04
0.864	2.27e-08	2.21e-03	1.35e-03	3.18e-04	–1.67e-03	7.38e-04
0.868	2.27e-08	2.19e-03	1.32e-03	3.13e-04	–1.71e-03	7.00e-04
0.872	2.22e-08	2.18e-03	1.20e-03	2.49e-04	–1.65e-03	5.79e-04
0.876	2.15e-08	2.16e-03	1.06e-03	6.50e-05	–1.54e-03	3.86e-04
0.880	2.11e-08	2.15e-03	9.49e-04	–2.75e-04	–1.39e-03	1.42e-04
0.884	2.11e-08	2.13e-03	9.05e-04	–7.77e-04	–1.23e-03	–1.19e-04
0.888	2.14e-08	2.11e-03	9.32e-04	–1.40e-03	–1.08e-03	–3.50e-04
0.892	2.16e-08	2.10e-03	1.01e-03	–2.06e-03	–9.51e-04	–5.12e-04
0.896	2.14e-08	2.08e-03	1.10e-03	–2.69e-03	–8.58e-04	–5.74e-04
0.900	2.09e-08	2.07e-03	1.17e-03	–3.22e-03	–8.19e-04	–5.37e-04
0.904	2.04e-08	2.06e-03	1.17e-03	–3.60e-03	–8.53e-04	–4.30e-04

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Table 32–11—Coefficients for worst-case channel and T2 Alien NEXT model *(continued)*

Time (µs)	Cable 0 m	Cable 100 m	Alien NEXT 1	Alien NEXT 2	Alien NEXT 3	Alien NEXT 4
0.908	2.02e-08	2.04e-03	1.07e-03	–3.81e-03	–9.70e-04	–2.86e-04
0.912	2.02e-08	2.03e-03	8.84e-04	–3.86e-03	–1.17e-03	–1.38e-04
0.916	2.05e-08	2.01e-03	6.43e-04	–3.76e-03	–1.43e-03	–3.73e-06
0.920	2.05e-08	2.00e-03	4.00e-04	–3.57e-03	–1.72e-03	1.07e-04
0.924	2.03e-08	1.99e-03	2.04e-04	–3.32e-03	–2.00e-03	1.97e-04
0.928	1.98e-08	1.97e-03	8.04e-05	–3.05e-03	–2.21e-03	2.83e-04
0.932	1.94e-08	1.96e-03	3.54e-05	–2.77e-03	–2.31e-03	3.84e-04
0.936	1.93e-08	1.95e-03	6.11e-05	–2.49e-03	–2.25e-03	5.12e-04
0.940	1.94e-08	1.93e-03	1.19e-04	–2.19e-03	–2.02e-03	6.60e-04
0.944	1.96e-08	1.92e-03	1.68e-04	–1.87e-03	–1.61e-03	7.99e-04
0.948	1.95e-08	1.91e-03	1.69e-04	–1.51e-03	–1.04e-03	8.98e-04
0.952	1.92e-08	1.90e-03	1.12e-04	–1.11e-03	–3.35e-04	9.23e-04
0.956	1.88e-08	1.88e-03	3.20e-05	–6.75e-04	4.63e-04	8.56e-04
0.960	1.86e-08	1.87e-03	–3.29e-05	–2.21e-04	1.31e-03	6.88e-04
0.964	1.85e-08	1.86e-03	–3.97e-05	2.28e-04	2.16e-03	4.27e-04
0.968	1.86e-08	1.85e-03	3.82e-05	6.47e-04	2.94e-03	1.05e-04
0.972	1.87e-08	1.84e-03	2.03e-04	1.01e-03	3.58e-03	–2.35e-04
0.976	1.86e-08	1.82e-03	4.37e-04	1.30e-03	4.03e-03	–5.42e-04
0.980	1.83e-08	1.81e-03	6.79e-04	1.50e-03	4.23e-03	–7.76e-04
0.984	1.80e-08	1.80e-03	8.54e-04	1.61e-03	4.14e-03	–9.10e-04
0.988	1.78e-08	1.79e-03	8.92e-04	1.65e-03	3.77e-03	–9.27e-04
0.992	1.78e-08	1.78e-03	7.59e-04	1.61e-03	3.13e-03	–8.27e-04
0.996	1.79e-08	1.77e-03	4.78e-04	1.51e-03	2.31e-03	–6.23e-04
1.000	1.79e-08	1.76e-03	9.92e-05	1.35e-03	1.38e-03	–3.43e-04
1.004	1.77e-08	1.75e-03	–3.03e-04	1.14e-03	4.42e-04	–2.81e-05
1.008	1.74e-08	1.74e-03	–6.46e-04	8.71e-04	–4.26e-04	2.80e-04
1.012	1.72e-08	1.73e-03	–8.64e-04	5.31e-04	–1.16e-03	5.35e-04
1.016	1.71e-08	1.71e-03	–9.09e-04	1.17e-04	–1.71e-03	6.95e-04
1.020	1.71e-08	1.70e-03	–7.85e-04	–3.71e-04	–2.06e-03	7.20e-04
1.024	1.72e-08	1.69e-03	–5.39e-04	–9.22e-04	–2.21e-03	5.83e-04
1.028	1.71e-08	1.68e-03	–2.39e-04	–1.51e-03	–2.20e-03	2.80e-04
1.032	1.69e-08	1.67e-03	4.62e-05	–2.08e-03	–2.04e-03	–1.70e-04
1.036	1.67e-08	1.66e-03	2.68e-04	–2.58e-03	–1.78e-03	–7.21e-04

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Table 32–11—Coefficients for worst-case channel and T2 Alien NEXT model *(continued)*

Time (µs)	Cable 0 m	Cable 100 m	Alien NEXT 1	Alien NEXT 2	Alien NEXT 3	Alien NEXT 4
1.040	1.65e-08	1.66e-03	3.93e-04	–2.92e-03	–1.45e-03	–1.31e-03
1.044	1.65e-08	1.65e-03	4.08e-04	–3.07e-03	–1.08e-03	–1.86e-03
1.048	1.65e-08	1.64e-03	3.24e-04	–2.97e-03	–6.97e-04	–2.29e-03
1.052	1.65e-08	1.63e-03	1.64e-04	-2.62e-03	-3.38e-04	-2.53e-03
1.056	1.64e-08	1.62e-03	–2.93e-05	–2.04e-03	–2.07e-05	–2.54e-03
1.060	1.62e-08	1.61e-03	–2.24e-04	–1.30e-03	2.39e-04	–2.32e-03
1.064	1.60e-08	1.60e-03	–3.91e-04	–4.72e-04	4.34e-04	–1.91e-03
1.068	1.59e-08	1.59e-03	–5.13e-04	3.49e-04	5.60e-04	–1.37e-03
1.072	1.59e-08	1.58e-03	–5.79e-04	1.08e-03	6.21e-04	–7.75e-04
1.076	1.59e-08	1.57e-03	–5.84e-04	1.66e-03	6.27e-04	–2.13e-04
1.080	1.59e-08	1.56e-03	–5.35e-04	2.04e-03	5.90e-04	2.42e-04
1.084	1.57e-08	1.56e-03	–4.46e-04	2.24e-03	5.24e-04	5.43e-04
1.088	1.55e-08	1.55e-03	–3.40e-04	2.26e-03	4.42e-04	6.80e-04
1.092	1.54e-08	1.54e-03	–2.40e-04	2.14e-03	3.58e-04	6.70e-04
1.096	1.53e-08	1.53e-03	–1.64e-04	1.95e-03	2.82e-04	5.53e-04
1.100	1.53e-08	1.52e-03	–1.21e-04	1.72e-03	2.23e-04	3.73e-04
1.104	1.53e-08	1.51e-03	–1.09e-04	1.48e-03	1.90e-04	1.72e-04
1.108	1.53e-08	1.51e-03	–1.19e-04	1.27e-03	1.85e-04	–1.10e-05
1.112	1.51e-08	1.50e-03	–1.38e-04	1.09e-03	2.03e-04	–1.51e-04
1.116	1.49e-08	1.49e-03	–1.54e-04	9.49e-04	2.33e-04	–2.31e-04
1.120	1.48e-08	1.48e-03	–1.57e-04	8.36e-04	2.60e-04	–2.52e-04
1.124	1.48e-08	1.47e-03	–1.42e-04	7.46e-04	2.72e-04	–2.18e-04
1.128	1.48e-08	1.47e-03	–1.14e-04	6.77e-04	2.53e-04	–1.33e-04
1.132	1.48e-08	1.46e-03	–8.40e-05	6.30e-04	1.95e-04	–6.35e-06
1.136	1.47e-08	1.45e-03	–6.31e-05	6.05e-04	9.72e-05	1.50e-04
1.140	1.45e-08	1.44e-03	–5.84e-05	5.99e-04	–2.78e-05	3.12e-04
1.144	1.44e-08	1.44e-03	–7.04e-05	6.01e-04	–1.58e-04	4.51e-04
1.148	1.43e-08	1.43e-03	–9.63e-05	6.02e-04	–.69e-04	5.45e-04
1.152	1.43e-08	1.42e-03	–1.29e-04	5.87e-04	–3.41e-04	5.76e-04
1.156	1.43e-08	1.42e-03	–1.60e-04	5.43e-04	–3.62e-04	5.36e-04
1.160	1.42e-08	1.41e-03	–1.81e-04	4.58e-04	–3.29e-04	4.30e-04
1.164	1.41e-08	1.40e-03	–1.83e-04	3.30e-04	–2.48e-04	2.72e-04
1.168	1.40e-08	1.39e-03	–1.65e-04	1.72e-04	–1.35e-04	9.19e-05

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Table 32–11—Coefficients for worst-case channel and T2 Alien NEXT model *(continued)*

Time (µs)	Cable 0 m	Cable 100 m	Alien NEXT 1	Alien NEXT 2	Alien NEXT 3	Alien NEXT 4
1.172	1.39e-08	1.39e-03	–1.28e-04	4.95e-06	–1.13e-05	–7.86e-05
1.176	1.38e-08	1.38e-03	–7.75e-05	–1.48e-04	1.02e-04	–2.10e-04
1.180	1.38e-08	1.37e-03	–1.90e-05	–2.62e-04	1.90e-04	–2.83e-04
1.184	1.38e-08	1.37e-03	4.03e-05	-3.19e-04	2.48e-04	-2.93e-04
1.188	1.37e-08	1.36e-03	9.40e-05	–3.07e-04	2.73e-04	–2.43e-04
1.192	1.36e-08	1.35e-03	1.37e-04	–2.28e-04	2.68e-04	–1.50e-04
1.196	1.35e-08	1.35e-03	1.66e-04	–9.21e-05	2.37e-04	–3.64e-05
1.200	1.34e-08	1.34e-03	1.80e-04	7.95e-05	1.86e-04	7.45e-05
1.204	1.34e-08	1.34e-03	1.79e-04	2.63e-04	1.22e-04	1.62e-04
1.208	1.34e-08	1.33e-03	1.62e-04	4.36e-04	5.03e-05	2.17e-04
1.212	1.33e-08	1.32e-03	1.27e-04	5.81e-04	–2.48e-05	2.37e-04
1.216	1.33e-08	1.32e-03	7.69e-05	6.83e-04	–9.88e-05	2.28e-04
1.220	1.32e-08	1.31e-03	1.24e-05	7.35e-04	–1.66e-04	2.01e-04
1.224	1.31e-08	1.30e-03	–6.03e-05	7.34e-04	–2.22e-04	1.66e-04
1.228	1.30e-08	1.30e-03	–1.36e-04	6.87e-04	–2.61e-04	1.35e-04
1.232	1.29e-08	1.29e-03	–2.14e-04	6.00e-04	–2.84e-04	1.13e-04
1.236	1.29e-08	1.29e-03	–2.89e-04	4.86e-04	–2.93e-04	1.02e-04
1.240	1.29e-08	1.28e-03	–3.66e-04	3.57e-04	–2.97e-04	9.58e-05
1.244	1.29e-08	1.27e-03	–4.41e-04	2.30e-04	–3.00e-04	9.07e-05
1.248	1.29e-08	1.27e-03	–5.17e-04	1.15e-04	–3.10e-04	7.92e-05

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32.6.1.3.2 Receiver test mode

To facilitate the testing of the receiver in the presence of synchronous 100BASE-T2 alien NEXT, a special receiver test mode shall be required to allow for receiver alien NEXT tolerance and jitter testing. For a PHY with an MII, this mode shall be enabled by setting bit 9.13 (MASTER-SLAVE Control register) of the MII management register set to a 1. A PHY without an MII shall provide a means to enable this test mode. This mode shall not be overridden except by clearing bit 9.13 or resetting the PHY.

When the receive test mode is enabled, the receiver shall configure itself in SLAVE mode, continually attempt to bring its receiver up until successful receiver operation is achieved and transmit symbols in idle mode. For a PHY with an MII, when the receiver is properly detecting the received data (loc_rcvr_status=OK), it shall set bit 10.13 of the MII management register to 1 and reset the error count in bits 10.0 through 10.7 (MSB) to zero. The error count shall be incremented for every symbol error detected in the received idle sequence (where rem_rcvr_status is assumed to be OK). Upon loss of proper data reception, the receiver shall clear bit 10.13. A PHY without an MII shall provide a means to realize this function. The vendor shall provide a means to enable this mode for conformance testing.

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32.6.1.3.3 Receiver differential input signals

Differential signals received on the receive inputs that were transmitted within the specifications given in 32.6.1.2, and have then passed through a link as defined in 32.7, shall be translated into one of the PMA_UNITDATA.indication messages with an symbol error ratio less than 10^{-10} and sent to the PCS after link bring-up.

Performance shall be tested in at least two configurations: using a 100 m link segment conformant to 32.7 and with a link segment less than 1 m in length between transmitter and receiver.

32.6.1.3.4 Receiver Alien NEXT tolerance

Differential signals received from the test channel defined in 32.6.1.3.1 shall be detected with a symbol error ratio less than 10^{-8} when the PHY is in receiver test mode for the following combinations of channel and worst-case alien NEXT responses, as shown in Table 32-13.

Table 32-13—Receiver Alien NEXT test cases

Case	Cable channels	NEXT Channels			
		A1	A2	B1	B2
1	0 m	Alien NEXT 1	Alien NEXT 3	Alien NEXT 4	Alien NEXT 2
2	0 m	Alien NEXT 1	Alien NEXT 4	Alien NEXT 3	Alien NEXT 2
3	100 m	Alien NEXT 1	Alien NEXT 3	Alien NEXT 4	Alien NEXT 2
4	100 m	Alien NEXT 1	Alien NEXT 4	Alien NEXT 3	Alien NEXT 2

NOTE—Implementers will find it practically impossible to meet the requirements of this subclause without using some form of adaptive equalization and cyclostationary interference suppression.

32.6.1.3.5 Receiver timing jitter

For the test channels described below, the peak-to-peak value of RX_CLK zero-crossing jitter shall be less than 1.3 ns after the receiver is properly receiving the data and has set bit 9.13 of the MII management register set to 1. When the jitter waveform on RX_CLK is filtered by a high pass filter having the transfer function below,[15] the peak-to-peak value of the resulting filtered timing jitter shall be less than 0.8 ns.

Test channels:

Channels 1–4 are the test channels described in 32.6.1.3.1 with the four combinations of worst-case channel and alien NEXT responses tabulated in 32.6.1.3.4.

Channels 5–6 are the test channels described in 32.6.1.3.1 with the combinations of worst-case channel and alien NEXT responses tabulated in cases 1 and 2 of 32.6.1.3.4 plus the addition of 100 m of Category 3 compliant cable between the test channel fixture and the PHY under test.

$$H_{\text{jitterfilter}}(f) = \frac{jf}{jf + 1000} \qquad f \text{ in Hz}$$

The RX_CLK of the MII shall be made available for this test. A PHY without an MII shall provide an equivalent clock.

[15] "j" denotes the positive square root of –1.

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32.6.1.3.6 Common-mode noise rejection

While receiving packets from a compliant 100BASE-T2 transmitter, connected to all MDI pins, a receiver shall send the proper PMA_UNITDATA.indication messages to the PCS for any differential input signal E_s that results in a signal E_{dif} that meets 32.6.1.3.3 even in the presence of common-mode voltages E_{cm} (applied as shown in Figure 32–21). E_{cm} shall be a 25 V peak-to-peak square wave, 500 kHz or lower in frequency, with edges no slower than 4 ns (20%-80%), connected to each of the pairs (BI_DA+, BI_DA-) and (BI_DB+, BI_DB-).

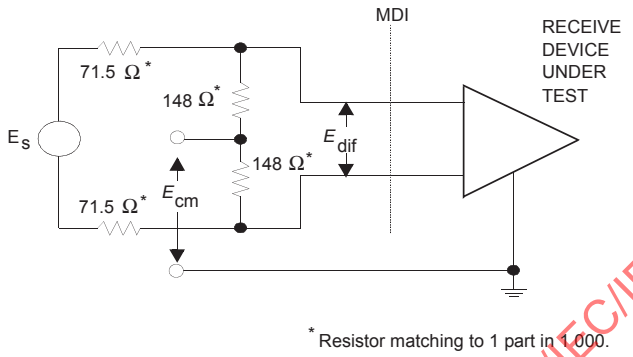

Figure 32–21—Receiver common-mode noise rejection test circuit

32.6.1.3.7 Receiver frequency tolerance

The receive feature shall properly receive incoming data with a 5-level symbol rate within the range 25.000 MHz ± 0.01%.

32.6.1.4 MDI Specifications

32.6.1.4.1 MDI differential impedance

The differential impedance as measured at the MDI for each transmit/receive channel shall be such that any reflection due to differential signals incident upon the MDI from a balanced cabling having an impedance of 100 Ω is at least 17 dB below the incident signal over the frequency range 2.0 MHz to 6.5 MHz and at least 12.9–20 $\log_{10}(f/10)$ dB over the frequency range 6.5 MHz to 25 MHz (f in MHz). This return loss shall be maintained at all times when the PHY is transmitting data.

32.6.1.4.2 MDI impedance balance

Over the frequency range 2.0 MHz to 25.0 MHz, the common-mode to differential-mode impedance balance of each channel of the MDI shall exceed

$$29 - 17\log\left(\frac{f}{10}\right) \text{ dB}$$

where f is the frequency in MHz when the transmitter is transmitting idle mode data (transmit test mode 3).

The balance is defined as

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$$20\log\left(\frac{E_{cm}}{E_{dif}}\right)$$

where E_{cm} is an externally applied sine wave voltage as shown in Figure 32–22 and E_{dif} is the resulting waveform due only to the applied sine wave and not the transmitted data.[16]

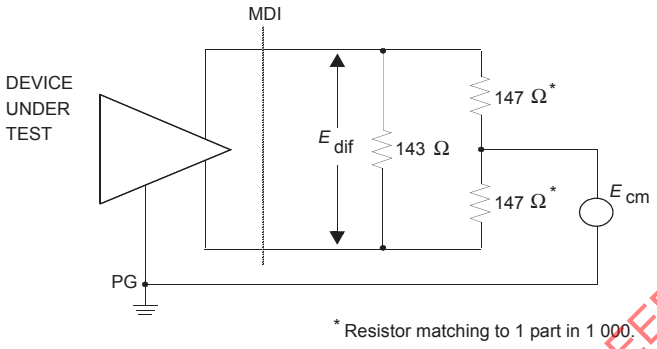

Figure 32–22—MDI impedance balance test circuit

NOTE—The balance of the test equipment (such as the matching of the test resistors) must be insignificant relative to the balance requirements.

32.6.1.4.3 MDI common-mode output voltage

The implementer should consider any applicable local, national, or international regulations. Driving balanced cable pairs with high-frequency common-mode voltages may cause radiated emissions that may result in interference to other equipment. FCC conducted and radiated emissions tests may require that the magnitude of the total common-mode output voltage, E_{cm_out}, on any transmit circuit, when measured as shown in Figure 32–23, be less than a few millivolts when transmitting data.

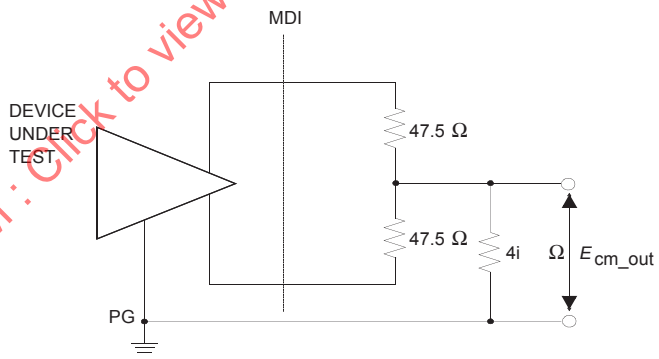

Figure 32–23—Common-mode output voltage test circuit

NOTE—The balance of the test equipment (such as the matching of the test resistors) must be insignificant relative to the balance requirements.

[16]Triggered averaging can be used to separate the component due to the applied common-mode sine wave from the transmitted data component.

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32.6.1.4.4 MDI fault tolerance

Transmitters and receivers shall withstand without damage the application of short circuits across any MDI port for an indefinite period of time and shall resume normal operation after such faults are removed. The magnitude of the current through such a short circuit shall not exceed 300 mA.

Transmitters shall withstand without damage a 1000 V common-mode impulse applied at E_{cm} of either polarity (as indicated in Figure 32–24). The shape of the impulse shall be 0.3/50 µs (300 ns virtual front time, 50 µs virtual time of half value), as defined in IEC 60060.

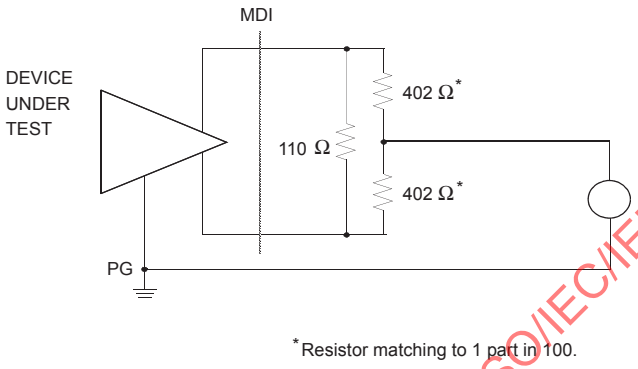

Figure 32–24—MDI fault tolerance test circuit

32.6.2 Power consumption

After 100 ms following PowerOn, the current drawn by the PHY shall not exceed 1.0 A when powered through the MII.

The PHY shall be capable of operating from all voltage sources allowed by Clause 22, including those current limited to 1.0 A, as supplied by the DTE or repeater through the resistance of all permissible MII cabling.

The PHY shall not introduce extraneous signals on the MII control circuits during normal power-up and power-down.

While in power-down mode, the PHY is not required to meet any of the 100BASE-T2 performance requirements.

32.7 Link segment characteristics

100BASE-T2 employs a dual duplex transmission system, i.e., two full duplex channels are used simultaneously to transmit data. The use of the term *link segment* in this clause refers to two duplex channels and the specifications for a link segment apply individually to each of the two duplex channels. Furthermore, the term duplex channel will be used to refer a single channel of the dual duplex link segment.

100BASE-T2 is designed to allow use of the pairs of the cabling other than the two used for the full duplex channels of the 100BASE-T2 service. Services supported for use in the other pairs are as follows:

a) 100BASE-T2
b) 10BASE-T
c) Digital phone services compliant with the ITU-T Recommendation I.430 and ANSI T1.605 and T1.601

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32.7.1 Cabling

Cabling and installation practices generally suitable for use with this standard appear in ISO/IEC 11801. Exceptions, notes, and additional requirements are as listed below.

a) 100BASE-T2 uses a star topology. Balanced cabling is used to connect PHY entities.
b) 100BASE-T2 is an ISO 11801 class C application, with additional installation requirements and transmission parameters specified in 32.7.2–32.7.4. The width of the PAM5 × 5 transmit spectrum is approximately 25 MHz (as shown in Figure 32–19). The aggregate data rate for two pairs using PAM5 × 5 coding is 100 Mb/s.
c) 100BASE-T2 shall use 2 pairs of balanced cabling, Category 3 or better, with a nominal characteristic impedance of 100 Ω.
d) When using Category 3 cabling for the link segment, Clause 32 recommends, but does not require, the use of Category 4 or better connecting hardware, patch cords and jumpers. The use of Category 4 or better connecting hardware increases the link segment composite NEXT loss, composite ELFEXT loss and reduces the link segment insertion loss. This lowers the link segment crosstalk noise which in turn decreases the probability of errors.
e) The use of shielding is outside the scope of this standard.
f) The use of other cabling systems is discussed in Annex 32A.

32.7.2 Link transmission parameters

Unless otherwise specified, link segment testing shall be conducted using source and load impedances of 100 Ω.

The tolerance on the poles of the test filter used in this clause shall be ± 1%.

32.7.2.1 Insertion loss

The insertion loss of a link segment shall be no more than 14.6 dB at all frequencies between 2 and 16 MHz. This consists of the attenuation of the balanced cabling pairs, connector losses, and reflection losses due to impedance mismatches between the various components of the link segment. The insertion loss specification shall be met when the link segment is terminated in source and load impedances that satisfy 32.6.1.4.1.

NOTE—The loss of PVC-insulated cabling exhibits significant temperature dependence. At temperatures greater than 40 °C, it may be necessary to use a less temperature-dependent cabling, such as many Fluorinated Ethylene Propylene (FEP), Polytetrafluoroethylene (PTFE), or Perfluoroalkoxy (PFA) plenum-rated cabling.

32.7.2.2 Differential characteristic impedance

The cable used in the links shall meet the requirements for characteristic impedance specified in ISO/IEC 11801. Connecting hardware shall meet the return loss requirements for connecting hardware specified in ISO/IEC 11801.

32.7.2.3 Coupling parameters

In order to limit the noise coupled into a duplex channel from an adjacent duplex channel, Near-End Crosstalk (NEXT) loss and Equal Level Far-End Crosstalk (ELFEXT) loss are specified for each link segment. In addition, since two dual-duplex connections may co-exist in a 4-pair cabling and a receiver on a duplex channel will be disturbed by crosstalk from one to three other duplex (or simplex) channels, Multiple-Disturber NEXT loss and Multiple-Disturber ELFEXT loss are also specified. When a 10BASE-T service is used within the same cabling, a restriction on the allowable NEXT loss to Insertion Loss (NIR) of the cabling is required and is specified in 32.7.2.3.5.

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32.7.2.3.1 Differential near-end crosstalk (NEXT) loss

The differential Near-End Crosstalk (NEXT) loss between the two duplex channels of a link segment is specified in order to limit the crosstalk noise at the near end of a link segment to meet the symbol error ratio objective specified in 32.1 and the noise specifications of 32.7.3. The NEXT loss between the two duplex channels of a link segment shall be at least $19.3 - 16.6\log_{10}(f/16)$ (where f is the frequency in MHz) over the frequency range 2 MHz to 16 MHz.

32.7.2.3.2 Multiple-disturber NEXT (MDNEXT) loss

Since two dual duplex applications (connections) may exist in a 4-pair cabling system, a received signal may be disturbed by multiple alien NEXT signals. The MDNEXT loss between each link segment duplex channel and the two alien data carrying duplex channels shall be at least $19.0 - 16.6\log_{10}(f/16)$ dB (where f is the frequency in MHz) over the frequency range 2.0 MHz to 16 MHz. MDNEXT is computed as the power sum of the individual NEXT losses. This specification is consistent with two disturbers, each with a NEXT loss of at least $22.0 - 16.6\log_{10}(f/16)$.

NOTE—Since the self NEXT noise from the other duplex channel of a connection can be cancelled using digital signal processing techniques whereas the alien NEXT noise from an alien connection can not be cancelled in the same fashion, the self NEXT noise is treated differently than the alien NEXT noise and is not included in the MDNEXT calculation.

32.7.2.3.3 Equal level far-end crosstalk loss (ELFEXT)

Equal Level Far-End Crosstalk (ELFEXT) loss is specified in order to limit the crosstalk noise at the far end of a link segment to meet the symbol error ratio objective specified in 32.1 and the noise specifications of 32.7.3. Far-End Crosstalk (FEXT) noise is the crosstalk noise that appears at the far end of one of the duplex channels which is coupled from one of the duplex channels with the noise source (transmitters) at the near end. ELFEXT loss is the ratio of the data signal to FEXT noise at the far end output of a duplex channel. To limit the FEXT noise from an adjacent duplex channel, the ELFEXT loss between each duplex channel shall be greater than $20.9 - 20\log_{10}(f/16)$ dB (where f is the frequency in MHz) over the frequency range 2 MHz to16 MHz. ELFEXT loss at frequency f and distance l is defined as

$$ELFEXT_Loss(f,l) = 20\log_{10}(Vpds/Vpcn) - SLS_Loss(\text{dB})$$

where $Vpds$ = peak voltage of disturbing signal (near-end transmitter), $Vpcn$ = peak crosstalk noise at far-end of disturbed channel, and SLS_Loss = insertion loss of the disturbing channel.

32.7.2.3.4 Multiple-disturber ELFEXT (MDELFEXT) loss

Since two duplex channels are used to transfer data between PHYs and two connections can exist in a 4-pair cabling, the FEXT noise that is coupled into a data carrying duplex channel is from one to three disturbers. The MDELFEXT loss between a duplex channel and the other data carrying duplex channels shall be greater than $19.9 - 20\log_{10}(f/16)$ (where f is the frequency in MHz) over the frequency range 2 MHz to 16 MHz.This specification is consistent with three disturbers, one with a FEXT loss of at least $20.9 - 20\log_{10}(f/16)$ and two with a FEXT loss of at least $27.0 - 20\log_{10}(f/16)$.

MDELNEXT is computed as the power sum of the individual FEXT losses.

32.7.2.3.5 10BASE-T NEXT loss to insertion loss ratio requirement

The objective of this specification is to support the coexistence of a 100BASE-T2 link segment and a 10BASE-T link segment in a 4-pair cable. When a 100BASE-T2 link segment operates in the same 4-pair cable with a 10BASE-T link segment, each 100BASE-T2 duplex channel will receive alien NEXT noise signals from the 10BASE-T link segment. To ensure reliable operation, a minimum signal-to-noise ratio must

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be maintained. This minimum signal-to-noise ratio is assured by meeting the following NEXT loss to insertion loss ratio (NIR).

NIR is defined by the following equation:

$$NIR\ (\text{dB}) = (AdjustedNEXTLoss - InsertionLoss_{6\ \text{MHz}})$$

where $InsertionLoss_{6\ \text{MHz}}$ is the maximum of the insertion loss at 6 MHz of the two duplex channels of the 100BASE-T2 link segment and *AdjustedNEXTLoss* is determined by the following algorithm:

AdjustedNEXTLoss Algorithm

Step 1. Measure the NEXT loss as a function of frequency over the range 1 MHz to 16 MHz for each of the six pair combinations between the four pairs of the cabling. The maximum spacing in frequency of the samples shall be 250 kHz.

Step 2. Add $16.6\log_{10}(f/16)$ to the NEXT loss measurements (where f is frequency in MHz) to normalize the NEXT loss as a function of frequency.

Step 3. Determine the minimum value of the normalized NEXT loss across the frequency range over all pair combinations. The minimum value is the AdjustedNEXTLoss.

The NIR shall be greater than 19.4 dB.

32.7.2.4 Delay

Since 100BASE-T2 sends information over two duplex channels in parallel, the propagation delay of each channel and the difference in delay are specified to comply with network round-trip delay of the two channels and ensure proper decoding by receivers, respectively.

32.7.2.4.1 Maximum link delay

The propagation delay of a link segment shall not exceed 5.7 ns/m at all frequencies between 2 MHz and 25 MHz.

32.7.2.4.2 Difference in link delays

The difference in propagation delay, or skew, under all conditions, between the two duplex channels of a link segment shall not exceed 90 ns at all frequencies between 2 MHz and 25 MHz. It is a further functional requirement that, once installed, the skew between the duplex links due to environmental conditions shall not vary more than ± 20 ns, within the above requirement.

32.7.3 Noise

The noise level on the link segments shall be such that the cabling noise requirements which follow are met. The noise environment consists generally of a main contributor, self-induced and alien near-end crosstalk noise, and a lessor contributor, far-end crosstalk noise.

The noise environment for 100BASE-T2 can consist of the following elements:

a) Echo from the local transmitter on the same pair (duplex channel). Echo is caused by the hybrid used to achieve simultaneous bidirectional transmission of data in the T2 system and by impedance mismatches in the link segment. It is practically impossible to achieve robust performance without using echo cancellation to reduce this noise to a small residual. Echo cancellation is possible since the symbols transmitted from the disturbing local transmitter are available to the cancellation processor.

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b) Near-end crosstalk (NEXT) noise from the local transmitter on the other pair (duplex channel) of the link segment. This is often referred to as self NEXT noise since the source is from the same link segment. NEXT noise cancellation is typically used to reduce this noise to a small residual. NEXT noise cancellation is possible since the symbols transmitted from the disturbing local transmitter are available to the cancellation processor.

c) Far-end crosstalk (FEXT) noise from the remote transmitters on the other pair (duplex channel) of the link segment. This is often referred to as self FEXT noise since the source is from the same link segment. Self FEXT noise can not be cancelled in the same way as echo and self NEXT noise since the symbols from the remote transmitter are not immediately available; however, in the link configurations used for 100BASE-T2, self FEXT noise is much smaller than self NEXT noise and can generally be neglected.[17]

d) Noise from non-idealities in the duplex channels, transmitters and receivers; for example, DAC/ADC non-linearity, electrical noise (shot and thermal) and non-linear channel characteristics.

e) Noise from sources outside the cabling which couple into the link segment via electric and magnetic fields.

f) Noise from services in adjacent wire pairs in the same cable sheath. These services generate near- and far-end crosstalk and are often referred to as alien NEXT noise and alien FEXT noise since the sources are not from the link segment of the disturbed duplex channel. Since the transmitted symbols from an alien NEXT noise source are not available to the PHY of the disturbed duplex channel, it is not possible to cancel the alien NEXT noise as can be done for self NEXT noise. If the alien NEXT noise is from a 100BASE-T2 transceiver, a technique termed cyclostationary interference suppression can be used to suppress the alien NEXT noise. It will be practically impossible achieve reliable operation in the presence of alien NEXT noise meeting the limits of the specifications in subclause 32.6 without using some form of cyclostationary interference suppression. 10BASE-T can not be suppressed and therefore an additional constraint has been placed on the link (see subclause 32.7.2.3.5) to ensure adequate signal to noise levels for reliable performance. Digital phone services compliant with the ITU-T Recommendation I.430 and ANSI T1.605 and T1.601 also can not be suppressed but produce substantially smaller crosstalk than 10BASE-T and thus do not require any additional constraints on the link.

100BASE-T2 supports three types of service in adjacent pairs of the same cable: 100BASE-T2, 10BASE-T, and digital phone service compliant with the ISDN-BR U and S/T interfaces. Analog phone service is not supported since the noise generated during off-hook transitions and ringing source from older PBX equipment can cause bit errors to occur.

NOTE—Due to the use of noise cancellation, cyclostationary interference suppression and the use of adaptive equalization, there is no meaningful way to add up the noises at the input to the receiver into an overall noise level and simulation of a design is required to determine the contribution of each source to the final error at the symbol decision point.

32.7.3.1 Near-end crosstalk noise

The MDNEXT (Multiple-Disturber Near-End Crosstalk) noise on a duplex channel from an alien connection depends on the signal spectrum on the alien channels and the crosstalk between the alien channels and the disturbed channel.

The MDNEXT noise on each duplex link of a link segment shall not exceed 182 mVp.

This specification is compatible with the following assumptions:

[17]Additionally, FEXT noise may be suppressed to some degree via cyclostationary interference suppression; however, in the presence of alien NEXT noise, the equalizer will be primarily suppressing the alien NEXT noise.

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a) Two disturbing alien pairs with a NEXT loss greater than 22.0 dB at 16 MHz
b) All disturbers combined on a power sum basis

The MDNEXT noise is the noise measured at the output of a filter connected to the output of the near end of a disturbed link segment using maximum level 100BASE-T2 transmitters attached to the near end of an alien disturbing link segment. Each continuous transmit signal is generated by a transceiver in idle mode meeting the data scrambling and encoding rules in 32.3, e.g., a transmitter in transmit test mode 3.

32.7.3.2 Far-end crosstalk noise

The MDFEXT (Multiple-Disturber Far-End Crosstalk) noise on a duplex channel depends on the signal spectrum on the disturbing channels and the various crosstalk losses between those channels and the disturbed channel.

The MDFEXT noise on a link segment shall not exceed 54.4 mVp.

This specification is compatible with the following assumptions:

a) One disturbing pair with ELFEXT (Equal Level Far-End Crosstalk) loss greater than 20.9 dB at 16 MHz
b) Two additional disturbers with ELFEXT (Equal Level Far-End Crosstalk) loss greater than 27.0 dB at 16 MHz
c) All disturbers combined on a power sum basis

The MDFEXT noise is the noise measured at the output of a filter connected to the output of the far end of a disturbed link segment using maximum level 100BASE-T2 transmitters attached to the near end of the other duplex channel of the link segment and both duplex channels of an alien disturbing link segment. Each continuous transmit signal is generated by a transceiver in idle mode meeting the data scrambling and encoding rules in 32.3, e.g., a transmitter in transmit test mode 3.

The filter is a 5th order Butterworth filter with a 3 dB cutoff at 23 MHz.

32.7.3.3 External coupled noise

Noise coupled from external sources, measured at the output of a filter connected to the output of the near end of a disturbed link segment shall not exceed 25 mV peak.[18]

The filter is a 5th order Butterworth filter with a 3 dB cutoff at 23 MHz.

32.7.4 Installation practice

32.7.4.1 Connector installation practices

The amount of untwisting in a pair as a result of termination to connecting hardware should be no greater than 25 mm (1.0 in.) for Category 3 cabling. This is the same value recommended in ISO/IEC 11801 for Category 4 connectors.

32.7.4.2 Restrictions on use of Category 3 cabling with more than four pairs

Jumper cabling, or horizontal runs, made from more than four pairs of Category 3 cabling shall not be used.

[18]This assumes the link has worst-case attenuation and alien NEXT and that the noise has the worst possible properties. In the absence of alien NEXT the tolerance to external noise sources is substantially increased. Tolerance to stationary noise such as continuous wave interference from AM radio can be substantially higher since the equalizer can notch out frequencies with poor signal-to-noise ratios. Tolerance to isolated impulse noise events is also typically much higher and dependent on the shape of the impulse.

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32.7.4.3 Restrictions on use of Category 5 cabling with up to 25 pairs

Cables made from up to 25 pairs of Category 5 cable are allowed. Such cables, if used, shall be limited in length to no more than 90 m total. The services in the cable shall be limited to any combination 100BASE-T2, 10BASE-T and digital phone services compliant with the ITU-T Recommendation I.430 and ANSI T1.605 and T1.601 interfaces up to a total of 12 services in the cable.

32.8 MDI specification

This subclause defines the MDI. The link topology requires a crossover function between PMAs. Implementation and location of this crossover are also defined in this subclause.

32.8.1 MDI connectors

Eight-pin connectors meeting the requirements of section 3 and Figures 1–4 of IEC 60603-7, Detail Specification for Connectors, 8-Way shall be used as the mechanical interface to the balanced cabling. The plug connector shall be used on the balanced cabling and the jack on the PHY. These connectors are depicted (for informational use only) in Figures 32–25 and 32–26. Table 32–14 shows the assignment of PMA signals to connector contacts for PHYs.

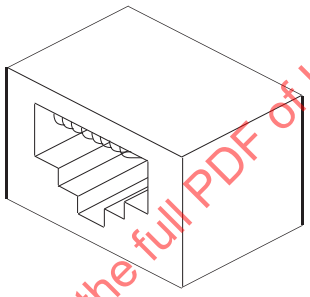

Figure 32–25—MDI connector

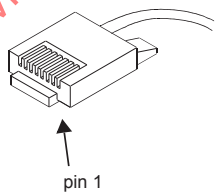

Figure 32–26—Balanced cabling connector

32.8.2 Crossover function

Although the crossover function is not required for successful operation of 100BASE-T2, it is a functional requirement that a crossover function be implemented in every link segment to support the operation of Auto-Negotiation. The crossover function connects the transmitters of one PHY to the receivers of the PHY at the other end of the link segment. Crossover functions may be implemented internally to a PHY or elsewhere in the link segment. For a PHY that does not implement the crossover function, the MDI labels in the last column of Table 32–14 refer to its own internal circuits (second column). For PHYs that do implement the internal crossover, the MDI labels in the last column of Table 32–14 refer to the internal circuits of the remote PHY of the link segment. Additionally, the MDI connector for a PHY that implements the crossover function shall be marked with the graphical symbol X. The crossover function specified here is compatible with the crossover function specified in 14.5.2 for pairs TD and RD.

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Table 32–14—Assignment of PMA signals to MDI pin-outs

Contact	PHY without internal crossover (100BASE-T2 operation)	PHY with internal crossover (Auto-Negotiation operation)	MDI labeling requirement
1	BI_DA+	BI_DB+	BI_DA+
2	BI_DA-	BI_DB-	BI_DA-
3	BI_DB+	BI_DA+	BI_DB+
4	Not used	Not used	
5	Not used	Not used	
6	BI_DB-	BI_DA-	BI_DB-
7	Not used	Not used	
8	Not used	Not used	

When a link segment connects a DTE to a repeater, it is recommended the crossover be implemented in the PHY local to the repeater. If both PHYs of a link segment contain internal crossover functions, an additional external crossover is necessary. It is recommended that the crossover be visible to an installer from one of the PHYs. When both PHYs contain internal crossovers, it is further recommended in networks in which the topology identifies either a central backbone segment or a central repeater that the PHY furthest from the central element be assigned the external crossover to maintain consistency.

Implicit implementation of the crossover function within a twisted-pair cable, or at a wiring panel, while not expressly forbidden, is beyond the scope of this standard.

32.9 System considerations

The repeater unit specified in Clause 27 forms the central unit for interconnecting 100BASE-T2 twisted-pair links in networks of more than two nodes. It also provides the means for connecting 100BASE-T2 balanced cabling links to other 100 Mb/s baseband segments. The proper operation of a CSMA/CD network requires that network size be limited to control round-trip propagation delay as specified in Clause 29.

When operated in Full Duplex mode where CSMA/CD requirements do not apply, 100BASE-T2 balanced cabling links are limited to 100 m as per ISO/IEC 11801.

32.10 Environmental specifications

32.10.1 General safety

All equipment meeting this standard shall conform to IEC 60950.

32.10.2 Network safety

This clause sets forth a number of recommendations and guidelines related to safety concerns; the list is neither complete nor does it address all possible safety issues. The designer is urged to consult the relevant local, national, and international safety regulations to ensure compliance with the appropriate requirements.

LAN cabling systems described in this clause are subject to at least four direct electrical safety hazards during their installation and use. These hazards are as follows:

a) Direct contact between LAN components and power, lighting, or communications circuits
b) Static charge buildup on LAN cabling and components

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c) High-energy transients coupled onto the LAN cabling system
d) Voltage potential differences between safety grounds to which various LAN components are connected

Such electrical safety hazards must be avoided or appropriately protected against for proper network installation and performance. In addition to provisions for proper handling of these conditions in an operational system, special measures must be taken to ensure that the intended safety features are not negated during installation of a new network or during modification or maintenance of an existing network.

32.10.2.1 Installation

It is a mandatory functional requirement that sound installation practice, as defined by applicable local codes and regulations, be followed in every instance in which such practice is applicable.

32.10.2.2 Grounding

Any safety grounding path for an externally connected PHY shall be provided through the circuit ground of the MII connection.

WARNING

It is assumed that the equipment to which the PHY is attached is properly grounded, and not left floating nor serviced by a "doubly insulated, ac power distribution system." The use of floating or insulated equipment, and the consequent implications for safety, are beyond the scope of this standard.

32.10.2.3 Installation and maintenance guidelines

It is a mandatory functional requirement that, during installation and maintenance of the cabling plant, care be taken to ensure that non-insulated network cabling conductors do not make electrical contact with unintended conductors or ground.

32.10.2.4 Telephony voltages

The use of building wiring brings with it the possibility of wiring errors that may connect telephony voltages to 100BASE-T2 equipment. Other than voice signals (which are low voltage), the primary voltages that may be encountered are the "battery" and ringing voltages. Although there is no universal standard, the following maximums generally apply.

Battery voltage to a telephone line is generally 56 Vdc applied to the line through a balanced 400 Ω source impedance.

Ringing voltage is a composite signal consisting of an AC component and a DC component. The ac component is up to 175 V peak at 20 Hz to 60 Hz with a 100 Ω source resistance. The DC component is 56 Vdc with 300 Ω to 600 Ω source resistance. Large reactive transients can occur at the start and end of each ring interval.

Although 100BASE-T2 equipment is not required to survive such wiring hazards without damage, application of any of the above voltages shall not result in any safety hazard.

NOTE—Wiring errors may impose telephony voltages differentially across 100BASE-T2 transmitters or receivers. Because the termination resistance likely to be present across a receiver's input is of substantially lower impedance than an off-hook telephone instrument, receivers will generally appear to the telephone system as off-hook telephones. Therefore, full-ring voltages will be applied for only short periods. Transmitters that are coupled using transformers will similarly appear like off-hook telephones (though perhaps a bit more slowly) due to the low resistance of the transformer coil.

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32.10.3 Environment

32.10.3.1 Electromagnetic emission

The twisted-pair link shall comply with applicable local and national codes for the limitation of electromagnetic interference.

32.10.3.2 Temperature and humidity

The twisted-pair link is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

It is recommended that manufacturers indicate in the literature associated with the PHY the operating environmental conditions to facilitate selection, installation, and maintenance.

32.10.4 Cabling specifications

All equipment subject to this clause shall conform to the requirements of 14.7 and applicable sections of ISO/IEC 11801.

32.11 PHY labeling

It is recommended that each PHY (and supporting documentation) be labeled in a manner visible to the user with at least the following parameters:

a) Data rate capability in Mb/s
b) Power level in terms of maximum current drain (for external PHYs)
c) Port type (i.e., 100BASE-T2)
d) Any applicable safety warnings

See also 32.8.2.

32.12 Delay constraints

Proper operation of a CSMA/CD LAN, operating in half duplex mode, demands that there be an upper bound on the propagation delays through the network. This implies that MAC, PHY and repeater implementers must conform to certain delay minima and maxima, and that network planners and administrators conform to constraints regarding the cabling topology and concatenation of devices. MAC constraints are contained in Clause 21. Topological constraints are contained in Clause 29. In the full duplex mode of operation, DTEs are not required to conform to the constraints specified in this clause.

The reference point for all MDI measurements is the peak point of the mid-cell transition corresponding to the reference code-bit, as measured at the MDI. Although 100BASE-T2 output is scrambled, it is assumed that these measurements are made via apparatuses that appropriately account for this.

32.12.1 PHY delay constraints (exposed MII)

Every 100BASE-T2 PHY with an exposed MII shall comply with the bit delay constraints specified in Table 32–15. These figures apply for all 100BASE-T2 PMDs.

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Table 32–15—MDI to MII delay constraints (exposed MII)

Sublayer Measurement Points	Event	Min (bits)	Max (bits)	Input Timing Reference	Output Timing Reference
MII ⇔ MDI	TX_EN Sampled to MDI Output	7	9	TX_CLK rising	1st symbol of SSD
	MDI input to CRS assert		25	1st symbol of SSD	
	MDI input to CRS deassert		29	1st ONE	
	MDI input to COL assert		25	1st symbol of SSD	
	MDI input to COL deassert		29	1st symbol of SSD	
	TX_EN sampled to CRS assert	0	4	TX_CLK rising	
	TX_EN sampled to CRS deassert	0	16	TX_CLK rising	

32.12.2 DTE delay constraints (unexposed MII)

Every 100BASE-T2 DTE with no exposed MII shall comply with the bit delay constraints specified in Table 32–16. These figures apply for all 100BASE-T2 PMDs.

Table 32–16—DTE delay constraints (unexposed MII)

Sublayer Measurement Points	Event	Min (bits)	Max (bits)	Input Timing Reference	Output Timing Reference
MAC ⇔ MDI	MAC transmit start to MDI output		13		1st symbol of SSD
	MDI input to MDI output (worst-case non-deferred transmit)		50	1st symbol of SSD	1st symbol of SSD
	MDI input to collision detect		33	1st symbol of SSD	
	MDI input to MDI output = Jam (worst-case collision response)		50	1st symbol of SSD	1st symbol of SSD

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32.13 Protocol implementation conformance statement (PICS) proforma for Clause 32, Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer and baseband medium, type 100BASE-T2[19]

The supplier of a protocol implementation that is claimed to conform to Clause 32, Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer and baseband medium, type 100BASE-T2, shall complete the following protocol implementation conformance statement (PICS) proforma.

Instructions for interpreting and filling out the PICS proforma may be found in Clause 21.

32.13.1 Identification

32.13.1.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1— Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

32.13.1.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 32, Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer and baseband medium, type 100BASE-T2
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exceptions items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	

Date of Statement	

[19]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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32.13.2 Major capabilities/options

Item	Feature	Subclause	Status	Support	Value/Comment
*MII	Exposed MII interface	32.1.3.2	O	Yes [ ] No [ ]	Devices supporting this option must also support the PCS option.
PC	PHY Control functions	32.2	M	Yes [ ]	Required for proper operation of the PHY.
*PCS	PCS functions	32.3	O	Yes [ ] No [ ]	Required for integration with DTE or MII.
*PMA	Exposed PMA service interface	32.4.2	O	Yes [ ] No [ ]	Required for integration into symbol level repeater core.
NWY	Support for Auto-Negotiation (Clause 28)	32.1.3.4	M	Yes [ ]	Required
*INS	Installation/cabling	32.7.4	O	Yes [ ] No [ ]	Items marked with INS include installation practices and cabling specifications not applicable to a PHY manufacturer.

32.13.3 Compatibility considerations

Item	Feature	Subclause	Status	Support	Value/Comment
CCO1	Compatibility at the MDI	32.1.3.1	M	Yes [ ]	
CCO2	Auto-Negotiation required	32.1.3.4	M	Yes [ ]	
CCO3	State diagrams prevail	32.1.4	M	Yes [ ]	In discrepancy between text and state diagram.

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32.13.4 PHY control function

Item	Feature	Subclause	Status	Support	Value/Comment
PC01	PHY Control shall	32.2.1	M	Yes [ ]	Comply with the state diagram descriptions given in Figure 32–5.
PC02	PHY Control shall	32.2.2.1.2	M	Yes [ ]	Generate PHYC_CONFIG.indication messages synchronously with every MII TX_CLK cycle.
PC03	Upon receipt of the PHYC_CONFIG primitive, PCS Transmit and PMA Clock Recovery shall	32.2.2.1.3	M	Yes [ ]	Perform their functions in master or slave configuration according to the value of the parameter config.
PC04	PHY Control shall	32.2.2.2.2	M	Yes [ ]	Generate PHYC_LOCRXSTATUS.indication messages synchronously with every MII TX_CLK cycle.
PC05	Upon reception of the PHYC_LOCRXSTATUS.indication primitive, PCS Transmit shall	32.2.2.2.3	M	Yes [ ]	Perform its function according to the value assumed by the parameter loc_cvr_status.
PC06	PHY Control shall	32.2.2.3.2	M	Yes [ ]	Generate PHYC_TXMODE.indication messages synchronously with every MII TX_CLK cycle.
PC07	Upon receipt of the PHYC_TXMODE.indication primitive, the PCS shall	32.2.2.3.3	M	Yes [ ]	Perform its Transmit function as described in 32.3.1.2.
PC8	The PCS shall	32.2.2.3.2	M	Yes [ ]	Generate PHYC_RXSTATUS.request messages synchronously with signals received at the MDI.
PC9	The PCS shall	32.2.2.4.2	M	Yes [ ]	Generate PHYC_REMRXSTATUS.request messages synchronously with signals received at the MDI.
PC10	PCS Transmit shall	32.2.3	M	Yes [ ]	Send quinary symbols according to the value assumed by tx_mode.
PC11	When tx_mode assumes the value of SEND_N	32.2.3	M	Yes [ ]	Transmission of sequences of quinary symbols representing an MII data stream, the idle mode, or control sequences shall take place.
PC12	When tx_mode assumes the value of SEND_I	32.2.3	M	Yes [ ]	Transmission of sequences of quinary symbols representing the idle mode shall take place.

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32.13.5 Physical Coding Sublayer (PCS) or Physical Medium Attachment (PMA) sublayer

32.13.5.1 PCS transmit functions

Item	Feature	Subclause	Status	Support	Value/Comment
PCT01	The PCS shall	32.3.5.1	M	Yes [ ]	Implement the Transmit process as depicted in Figure 32–12 including compliance with the associated state variables specified in 32.3.4.
PCT02	PCS Transmit function shall	32.3.1.2	M	Yes [ ]	Conform to the PCS Transmit state diagram in Figure 32–12.
PCT03	If the parameter config provided to the PCS by the PHY Control function via the PHY-C_CONFIG.indication message assumes the value MASTER, PCS Transmit shall	32.3.1.2.1	M	Yes [ ]	Employ the transmitter side-stream scrambler generator polynomial specified for use with MASTER in 32.3.1.2.1.
PCT04	If the parameter config provided to the PCS by the PHY Control function via the PHY-C_CONFIG.indication message assumes the value SLAVE, PCS Transmit shall	32.3.1.2.1	M	Yes [ ]	Employ the transmitter side-stream scrambler generator polynomial specified for use with SLAVE in 32.3.1.2.1.
PCT05	Transmission of quinary symbol pairs over wire pairs	32.3.1.2	M	Yes [ ]	Symbols A_n and B_n are transmitted over BI_DA and BI_DB respectively.

32.13.5.2 PCS receive functions

Item	Feature	Subclause	Status	Support	Value/Comment
PCR01	The PCS shall	32.3.5.2	M	Yes [ ]	Implement the Receive process as depicted in Figure 32–13 including compliance with the associated state variables as specified in 32.3.4.
PCR02	PCS Receive function shall	32.3.1.3	M	Yes [ ]	Conform to the PCS Receive state diagram shown in Figure 32–13.
PCR03	For side-stream descrambling, the MASTER PHY shall employ	32.3.1.3.1	M	Yes [ ]	The receiver scrambler generator polynomial specified for MASTER operation in 32.3.1.3.1.
PCR04	For side-stream descrambling, the SLAVE PHY shall employ	32.3.1.3.1	M	Yes [ ]	The receiver scrambler generator polynomial specified for SLAVE operation in 32.3.1.3.1.

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32.13.5.3 Other PCS functions

Item	Feature	Subclause	Status	Support	Value/Comment
PCO1	The PCS Reset function shall	32.3.1.1	M	Yes [ ]	Be executed any time "power on," receipt of a request for reset from the management entity, or receipt of a request for reset from the PHY Control occur.
PCO2	THE PCS shall	32.3.1.4	M	Yes [ ]	Implement the PCS Carrier Sense function shown in Figure 32–14.
PCO3	PCS Carrier Sense function shall	32.3.5.3	M	Yes [ ]	Comply with the PCS Carrier Sense state diagram shown in Figure 32–14 including compliance with the associated state variables specified in 32.3.4.
PCO4	MII COL signal shall be asserted while	32.3.1.5	M	Yes [ ]	A PCS collision is being detected.
PCO5	The MII signal COL shall remain deasserted.	32.3.1.5	M	Yes [ ]	A PCS collision is not being detected.
PCO6	No spurious PCS management entity signals shall be emitted onto the MDI while the PHY is held in power down mode as defined in 22.2.4.1.5, independently of the value of TX_EN, or when released from power down mode, or when power is first applied to the PHY.	32.3.2.2	M	Yes [ ]	
PCO7	Frames passed from the PCS to the PMA sublayer shall	32.3.3	M	Yes [ ]	Have the structure shown in Figure 32–11.
PCO8	TX_CLK shall be generated	32.3.4.2	M	Yes [ ]	Synchronously with symb_timer with tolerance as specified in 32.6.1.2.6.

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32.13.5.4 PMA functions

Item	Feature	Subclause	Status	Support	Value/Comment
PMF1	PMA Reset function shall be executed	32.4.1.1.1	M	Yes [ ]	At power on and upon receipt of a reset request from the management entity.
PMF2	PMA transmit shall continuously transmit	32.3.1.2	M	Yes [ ]	Onto the MDI pulses modulated by the quinary symbols given by tx_symb_vector[BI_DA] and tx_symb_vector[BI_DB] respectively.
PMF3	The two transmitters shall be driven by the same transmit clock.	32.4.1.1.2	M	Yes [ ]	
PMF4	PMA Transmit function will follow	32.4.1.1.2	M	Yes [ ]	The mathematical description given in 32.4.1.2.1.
PMF5	PMA Transmit shall comply with	32.4.1.1.2	M	Yes [ ]	The electrical specifications given in 32.6.
PMF6	PMA Receive function shall translate	32.4.1.1.3	M	Yes [ ]	The signals received on pairs BI_DA and BI_DB into the PMA_UNITDATA.indication parameter rx_symb_vector with a symbol error ratio of less than one part in 10^{10}.
PMF7	The Link Monitor function shall	32.4.1.1.4	M	Yes [ ]	Comply with the state diagram shown in Figure 32–17.
PMF8	Clock Recovery function shall provide	32.4.1.1.5	M	Yes [ ]	A clock suitable for synchronous signal sampling on each line so that the symbol error ratio indicated in 32.4.1.1.3 is achieved.
PMF9	The waveform obtained at the MDI shall comply with	32.4.1.2.1	M	Yes [ ]	The electrical specifications given in 32.6.
PMF10	The two signals received on pair BI_DA and BI_DB shall be processed within the PMA Receive function to yield	32.4.1.2.2	M	Yes [ ]	The quinary received symbols rx_symb_vector[BI_DA] and rx_symb_vector[BI_DB].

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32.13.5.5 PMA service interface

Item	Feature	Subclause	Status	Support	Value/Comment
PMS1	Continuous generation of PMA_TYPE	32.4.1.2.2	M	Yes [ ]	
PMS2	Generation of PMA_UNITDATA.indication (SYMB_PAIR) messages	32.4.2.3.2	M	Yes [ ]	Synchronous with data received at the MDI.
PMS3	The PMA shall generate	32.4.2.5.2	M	Yes [ ]	PMA_LINK.indication to indicate the value of link_status.
PMS4	Effect of receipt of PMA_LINK.request messages	32.4.2.4.3	M	Yes [ ]	While link_control=SCAN_FOR_CARRIER or link_control=DISABLE, the PMA shall report link_status=fail; while link_control=ENABLE, PHY determines operations to be performed by the PHY.

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32.13.5.6 Management functions

Item	Feature	Subclause	Status	Support	Value/Comment
MF1	A 100BASE-T2 PHY shall	32.5	M	Yes [ ]	Use register addresses 9 and 10 for its control and status functions.
MF2	Register 9 shall	32.5.3.1	M	Yes [ ]	Provide values as specified in Table 32–4.
MF3	A PHY with 100BASE-T2 capability shall	32.5.3.1.1	M	Yes [ ]	Be placed in transmitter test mode 1 when bit 9.15 is set to logic zero and bit 9.14 is set to logic one.
MF4	A PHY with 100BASE-T2 capability shall	32.5.3.1.1	M	Yes [ ]	Be placed in transmitter test mode 2 when bit 9.15 is set to logic one and bit 9.14 is set to logic zero.
MF5	A PHY with 100BASE-T2 capability shall	32.5.3.1.1	M	Yes [ ]	Be placed in transmitter test mode 3 when bit 9.15 is set to logic one and bit 9.14 is set to logic one.
MF6	A PHY with 100BASE-T2 capability shall	32.5.3.1.2	M	Yes [ ]	Be placed in receiver test mode when bit 9.13 is set to logic one.
MF7	MASTER-SLAVE configuration negotiation will determine PHY configuration if	32.5.3.1.3	M	Yes [ ]	Bit 9.12 is set to logic zero.
MF8	Manual MASTER-SLAVE configuration will be set manually using bit 9.11 to set the value if	32.5.3.1.3	M	Yes [ ]	Bit 9.12 is set to logic one.
MF9	Bit 9.11 shall be used to report the results of manual MASTER-SLAVE configuration.	32.5.3.1.4	M	Yes [ ]	
MF10	Bit 9.10 shall	32.5.3.1.5	M	Yes [ ]	Be set to logic zero if the PHY is a DTE device and be set to logic one if the PHY is a repeater device port.
MF11	Bits 9.9:0 shall	32.5.3.1.6	M	Yes [ ]	Be set to logic zero.
MF12	Bits 9.9:0 shall be ignored when read	32.5.3.1.6	M	Yes [ ]	
MF13	A PHY shall return a value of zero for bits 9.9:0.	32.5.3.1.6	M	Yes [ ]	
MF14	Register 10 shall	32.5.3.1.2	M	Yes [ ]	Be used as shown in Table 32–5.
MF15	Bits 10.11:8 shall	32.5.3.2.5	M	Yes [ ]	Be set to logic zeros by default.
MF16	The MASTER-SLAVE Manual Configuration Fault bit shall be implemented	32.5.3.2.1	M	Yes [ ]	With a latching function, such that the occurrence of a MASTER-SLAVE Manual Configuration Fault will cause the MASTER-SLAVE Manual Configuration Fault bit to be set and remain set until cleared.

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32.13.5.6 Management functions *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
MF17	The MASTER-SLAVE Manual Configuration Fault bit shall be cleared	32.5.3.2.1	M	Yes [ ]	Each time register 10 is read by the management interface.
MF18	The MASTER-SLAVE Management Configuration Fault bit shall also be cleared by	32.5.3.2.1	M	Yes [ ]	A 100BASE-T2 PMA reset.
MF19	Bits 10:11:8 shall	32.5.3.2.5	M	Yes [ ]	Be ignored when read.
MF20	A PHY shall return a value of zero for bits10.11:8.	32.5.3.2.5	M	Yes [ ]	

32.13.5.7 100BASE-T2 specific Auto-Negotiation requirements

Item	Feature	Subclause	Status	Support	Value/Comment
AN1	Base Page will be followed with	32.5.4.2	M	Yes [ ]	A Next Page with a message code containing the 100BASE-T2 Technology Ability Message Code (7).
AN2	Message Next Page shall be followed with	32.5.4.2	M	Yes [ ]	Unformatted Message Next Page containing the 100BASE-T2 Technology Ability Fields as described in Table 32–6.
AN3	MASTER-SLAVE relationship shall be determined by	32.5.4.3	M	Yes [ ]	Using Table 32–7with the 100BASE-T2 Technology Ability Next Page bit values specified in Table 32–6.
AN4	A seed counter shall be provided to	32.5.4.3	M	Yes [ ]	Track the generation of seeds.
AN5	At start-up, the seed counter shall be set to	32.5.4.3	M	Yes [ ]	Zero.
AN6	The seed counter shall be incremented	32.5.4.3	M	Yes [ ]	Every time a new random seed is sent.
AN7	Maximum seed attempts before declaring a MASTER_SLAVE configuration Resolution Fault	32.5.4.3	M	Yes [ ]	Seven.
AN8	During MASTER_SLAVE configuration, the device with the lower seed value shall	32.5.4.3	M	Yes [ ]	Become the SLAVE.

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32.13.5.7 100BASE-T2 specific Auto-Negotiation requirements *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
AN9	Both PHYs set in manual mode to be either MASTER or SLAVE shall be treated as	32.5.4.3	M	Yes [ ]	MASTER-SLAVE resolution fault (Failure) condition
AN10	MASTER-SLAVE resolution fault (failure) condition shall result in	32.5.4.3	M	Yes [ ]	MASTER-SLAVE Configuration Resolution Fault bit (10.15) to be set
AN11	MASTER-SLAVE Configuration resolution fault condition shall be treated as	32.5.4.3	M	Yes [ ]	MASTER-SLAVE Configuration Resolution complete

32.13.5.8 PMA electrical specifications

Item	Feature	Subclause	Status	Support	Value/Comment
PME1	The value of all components in test circuits shall be accurate to within	32.6	M	Yes [ ]	±1%.
PME2	The PHY shall provide electrical isolation between	32.6.1.1	M	Yes [ ]	The DTE or repeater circuits including frame ground, and all MDI leads.
PME3	PHY-provided electrical separation shall withstand at least one of three electrical strength tests	32.6.1.1	M	Yes [ ]	a) 1500 V rms at 50–60Hz for 60 s, applied as specified in section 5.3.2 of IEC 60950. b) 2250 Vdc for 60 s, applied as specified in Section 5.3.2 of IEC 60950. c) a sequence of ten 2400 V impulses of alternating polarity, applied at intervals of not less than 1 s. The shape of the impulses shall be 1.2/50 µs. (1.2 µs virtual front time, 50 µs virtual time or half value), as defined in IEC 60950.
PME4	There shall be no insulation breakdown as defined in Section 5.3.2 of IEC 60950, during the test.	32.6.1.1	M	Yes [ ]	
PME5	The resistance after the test shall be at least	32.6.1.1	M	Yes [ ]	2 MΩ, measured at 500 Vdc.
PME6	The PMA shall provide the Transmit function specified in 32.4.1.1.2 in accordance with the electrical specifications of this clause.	32.6.1.2	M	Yes [ ]	

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32.13.5.8 PMA electrical specifications *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
PME7	Where a load is not specified, the transmitter shall meet all the requirements of this clause with a 100 Ω resistive differential load connected to each transmitter output.	32.6.1.2	M	Yes [ ]	
PME8	The tolerance on the poles of the test filters used in 32.6 shall be	32.6.1.2	M	Yes [ ]	±1%
PME9	A special transmit test mode shall be required to allow for testing of the transmitter waveform	32.6.1.2.1	M	Yes [ ]	
PME10	A test mode for measuring transmitter output jitter is required.	32.6.1.2.1	M	Yes [ ]	
PME11	For a PHY with a MII interface, the transmit test mode shall be enabled by	32.6.1.2.1	M	Yes [ ]	Setting bit 9.15 and 9.14 (MASTER-SLAVE Control register) of the MII management register set as shown in Table 32–6.
PME12	These test modes shall only change the data symbols provided to the transmitter circuitry and may not alter the electrical characteristics of the transmitter	32.6.1.2.1	M	Yes [ ]	
PME13	When transmit test mode 1 is enabled, the PHY shall transmit	32.6.1.2.1	M	Yes [ ]	The sequence of data symbols specified in 32.6.1.2.1 continuously from both transmitters.
PME14	When in test mode 1, the transmitter shall time the transmitted symbols	32.6.1.2.1	M	Yes [ ]	From a 25.000 MHz ± 0.01% clock.
PME15	When test mode 2 is enabled, the PHY shall transmit	32.6.1.2.1	M	Yes [ ]	The data symbol sequence {+2,–2} repeatedly on both channels.
PME16	When in test mode 2, the transmitter shall time the transmitted symbols	32.6.1.2.1	M	Yes [ ]	From a 25.000 MHz ± 0.01% clock.
PME17	A PHY without a MII shall provide a means to enter this test mode.	32.6.1.2.1	M	Yes [ ]	
PME18	The vendor shall	32.6.1.2.1	M	Yes [ ]	Provide a means to enable these modes for testing.

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32.13.5.8 PMA electrical specifications *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
PME19	When in transmit test mode 1 and observing the differential signal output at the MDI, terminated in 100 Ω, preprocessed by the high pass filter defined below, for either pair, with no intervening cable, the absolute value of the peak of the waveform at points A and B as defined in Figure 32–18 shall fall within	32.6.1.2.2	M	Yes [ ]	The range of 1.71V to 1.91 V (1.81 V ± 0.5 dB).
PME20	The absolute value of the peak of the waveforms at points A and B shall	32.6.1.2.2	M	Yes [ ]	Differ by less than 2%.
PME21	The absolute value of the peak of the waveform at points C and D as defined in Figure 32–18 shall differ	32.6.1.2.2	M	Yes [ ]	From 0.5 times the average of the absolute values of the peaks of the waveform at points A and B by less than 2%.
PME22	The preprocessing filter shall have	32.6.1.2.2	M	Yes [ ]	The transfer function specified in 32.6.1.2.2.
PME23	When in transmit test mode 1 and observing the differential transmitted output at the MDI, for either pair, with no intervening cabling, the peak value of the waveform at point F as defined in Figure 32–17 shall be	32.6.1.2.3	M	Yes [ ]	Greater than 70.5% of the peak value of the waveform at point E. A preprocessing filter is not used for this measurement.
PME24	The transmitter differential output voltage shall be measured at the output of the high pass filter defined in 32.6.1.2.2 with no intervening cables.	32.6.1.2.4	M	Yes [ ]	
PME25	The voltage waveforms at points A, B, C and D as defined in Figure 32–17, when normalized by their respective peak values, shall	32.6.1.2.4	M	Yes [ ]	Lie within the time domain template defined in Figure 32–18 and the piecewise linear interpolation between the points in Table 32–6
PME26	The magnitude in dB of the Fourier transform of the waveforms at points A, B, C and D shall	32.6.1.2.4	M	Yes [ ]	Lie within the transmit frequency domain template defined in Figure 32–18 and the piecewise linear interpolation between the points in Table 32–7.
PME27	The time span of the waveforms so processed shall be	32.6.1.2.4	M	Yes [ ]	–80 ns to +2000 ns with the 0 ns point of the waveform aligned as for the time domain mask shown in Figure 32–18 and the magnitude of the Fourier transform should be normalized so that the maximum value is at 0 dB.

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32.13.5.8 PMA electrical specifications *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
PME28	When in transmit mode 2, the peak-to-peak jitter of the zero crossings of the differential signal output at the MDI shall	32.6.1.2.5	M	Yes [ ]	Be less than 0.5 ns.
PME29	The quinary symbol transmission rate on each pair shall be	32.6.1.2.6	M	Yes [ ]	25.000 MHz ± 0.01%.
PME30	The PMA shall provide	32.6.1.3	M	Yes [ ]	The Receive function specified in 32.4.1.3 in accordance with the electrical specifications of this clause.
PME31	The patch cabling and interconnecting hardware used in test configurations shall	32.6.1.3	M	Yes [ ]	Meet or exceed ISO/IEC 11801 Category 3 specifications.
PME32	The combined responses of the test fixture TX block and NEXT or cabling channel blocks shall be	32.6.1.3.1	M	Yes [ ]	Those defined in Table 32–8.
PME33	The output impedance of the test channel shall be	32.6.1.3	M	Yes [ ]	Consistent with 32.6.1.4.1.
PME34	The idle symbol generator outputs shall be	32.6.1.3	M	Yes [ ]	Conformant with the idle signaling specified in 32.3 with loc_rcvr_status=OK.
PME35	The clock source shall	32.6.1.3	M	Yes [ ]	Result in a quinary symbol transmission rate conformant with 32.6.1.2.6.
PME36	The jitter on the clock source shall be	32.6.1.3	M	Yes [ ]	Less than 0.2 ns.
PME37	The test channel implementation shall ensure that the ratio of the squared error between the implemented NEXT channel symbol responses and the specified NEXT channel symbol responses to the energy in the specified NEXT channel symbol responses shall be	32.6.1.3	M	Yes [ ]	Less than 5%.
PME38	The test channel implementation shall ensure that the energy of the implemented NEXT channel impulse responses and the energy of the specified NEXT channel impulse responses shall	32.6.1.3	M	Yes [ ]	Differ by less than ±0.25 dB.
PME39	A special receiver test mode shall be required to allow for receiver alien NEXT tolerance and jitter testing.	32.6.1.3.2	M	Yes [ ]	
PME40	For a PHY with a MII interface, this mode shall be enabled by	32.6.1.3.2	M	Yes [ ]	Setting bit 9.13 (MASTER-SLAVE Control Register) of the MII management register set to a 1.

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32.13.5.8 PMA electrical specifications *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
PME41	A PHY without an MII shall provide	32.6.1.3.2	M	Yes [ ]	A means to enable this test mode.
PME42	This mode shall not be overridden except by	32.6.1.3.2	M	Yes [ ]	Clearing bit 9.13 or resetting the PHY.
PME43	When the receive test mode is enabled, the receiver shall	32.6.1.3.2	M	Yes [ ]	Configure itself in SLAVE mode, continually attempt to bring its receiver up until successful receiver operation is achieved and transmit symbols in idle mode.
PME44	For a PHY with a MII interface, when the receiver is properly detecting the received data, it shall set	32.6.1.3.2	M	Yes [ ]	Bit 10.13 of the MII management register set to 1 and reset the error count in bit 10.0–10.7 (MSB) to zero.
PME45	The error count shall be incremented	32.6.1.3.2	M	Yes [ ]	For every symbol error detected in the received idle sequence.
PME46	Upon loss of proper data reception, the receiver shall	32.6.1.3.2	M	Yes [ ]	Clear bit 10.13.
PME47	A PHY without an MII shall provide	32.6.1.3.2	M	Yes [ ]	A means to provide the functions defined in PME43 through PME46.
PME48	The vendor shall provide a means to enable this mode for conformance testing.	32.6.1.3.2	M	Yes [ ]	
PME49	Differential signals received on the receive inputs that were transmitted within the constraints of 32.6.1.2, and have then passed through a link as defined in 32.7, shall be translated into	32.6.1.3.3	M	Yes [ ]	One of the PMA_UNITDATA.indication messages with an bit error ratio less than 10^{-10} and sent to the PCS after link bring-up.
PME50	Performance shall be tested	32.6.1.3.3	M	Yes [ ]	In at least two configurations: using a 100 m link segment conformant to 32.7 and with a link segment less than one meter in length between transmitter and receiver.
PME51	Differential signals received from the test channel defined in 32.6.1.3.1 shall be detected	32.6.1.3.4	M	Yes [ ]	With a symbol error ratio less than 10^{-10} when the PHY is in receiver test mode for the combinations of channel and worst-case alien NEXT responses specified in 32.6.1.2.
PME52	In the test configuration described in 32.6.1.3.1 and for all combinations of worst-case channel and alien NEXT coefficients tabulated in 32.6.1.3.4, the peak-to-peak value of the RX_CLK zero-crossing jitter shall be less than	32.6.1.3.5	M	Yes [ ]	1.3 ns after the receiver is properly receiving the data and has set bit 9.13 of the MII management register set to 1.

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32.13.5.8 PMA electrical specifications *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
PME53	When the jitter waveform is filtered by a high pass filter having the transfer function specified in 32.6.1.3.4, the peak-to-peak value of the jitter waveform shall be less than	32.6.1.3.5	M	Yes [ ]	0.8 ns.
PME54	The RX_CLK of the MII shall be made available for the receiver jitter test specified in 32.6.1.3.5.	32.6.1.3.5	M	Yes [ ]	
PME55	A PHY without an MII shall provide an equivalent to the MII RX-CLK clock for the receiver jitter test specified in 32.6.1.3.5.	32.6.1.3.5	M	Yes [ ]	
PME56	While receiving packets from a compliant 100BASE-T2 transmitter connected to all MDI pins, a receiver shall send the	32.6.1.3.6	M	Yes [ ]	Proper PMA_UNITDATA.indication messages to the PCS for any differential input signal E_s that results in a signal E_{dif} that meets 32.6.1.3.3 even in the presence of common-mode voltages E_{cm} (applied as shown in Figure 32–21).
PME57	E_{cm} shall be	32.6.1.3.6	M	Yes [ ]	A 25 V peak-to-peak square wave, 500 kHz or lower in frequency, with edges no slower than 4 ns (20%–80%), connected to each of the pairs BI_DA+, BI_DA-, BI_DB+ and BI_DB-.
PME58	The receive feature shall properly receive	32.6.1.3.7	M	Yes [ ]	Incoming data with a 5-level symbol rate within the range 25.000 MHz ± 0.01%.
PME59	The differential impedance as measured at the MDI for each transmit/receive channel shall be such that	32.6.1.4.1	M	Yes [ ]	Any reflection due to differential signals incident upon the MDI from a balanced cabling having an impedance of 100 Ω is at least 17 dB below the incident signal, over the frequency range of 2.0 MHz to 25.0 MHz and at least $12.9–20\log_{10}(f/10)$ dB over the frequency range 6.5 MHz to 25 MHz (f in MHz).
PME60	This return loss shall be maintained	32.6.1.4.1	M	Yes [ ]	At all times when the PHY is transmitting data.
PME61	The common-mode to differential-mode impedance balance of each transmit output shall exceed	32.6.1.4.2	M	Yes [ ]	The value specified by the equations specified in 32.6.1.2.6 over the range 2.0–25.0 MHz.

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32.13.5.8 PMA electrical specifications *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
PME62	Transmitters and receivers shall tolerate	32.6.1.4.4	M	Yes [ ]	The application of short circuits between the leads of any receive input for an indefinite period of time without damage.
PME63	Transmitters and receivers shall resume	32.6.1.4.4	M	Yes [ ]	Normal operation after such faults are removed.
PME64	The magnitude of the current through the short circuit specified in PME62 shall not exceed	32.6.1.4.4	M	Yes [ ]	300 mA.
PME65	Transmitters shall withstand without damage	32.6.1.4.4	M	Yes [ ]	A 1000 V common-mode impulse of either polarity (E_{cm} as indicated in Figure 32–24).
PME66	The shape of the impulse shall be	32.6.1.4.4	M	Yes [ ]	0.3/50 µs (300 ns virtual front time, 50 µs virtual time of half value), as defined in IEC 60060.
PME67	After 100 ms following PowerOn, the current drawn by the PHY shall not exceed	32.6.2	M	Yes [ ]	1.0 A when powered through the MII.
PME68	The PHY shall	32.6.2	M	Yes [ ]	Be capable of operating from all voltage sources allowed by Clause 22, including those current limited to1.0 A, as supplied by the DTE or repeater through the resistance of all permissible MII cabling.
PME69	The PHY shall not introduce	32.6.2	M	Yes [ ]	Extraneous signals on the MII control circuits during normal power-up and power-down.

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32.13.5.9 Characteristics of the link segment

Item	Feature	Subclause	Status	Support	Value/Comment
LKS1	100BASE-T2 links shall use	32.7.1	M	Yes [ ]	2 pair of balanced cabling, CAT 3 or better, with a nominal impedance of 100 Ω.
LKS2	Unless otherwise specified, link segment testing shall be conducted using	32.7.2	M	Yes [ ]	Source and load impedances of 100 Ω
LKS3	The tolerance on the poles of the test filter used in this section shall be	32.7.2	M	Yes [ ]	± 1%.
LKS4	The insertion loss of a link segment shall be no more than	32.7.2.1	M	Yes [ ]	14.6 dB at all frequencies between 2 and 16 MHz.
LKS5	The insertion loss specification shall be met when	32.7.2.1	M	Yes [ ]	The link segment is terminated in source and load impedances that satisfy 32.6.1.4.1.
LKS6	The magnitude of the differential characteristic impedance of a 3 m segment of balanced cabling pair used in a link shall be	32.7.2.2	M	Yes [ ]	Between 85 and 115 Ω for all frequencies between 2 and 16 MHz.
LKS7	The NEXT loss between each of the two duplex channels of a link segment shall be	32.7.2.3.1	M	Yes [ ]	At least $19.3–16.6\log_{10}(f/16)$ (where f is the frequency in MHz) over the frequency range 2.0 to 16 MHz.
LKS8	The NEXT loss between link segments of two different connections shall be	32.7.2.3.1	M	Yes [ ]	At least $22.0 –16.6\log_{10}(f/16)$ (where f is the frequency in MHz) over the frequency range 2.0 to 16 MHz.
LKS9	The MDNEXT loss between a link segment and the two alien data carrying channels shall be	32.7.2.3.2	M	Yes [ ]	At least $19.0–16.6\log_{10}(f/16)$ dB (where f is the frequency in MHz) over the frequency range 2.0 to 16 MHz.
LKS10	To limit the FEXT noise from an adjacent channel, the ELFEXT loss between channels shall be	32.7.2.3.3	M	Yes [ ]	Greater than $20.9–20\log_{10}(f/16)$ dB as defined in 32.7.2.3.3
LKS11	The MDELFEXT loss between a duplex channel and the other data carrying duplex channels shall be	32.7.2.3.4	M	Yes [ ]	Greater than $19.9–20\log10(f/16)$ (where f is the frequency in MHz) over the frequency range 2.0 to 16 MHz.
LKS12	The maximum spacing of the frequency in the sample shall be	32.7.2.3.5	M	Yes [ ]	250 kHz.

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32.13.5.9 Characteristics of the link segment *(continued)*

Item	Feature	Subclause	Status	Support	Value/Comment
LKS13	When 10BASE-T service is used in adjacent pairs, the channel shall provide	32.7.2.3.5	M	Yes [ ]	A NEXT loss to Insertion loss Ratio (NIR) greater than 19.4 dB.
LKS14	The propagation delay of a link segment shall not exceed	32.7.2.4.1	M	Yes [ ]	5.7 ns/meter at all frequencies between 2.0–25.0 MHz.
LKS15	The difference in propagation delay, or skew, under all conditions, between the fastest and the slowest channel in a link segment shall not exceed	32.7.2.4.2	M	Yes [ ]	50 ns at all frequencies between 2.0–25.0 MHz.
LKS16	Once installed, the skew between pairs due to environmental conditions shall not vary	32.7.2.4.2	M	Yes [ ]	More than ± 10 ns.
LKS17	The noise level on the link segments shall be such that	32.7.3	M	Yes [ ]	The objective error ratio is met.
LKS18	The MDNEXT noise on a link segment shall not exceed	32.7.3.1	M	Yes [ ]	182 mVp.
LKS19	The MDFEXT noise on a link segment shall not exceed	32.7.3.2	M	Yes [ ]	54.4 mVp.
LKS20	Cables made from up to 25 pairs of Category 5 cabling, if used, shall be limited in length to no more than	32.7.4.3	O	Yes [ ]	90 m total.
LKS21	The services in 25 pair Category 5 cabling shall be limited to any combination of 100BASE-T2, 10BASE-T and digital phone service compliant with the ISDN-BR U and S/T interfaces up to a total of 12 services in the cable.	32.7.4.3	M	Yes [ ]	
LKS22	Jumper cabling, or horizontal runs, made from more than 4 pairs of Category 3 cabling shall not be used	32.7.4.3	M	Yes [ ]	

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32.13.5.10 MDI requirements

Item	Feature	Subclause	Status	Support	Value/Comment
MDI1	MDI connector	32.8.1	M	Yes [ ]	8-Way connector as per IEC 60603-7.
MDI2	Connector used on cabling	32.8.1	M	Yes [ ]	Plug.
MDI3	Connector used on PHY	32.8.1	M	Yes [ ]	Jack (as opposed to plug).
MDI4	AN MDI connector for the PHY that implements the crossover function shall be marked	32.8.2	M	Yes [ ]	With the graphical symbol "X".

32.13.5.11 General safety and environmental requirements

Item	Feature	Subclause	Status	Support	Value/Comment
ENV1	Conformance to safety specifications	32.10.1	M	Yes [ ]	IEC 60950.
ENV2	Installation practice	32.10.2.1	M	Yes [ ]	Sound practice, as defined by applicable local codes.
ENV3	Any safety grounding path for an externally connected PHY shall be provided through the circuit ground of the MII connection.	32.10.2.2	M	Yes [ ]	
ENV4	Care taken during installation to ensure that non-insulated network cabling conductors do not make electrical contact with unintended conductors or ground.	32.10.2.3	M	Yes [ ]	
ENV5	Application of voltages specified in 32.10.2.4 does not result in any safety hazard.	32.10.2.4	M	Yes [ ]	
ENV6	Conformance with local and national codes for the limitation of electromagnetic interference.	32.10.3.1	M	Yes [ ]	
ENV7	All equipment subject to this clause shall conform to	32.10.4	M	Yes [ ]	The requirements of 14.7 and the applicable sections of ISO/IEC 11801.

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32.13.5.12 Timing requirements exposed MII

Item	Feature	Subclause	Status	Support	Value/Comment
TME1	TX-EN (sampled to MDI output)	32.12.1	M	Yes [ ]	7–9 bit times
TME2	MDI input to CRS assert	32.12.1	M	Yes [ ]	25 bit times
TME3	MDI input to CRS deassert	32.12.1	M	Yes [ ]	29 bit times
TME4	MDI input to COL assert	32.12.1	M	Yes [ ]	25 bit times
TME5	MDI input to COL deassert	32.12.1	M	Yes [ ]	29 bit times
TME6	TX_EN sampled to CRS assert	32.12.1	M	Yes [ ]	0–4 bit times
TME7	TX_EN sampled to CRS deassert	32.12.1	M	Yes [ ]	0–16 bit times

32.13.5.13 Timing requirements unexposed MII

Item	Feature	Subclause	Status	Support	Value/Comment
TMU1	MAC transmit start to MDI output	32.12.2	M	Yes [ ]	13 bit times
TMU2	MDI input to MDI output (worst-case non-deferred transmit)	32.12.2	M	Yes [ ]	50 bit times
TMU3	MDI input to collision detect	32.12.2	M	Yes [ ]	33 bit times
TMU4	MDI input to MDI output = Jam (worst-case collision response)	32.12.2	M	Yes [ ]	50 bit times

32.13.5.14 Timing requirements: carrier assertion/deassertion constraint

Item	Feature	Subclause	Status	Support	Value/Comment
TMC1	Each DTE shall satisfy the relationship	36.5.3	M	Yes [ ]	(MAX MDI to MAC Carrier Deassert Detect)–(MIN MDI to MAC Carrier Assert Detect).

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33. Data Terminal Equipment (DTE) Power via Media Dependent Interface (MDI)

33.1 Overview

This clause defines the functional and electrical characteristics of two optional power (non-data) entities, a Powered Device (PD) and Power Sourcing Equipment (PSE), for use with the MAU defined in Clause 14 and the PHYs defined in Clause 25 and Clause 40. These entities allow devices to draw/supply power using the same generic cabling as is used for data transmission.

DTE powering is intended to provide a 10BASE-T, 100BASE-TX, or 1000BASE-T device with a single interface to both the data it requires and the power to process this data. This clause specifies the following:

a) A power source to add power to the 100 Ω balanced cabling system
b) The characteristics of a powered device's load on the power source and the structured cabling
c) A protocol allowing the detection of a device that requests power from a PSE
d) Methods to classify devices based on their power needs
e) A method for powered devices and power sourcing equipment to dynamically negotiate and allocate power
f) A method for scaling supplied power back to the detect level when power is no longer requested or required

The importance of item c) above should not be overlooked. Given the large number of legacy devices (both IEEE 802.3 and other types of devices) that could be connected to a 100 Ω balanced cabling system, and the possible consequences of applying power to such devices, the protocol to distinguish compatible devices and non-compatible devices is important to prevent damage to non-compatible devices.

The detection and powering algorithms are likely to be compromised by cabling that is not point-to-point, resulting in unpredictable performance and possibly damaged equipment.

This clause differentiates between the two ends of the powered portion of the link, defining the PSE and the PD as separate but related devices.

33.1.1 Objectives

The following are objectives of Power via MDI:

a) *Power*—A PD designed to the standard, and within its range of available power, can obtain both power and data for operation through the MDI and therefore needs no additional connections.
b) *Safety*—A PSE designed to the standard does not introduce non-SELV (Safety Extra Low Voltage) power into the wiring plant.
c) *Compatibility*—Clause 33 utilizes the MDIs of 10BASE-T, 100BASE-TX, and 1000BASE-T without modification. Type 1 operation adds no significant requirements to the cabling. Type 2 operation requires ISO/IEC 11801:1995 Class D or better cabling and a derating of the cabling maximum ambient operating temperature. The clause does not address the operation of 10GBASE-T. For 10GBASE-T operation, the channel model specified in Clause 55 needs to be met without regard to DTE Power via MDI presence or operation.
d) *Simplicity*—The powering system described here is no more burdensome on the end users than the requirements of 10BASE-T, 100BASE-TX, or 1000BASE-T.

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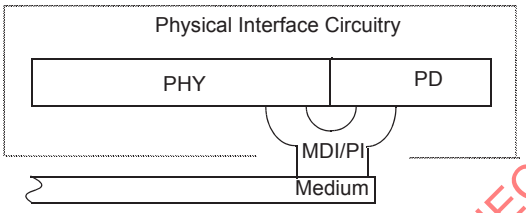
33.1.2 Compatibility considerations

All implementations of PD and PSE systems shall be compatible at their respective Power Interfaces (PIs) when used in accordance with the restrictions of Clause 33 where appropriate. Designers are free to implement circuitry within the PD and PSE in an application-dependent manner provided that the respective PI specifications are satisfied.

33.1.3 Relationship of DTE Power via MDI to the IEEE 802.3 Architecture

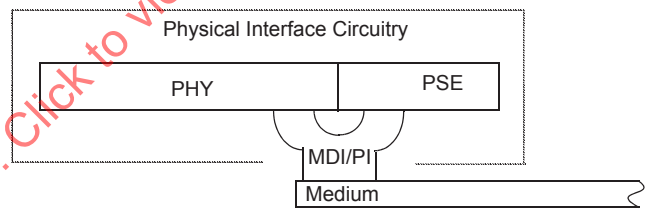
DTE Power via MDI comprises an optional non-data entity. As a non-data entity, it does not appear in a depiction of the OSI Reference Model. Figure 33–1 depicts the positioning of DTE Power via MDI in the case of the PD.



MDI = Medium Dependent Interface
PD = Powered Device
PHY = Physical Layer Device
PI = Power Interface

Figure 33–1—DTE Power via MDI powered device relationship to the physical interface circuitry and the IEEE 802.3 CSMA/CD LAN model

Figure 33–2 and Figure 33–3 depict the positioning of DTE Power via MDI in the cases of the Endpoint PSE and the Midspan PSE, respectively.



MDI = Medium Dependent Interface
PHY = Physical Layer Device
PI = Power Interface
PSE = Power Sourcing Equipment

Figure 33–2—DTE Power via MDI Endpoint power sourcing equipment relationship to the physical interface circuitry and the IEEE 802.3 CSMA/CD LAN model

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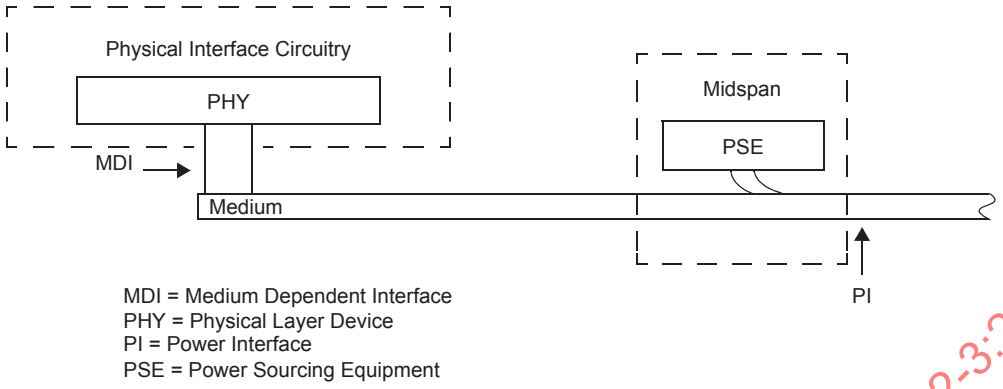

Figure 33–3—DTE Power via MDI Midspan power sourcing equipment relationship to the physical interface circuitry and the IEEE 802.3 CSMA/CD LAN model

The Power Interface (PI) is the generic term that refers to the mechanical and electrical interface between the PSE or PD and the transmission medium.

In an Endpoint PSE and in a PD, the PI is encompassed within the MDI.

PSE power interface specifications that are defined at the MDI apply to an Endpoint PSE. They may or may not apply to a Midspan PSE PI.

33.1.4 Type 1 and Type 2 system parameters

A power system, consisting of a single PSE, link segment, and a single PD, defined as either Type 1 or Type 2, has certain basic parameters defined according to Table 33–1. These parameters define not only certain performance characteristics of the system, but are also used in calculating the various electrical characteristics of PSEs and PDs as described in 33.2 and 33.3.

Table 33–1—Type 1 and Type 2 system parameters

Parameter	Symbol	Units	Type 1 value	Type 2 value	Additional information
Nominal highest DC current per pair	I_{Cable}	A	0.350	0.600	
Channel maximum DC pair loop resistance	R_{Ch}	Ω	20.0	12.5	
Minimum cable type			twisted-pair cabling per 14.4 and 14.5[a]	Class D	See 33.1.4.1, 33.1.4.2

[a]Class D recommended.

I_{Cable} is the current on one twisted pair in the multi-twisted pair cable. Two twisted pairs are required to source I_{Cable}—one carrying (+ I_{Cable}) and one carrying (– I_{Cable}), from the perspective of the PI.

It should be noted that the cable references use “DC loop resistance,” which refers to a single conductor. This clause uses “DC pair loop resistance,” which refers to a pair of conductors in parallel. Therefore, R_{Ch} is related to, but not equivalent to, the “DC loop resistance” called out in the cable references.

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33.1.4.1 Type 2 cabling requirement

Type 2 operation requires Class D, or better, cabling as specified in ISO/IEC 11801:1995 with the additional requirement that channel DC loop resistance shall be 25 Ω or less. These requirements are also met by Category 5e or better cable and components as specified in ANSI/TIA-568-C.2; or Category 5 cable and components as specified in ANSI/TIA/EIA-568-A.

Under worst-case conditions, Type 2 operation requires a 10 °C reduction in the maximum ambient operating temperature of the cable when all cable pairs are energized at I_{Cable} (see Table 33–1), or a 5 °C reduction in the maximum ambient operating temperature of the cable when half of the cable pairs are energized at I_{Cable}. Additional cable ambient operating temperature guidelines for Type 2 operation are provided in ISO/IEC TR 29125 [B48][20] and TIA TSB-184 [B60].

33.1.4.2 Type 1 and Type 2 channel requirement

Type 1 and Type 2 operation requires that the resistance unbalance shall be 3% or less. Resistance unbalance is a measure of the difference between the two conductors of a twisted pair in the 100 Ω balanced cabling system. Resistance unbalance is defined as in Equation (33–1):

$$\left.\frac{(R_{max} - R_{min})}{(R_{max} + R_{min})} \times 100 \right\}_{\%} \tag{33–1}$$

where

R_{max} is the resistance of the channel conductor with the highest resistance
R_{min} is the resistance of the channel conductor with the lowest resistance

33.2 Power sourcing equipment (PSE)

The PSE is the portion of the end station or midspan equipment that provides the power to a single PD. The PSE's main functions are as follows:

— To search the link section for a PD
— To supply power to the detected PD through the link section
— To monitor the power on the link section
— To remove power when no longer requested or required, returning to the searching state

An unplugged link section is one instance when power is no longer required. In addition, power classification mechanisms exist to provide the PSE with detailed information regarding the power needs of the PD.

A PSE is electrically specified at the point of the physical connection to the cabling.

33.2.1 PSE location

PSEs may be placed in two locations with respect to the link segment, either coincident with the DTE/Repeater or midspan. A PSE that is coincident with the DTE/Repeater is an "Endpoint PSE." A PSE that is located within a link segment that is distinctly separate from and between the MDIs is a "Midspan PSE." The requirements of this document shall apply equally to Endpoint and Midspan PSEs unless the requirement contains an explicit statement that it applies to only one implementation. The location of

[20]The numbers in brackets correspond to those of the bibliography in Annex A.

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Alternative A and Alternative B Endpoint PSEs and Midspan PSEs are illustrated in Figure 33–4, Figure 33–5, Figure 33–6, and Figure 33–7.

PSEs can be compatible with 10BASE-T, 100BASE-TX, and/or 1000BASE-T. PSEs may support either Alternative A, Alternative B, or both.

33.2.2 Midspan PSE types

There are two types of Midspan PSEs defined.

10BASE-T/100BASE-TX Midspan PSE:
: A Midspan PSE that results in a link that can support only 10BASE-T and 100BASE-TX operation (see Figure 33–6). Note that this limitation is due to the presence of the Midspan PSE whether it is supplying power or not.

1000BASE-T Midspan PSE:
: A Midspan PSE that results in a link that can support 10BASE-T, 100BASE-TX, and 1000BASE-T operation (see Figure 33–7).

NOTE—See 33.4.9.2 for Alternative A Midspan PSEs.

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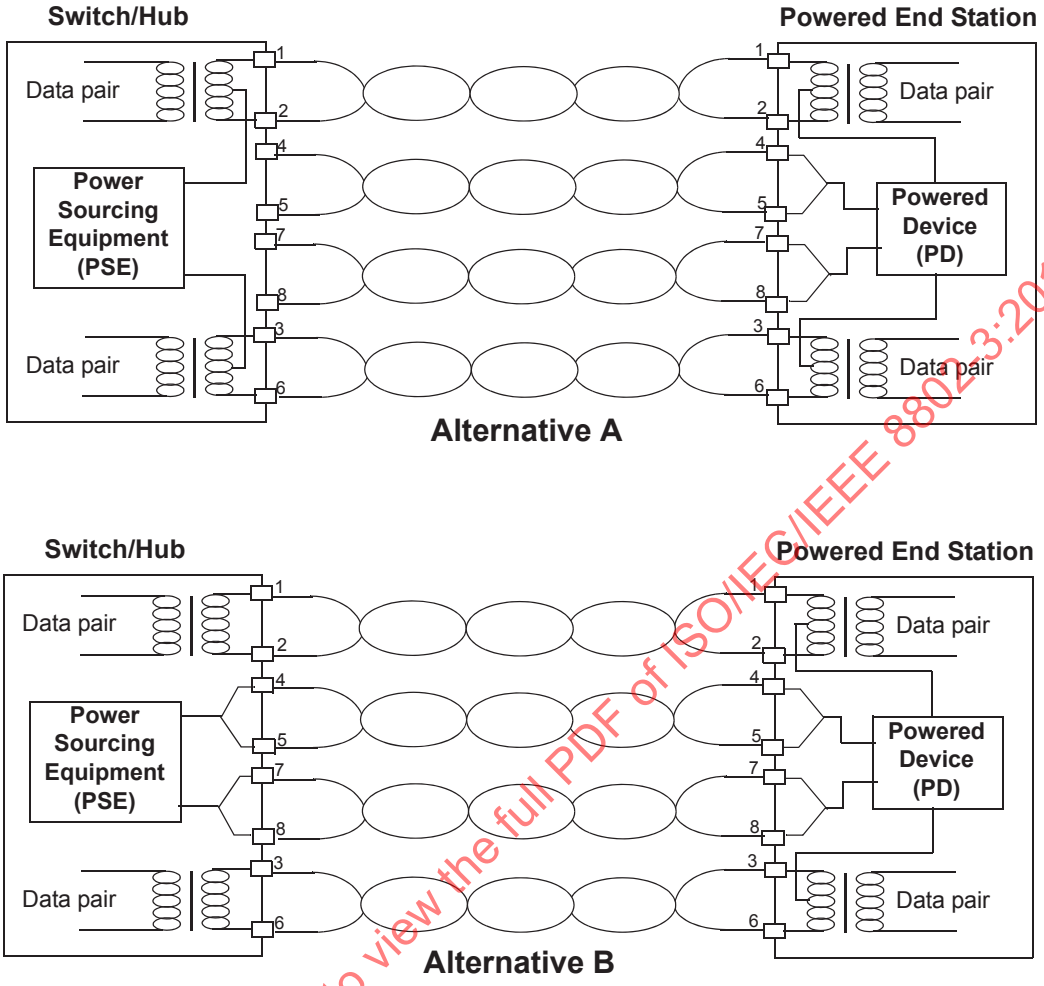

Figure 33–4—10BASE-T/100BASE-TX Endpoint PSE location overview

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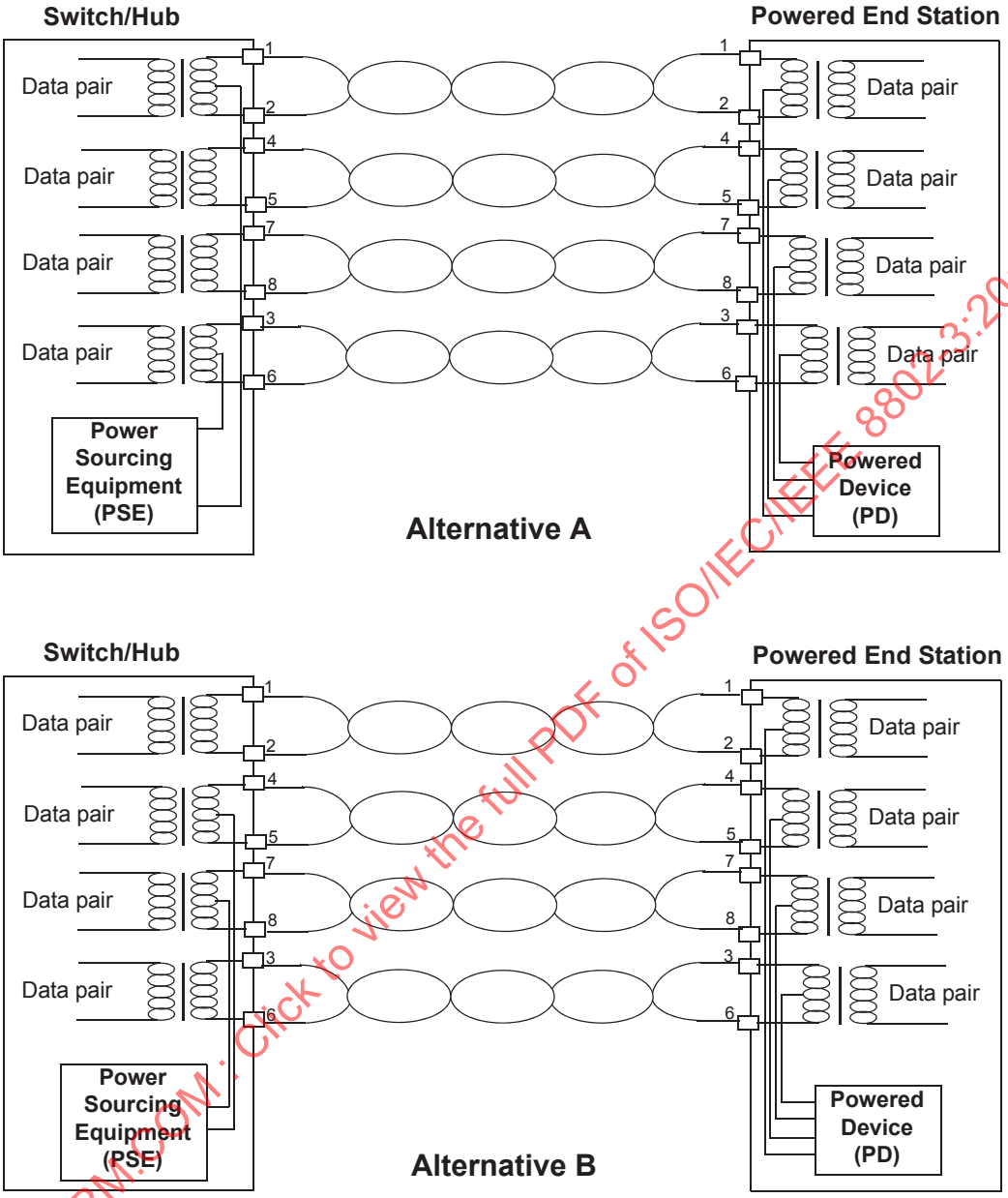

Figure 33–5—1000BASE-T Endpoint PSE location overview

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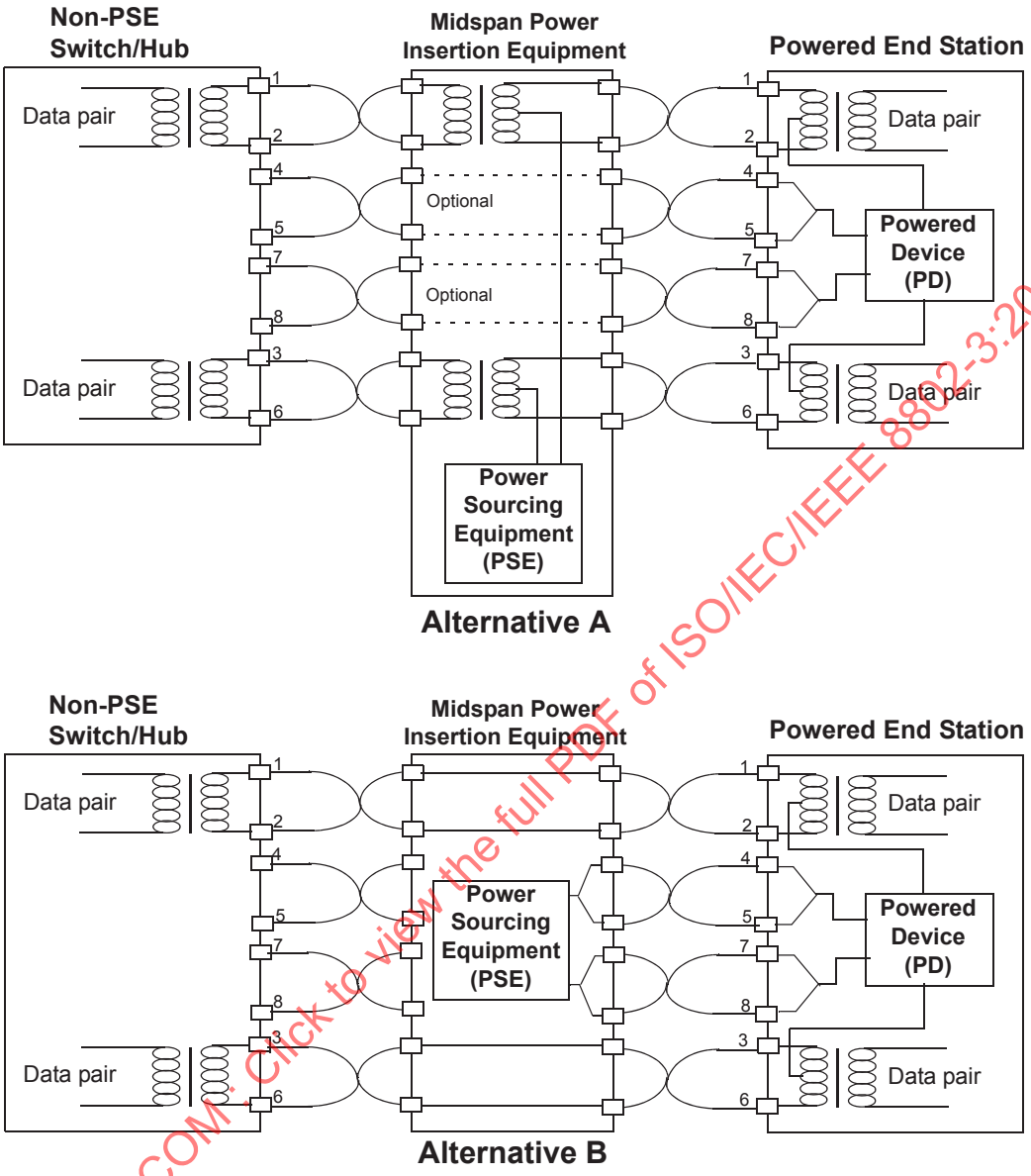

Figure 33–6—10BASE-T/100BASE-TX Midspan PSE location overview

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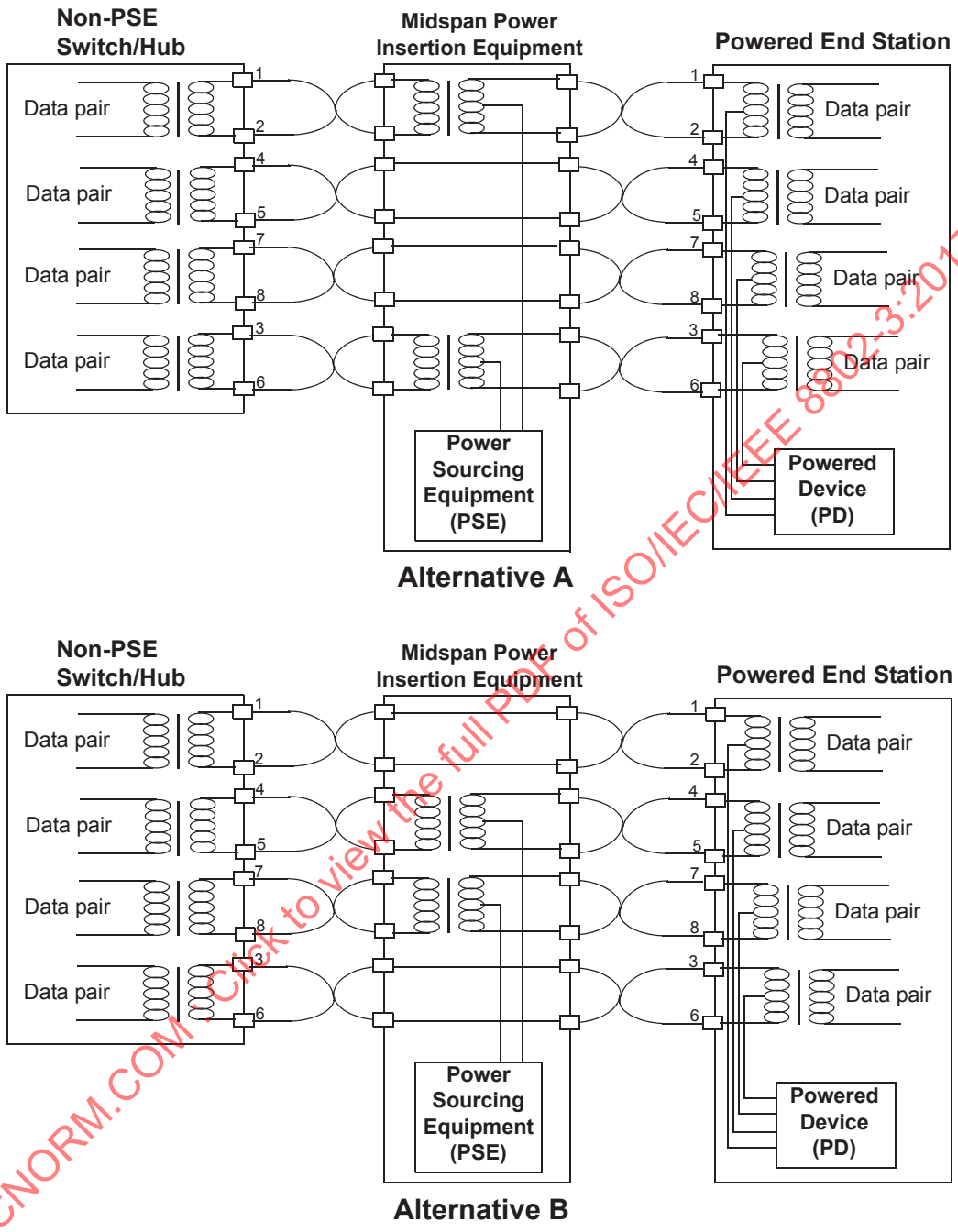

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Figure 33–7—1000BASE-T Midspan PSE location overview

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33.2.3 PI pin assignments

A PSE device may provide power via one of two valid four-wire connections. In each four-wire connection, the two conductors associated with a pair each carry the same nominal current in both magnitude and polarity. Figure 33–8, in conjunction with Table 33–2, illustrates the valid alternatives.

Table 33–2—PSE Pinout alternatives

Conductor	Alternative A (MDI-X)	Alternative A (MDI)	Alternative B (All)
1	Negative V_{PSE}	Positive V_{PSE}	
2	Negative V_{PSE}	Positive V_{PSE}	
3	Positive V_{PSE}	Negative V_{PSE}	
4			Positive V_{PSE}
5			Positive V_{PSE}
6	Positive V_{PSE}	Negative V_{PSE}	
7			Negative V_{PSE}
8			Negative V_{PSE}

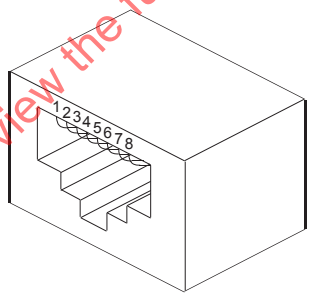

Figure 33–8—PD and PSE eight-pin modular jack

For the purposes of data transfer, the type of PSE data port is relevant to the far-end PD, and in some cases, to the cabling system between them. Therefore, Alternative A matches the positive voltage to the transmit pair of the PSE. PSEs that use automatically-configuring MDI/MDI-X ("Auto MDI-X") ports may choose either polarity choice associated with Alternative A configurations. For further information on the placement of MDI vs. MDI-X, see 14.5.2.

A PSE shall implement Alternative A, Alternative B, or both. While a PSE may be capable of both Alternative A and Alternative B, PSEs shall not operate both Alternative A and Alternative B on the same link segment simultaneously.

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33.2.4 PSE state diagrams

The PSE shall provide the behavior of the state diagrams shown in Figure 33–9, Figure 33–9 continued, and Figure 33–10.

33.2.4.1 Overview

Detection, classification, and power turn-on timing shall meet the specifications in Table 33–4, Table 33–10, and Table 33–11.

If power is to be applied, the PSE turns on power after a valid detection in less than T_{pon} as specified in Table 33–11. If the PSE cannot supply power within T_{pon}, it initiates and successfully completes a new detection cycle before applying power.

It is possible that two separate PSEs, one that implements Alternative A and one that implements Alternative B (see 33.2.1), may be attached to the same link segment. In such a configuration, and without the required backoff algorithm, the PSEs could prevent each other from ever detecting a PD by interfering with the detection process of the other.

A PSE performing detection using Alternative B may fail to detect a valid PD detection signature. When this occurs, the PSE backs off for at least T_{dbo} as specified in Table 33–11 before attempting another detection. During this backoff, the PSE shall not apply a voltage greater than V_{off} to the PI.

If a PSE performing detection using Alternative B detects an open circuit (see 33.2.5.5) on the link section, then that PSE may optionally omit the detection backoff.

If a PSE performing detection using Alternative A detects an invalid signature, it should complete a second detection in less than T_{dbo} min after the beginning of the first detection attempt. This allows an Alternative A PSE to complete a successful detection cycle prior to an Alternative B PSE present on the same link section that may have caused the invalid signature.

NOTE—A Type 1 PSE performing detection using Alternative A may need to have its DTE powering ability disabled when it is attached to the same link segment as a Type 2 Midspan PSE performing detection using Alternative B. This allows the Midspan PSE to successfully complete a detection cycle.

33.2.4.2 Conventions

The notation used in the state diagrams follows the conventions of state diagrams as described in 21.5.

33.2.4.3 Constants

The PSE state diagrams use the following constants:

PSE_TYPE
A constant indicating the type of the PSE
Values: 1: Type 1 PSE
2: Type 2 PSE

33.2.4.4 Variables

The PSE state diagrams use the following variables:

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class_num_events

A variable indicating the number of classification events performed by the PSE. A variable that is set in an implementation-dependent manner.

Values:0: PSE does not perform Physical Layer classification.
1: PSE performs 1-Event Physical Layer classification.
2: PSE performs 2-Event Physical Layer classification.

error_condition

A variable indicating the status of implementation-specific fault conditions or optionally other system faults that prevent the PSE from meeting the specifications in Table 33–11 and that require the PSE not to source power. These error conditions are different from those monitored by the state diagrams in Figure 33–10.

Values:FALSE:No fault indication.
TRUE:A fault indication exists.

I_{Inrush}

Output current during POWER_UP (see Table 33–11 and Figure 33–13).

I_{Port}

Output current (see 33.2.7.6).

legacy_powerup

This variable is provided for PSEs that monitor the PI voltage output and use that information to indicate the completion of PD inrush current during POWER_UP operation. Using only the PI voltage information may be insufficient to determine the true end of PD inrush current; use of a fixed T_{Inrush} period is recommended. A variable that is set in an implementation-dependent manner.

Values:TRUE:The PSE supports legacy power up; this value is not recommended.
FALSE:The PSE does not support legacy power up. It is highly recommended that new equipment use this value.

mr_mps_valid

The PSE monitors either the DC or AC Maintain Power Signature (MPS, see 33.2.9.1). This variable indicates the presence or absence of a valid MPS.

Values:FALSE:If monitoring both components of the MPS, the DC component of MPS is absent or the AC component of MPS is absent. If monitoring only one component of MPS, that component of MPS is absent.
TRUE: If monitoring both components of the MPS, the DC component of MPS and the AC component of MPS are both present. If monitoring only one component of MPS, that component of MPS is present.

mr_pse_alternative

This variable indicates which Pinout Alternative the PSE uses to apply power to the link (see Table 33–2). This variable is provided by a management interface that may be mapped to the PSE Control register Pair Control bits (11.3:2) or other equivalent function.

Values:A: The PSE uses PSE pinout Alternative A.
B: The PSE uses PSE pinout Alternative B.

mr_pse_enable

A control variable that selects PSE operation and test functions. This variables is provided by a management interface that may be mapped to the PSE Control register PSE Enable bits (11.1:0), as described below, or other equivalent functions.

Values:disable: All PSE functions disabled (behavior is as if there was no PSE functionality). This value corresponds to MDIO register bits 11.1:0 = '00'.
enable: Normal PSE operation. This value corresponds to MDIO register bits 11.1:0 = '01'.
force_power:Test mode selected that causes the PSE to apply power to the PI when there are no detected error conditions. This value corresponds to MDIO register bits 11.1:0 = '10'.

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option_detect_ted

This variable indicates if detection can be performed by the PSE during the ted_timer interval.

Values:FALSE:Do not perform detection during ted_timer interval.

TRUE:Perform detection during ted_timer interval.

option_vport_lim

This optional variable indicates if V_{PSE} is out of the operating range during normal operating state.

Values:FALSE:V_{PSE} is within the V_{Port_PSE} operating range as defined in Table 33–11.

TRUE:V_{PSE} is outside of the V_{Port_PSE} operating range as defined in Table 33–11.

ovld_detected

A variable indicating if the PSE output current has been in an overload condition (see 33.2.7.6) for at least T_{CUT} of a one second sliding time.

Values:FALSE:The PSE has not detected an overload condition.

TRUE:The PSE has detected an overload condition.

pd_dll_power_type

A control variable output by the PSE power control state diagram (Figure 33–27) that indicates the type of PD as advertised through Data Link Layer classification.

Values:1: PD is a Type 1 PD (default)

2: PD is a Type 2 PD

pi_powered

A variable that controls the circuitry that the PSE uses to power the PD.

Values:FALSE:The PSE is not to apply power to the link (default).

TRUE:The PSE has detected a PD, classified it if applicable, and determined the PD is to be powered; or power is being forced on in TEST_MODE.

power_applied

A variable indicating that the PSE has begun steady state operation by having asserted pi_powered, completed the ramp of voltage, is not in a current limiting mode, and is operating beyond the POWER_UP requirements of 33.2.7.5.

Values:FALSE:The PSE is either not applying power or has begun applying power but is still in POWER_UP.

TRUE:The PSE has begun steady state operation.

power_not_available

Variable that is asserted in an implementation-dependent manner when the PSE is no longer capable of sourcing sufficient power to support the attached PD. Sufficient power is defined by classification; see 33.2.6.

Values:FALSE:PSE is capable to continue to source power to a PD.

TRUE:PSE is no longer capable of sourcing power to a PD.

pse_available_power

This variable indicates the highest power PD Class that could be supported. The value is determined in an implementation-specific manner.

Values:0: Class 1

1: Class 2

2: Class 0 and Class 3

3: Class 4

pse_dll_capable

This variable indicates whether the PSE is capable of performing optional Data Link Layer classification. See 33.6. This variable is provided by a management interface that may be mapped to the PSE Control register Data Link Layer Classification Capability bit (11.5), as described below, or other equivalent functions. A variable that is set in an implementation-dependent manner.

Values:FALSE:The PSE's Data Link Layer classification capability is not enabled.

TRUE:The PSE's Data Link Layer classification capability is enabled.

pse_dll_enabled

A variable indicating whether the Data Link Layer classification mechanism is enabled. See 33.6.

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Values:FALSE:Data Link Layer classification is not enabled.
TRUE:Data Link Layer classification is enabled.

pse_ready
Variable that is asserted in an implementation-dependent manner to probe the link segment.
Values:FALSE:PSE is not ready to probe the link segment.
TRUE:PSE is ready to probe the link segment.

NOTE—Care should be taken when negating this variable in a PSE performing detection using Alternative A after an invalid signature is detected due to the delay it introduces between detection attempts (see 33.2.4.1).

pse_reset
Controls the resetting of the PSE state diagram. Condition that is TRUE until such time as the power supply for the device that contains the PSE overall state diagrams has reached the operating region. It is also TRUE when implementation-specific reasons require reset of PSE functionality.
Values:FALSE:Do not reset the PSE state diagram.
TRUE:Reset the PSE state diagram.

pse_skips_event2
The PSE can choose to bypass a portion of the classification state flow. A variable that is set in an implementation-dependent manner.
Values:FALSE:The PSE does not bypass MARK_EV1.
TRUE:The PSE does bypass MARK_EV1.

short_detected
A variable indicating if the PSE output current has been in a short circuit condition for T_{LIM} within a sliding window (see 33.2.7.7).
Values:FALSE:The PSE has not detected a short circuit condition.
TRUE:The PSE has detected qualified short circuit condition.

temp_var
A temporary variable used to store the value of the state variable mr_pd_class_detected.

PSEs shall meet at least one of the allowable variable definition permutations described in Table 33–3.

Table 33–3—Allowed PSE variable definition permutations

PSE Type	Variables	
	class_num_events	pse_dll_capable
Type 2	2	FALSE
		TRUE
	1	TRUE
Type 1	1	FALSE
		TRUE
	0	FALSE
		TRUE

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33.2.4.5 Timers

All timers operate in the manner described in 14.2.3.2 with the following addition: a timer is reset and stops counting upon entering a state where “stop x_timer” is asserted.

tcle1_timer
: A timer used to limit the first classification event time in 2-Event classification; see T_{CLE1} in Table 33–10.

tcle2_timer
: A timer used to limit the second classification event time in 2-Event classification; see T_{CLE2} in Table 33–10.

tdbo_timer
: A timer used to regulate backoff upon detection of an invalid signature; see T_{dbo} in Table 33–11.

tdet_timer
: A timer used to limit an attempt to detect a PD; see T_{det} in Table 33–11.

ted_timer
: A timer used to regulate a subsequent attempt to power a PD after an error condition causes power removal; see T_{ed} in Table 33–11. The default state of this timer is ted_timer_done.

tinrush_timer
: A timer used to monitor the duration of the inrush event; see T_{Inrush} in Table 33–11.

tme1_timer
: A timer used to limit the first mark event time in 2-Event classification; see T_{ME1} in Table 33–10.

tme2_timer
: A timer used to limit the second mark event time in 2-Event classification; see T_{ME2} in Table 33–10.

tmpdo_timer
: A timer used to monitor the dropout of the MPS; see T_{MPDO} in Table 33–11.

tpdc_timer
: A timer used to limit the classification time; see T_{pdc} in Table 33–10.

tpon_timer
: A timer used to limit the time for power turn-on; see T_{pon} in Table 33–11.

33.2.4.6 Functions

do_classification
: This function returns the following variables:

pd_requested_power: This variable indicates the power class requested by the PD. A Type 1 PSE that measures a Class 4 signature assigns that PD to Class 0. See 33.2.6.

Values:
- 0: Class 1
- 1: Class 2
- 2: Class 0 or Class 3
- 3: Class 4

mr_pd_class_detected: The class of the PD associated with the PD classification signature; see Table 33–7 and 33.2.6.

Values:
- 0: Class 0
- 1: Class 1
- 2: Class 2
- 3: Class 3
- 4: Class 4

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do_detection

This function returns the following variables:

signature:

This variable indicates the presence or absence of a PD.

Values: open_circuit:The PSE has detected an open circuit. This value is optionally returned by a PSE performing detection using Alternative B.
valid: The PSE has detected a PD requesting power.
invalid: Neither open_circuit, nor valid PD detection signature has been found.

mr_valid_signature:

This variable indicates that the PSE has detected a valid signature.

Values: FALSE: No valid signature detected.
TRUE: Valid signature detected.

do_mark

This function produces the classification mark event voltage. This function does not return any variables.

set_parameter_type

This function is used by a Type 2 PSE to evaluate the type of PD connected to the link based on Physical Layer classification or Data Link Layer classification results. The PSE's PI electrical requirements defined in Table 33–11 are set to values corresponding to either a Type 1 or Type 2 PSE. This function returns the following variable:

parameter_type: A variable used by a Type 2 PSE to pick between Type 1 and Type 2 PI electrical requirement parameter values defined in Table 33–11.

Values: 1: Type 1 PSE parameter values (default)
2: Type 2 PSE parameter values

When a Type 2 PSE powers a Type 2 PD, the PSE may choose to assign a value of '1' to parameter_type if mutual identification is not complete (see 33.2.6) and shall assign a value of '2' to parameter_type if mutual identification is complete.

When a Type 2 PSE powers a Type 1 PD, the PSE shall meet the PI electrical requirements of a Type 1 PSE, but may choose to meet the electrical requirements of a Type 2 PSE for I_{Con}, I_{LIM}, T_{LIM}, and P_{Type} (see Table 33–11).

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33.2.4.7 State diagrams

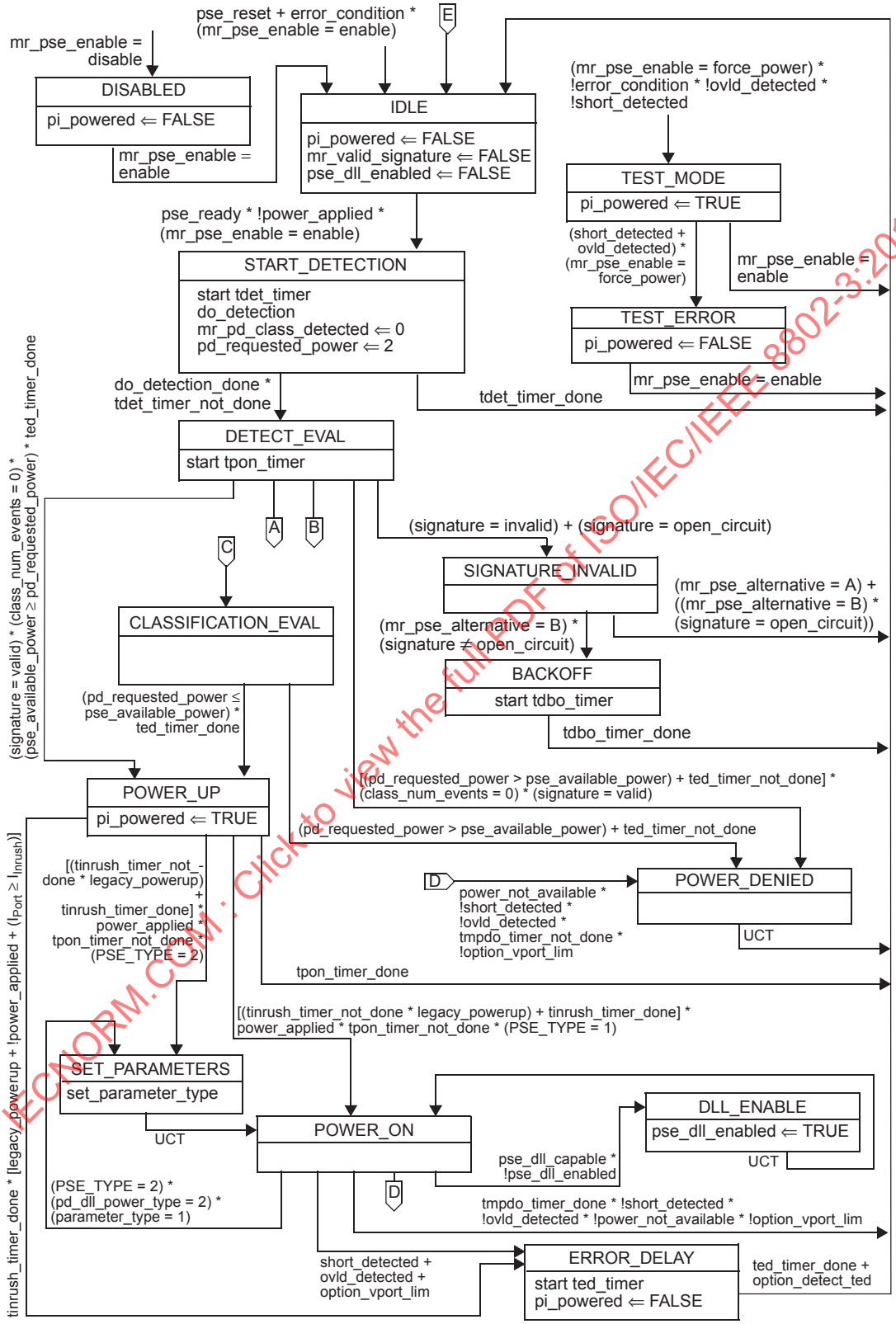

Figure 33–9—PSE state diagram

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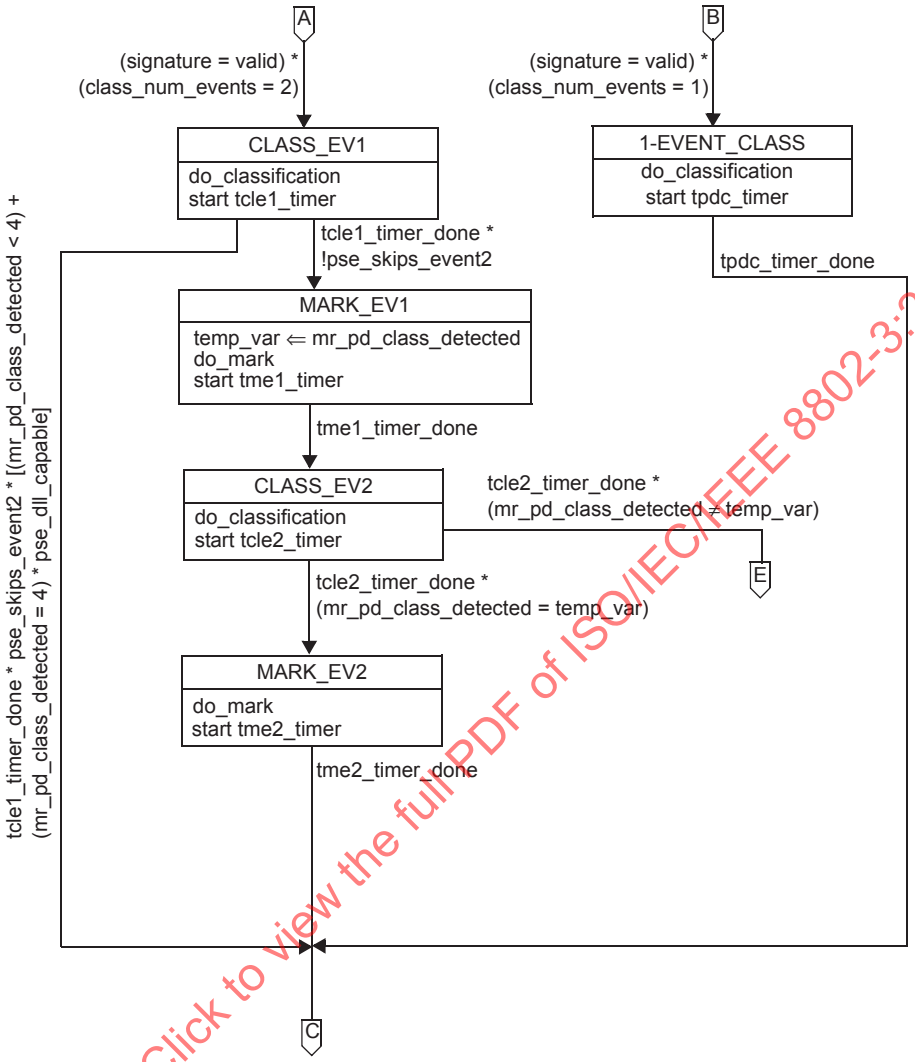

Figure 33–9—PSE state diagram *(continued)*

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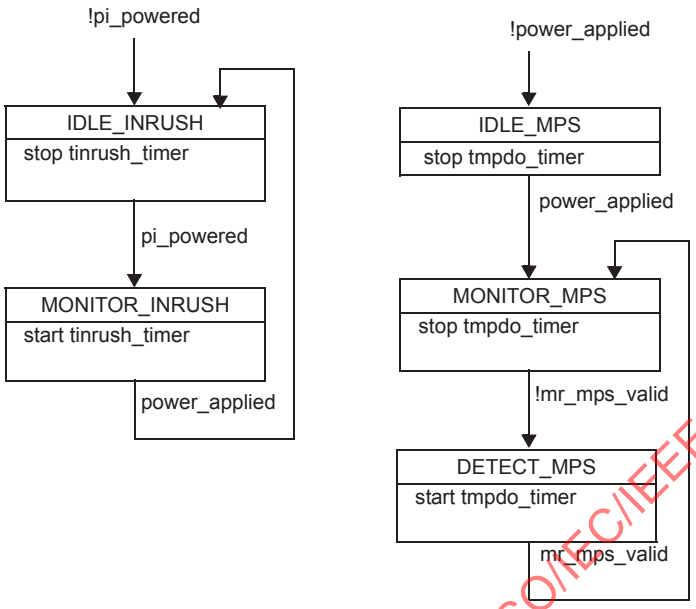

Figure 33–10—PSE monitor inrush and monitor MPS state diagrams

33.2.5 PSE detection of PDs

In any operational state, the PSE shall not apply operating power to the PI until the PSE has successfully detected a PD requesting power.

The PSE probes the link section in order to detect a valid PD detection signature. The PSE PI is connected to a PD through a link segment. In the following subclauses, the link is not called out to preserve clarity.

The PSE is not required to continuously probe to detect a PD signature. The period of time when a PSE is not attempting to detect a PD signature is implementation dependent. Also, a PSE may successfully detect a PD but then opt not to power the detected PD.

The PSE shall turn on power only on the same pairs as those used for detection.

33.2.5.1 PSE detection validation circuit

The PSE shall detect the PD by probing via the PSE PI. The PSE shall present a non-valid PD detection signature as defined in Table 33–15 when probed in either polarity by another PSE. An illustrative embodiment of a detection circuit is shown in Figure 33–11.

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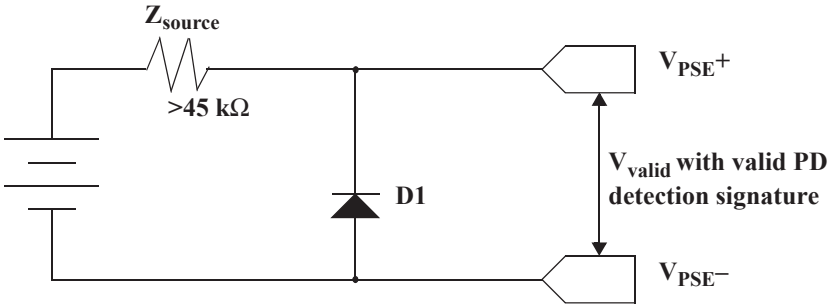

Figure 33–11—PSE detection source

A functional equivalent of the detection circuit that has no source impedance limitation but restricts the PSE detection circuit to the first quadrant is shown in Figure 33–12.

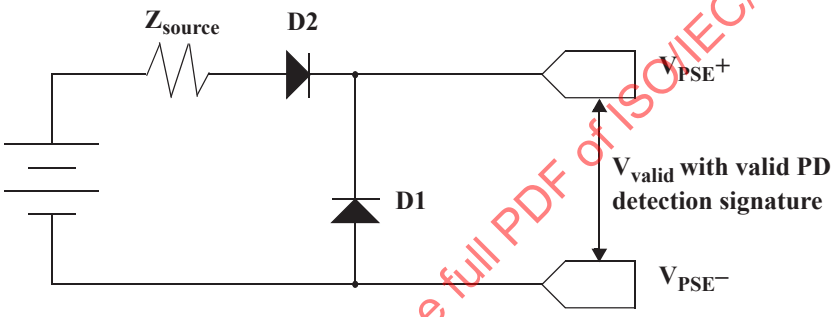

Figure 33–12—Alternative PSE detection source

In Figure 33–11 and Figure 33–12, the diode D1 presents a non-valid PD detection signature for a reversed voltage PSE to PSE connection.

The open circuit voltage and short circuit current shall meet the specifications in Table 33–4. The PSE shall not be damaged by up to 5 mA backdriven current over the range of V_{oc} as specified in Table 33–4. Output capacitance shall be as specified in Table 33–11.

Table 33–4—PSE PI detection state electrical requirements

Item	Parameter	Symbol	Unit	Min	Max	Additional information
1	Open circuit voltage	V_{oc}	V		30.0	In detection state only
2	Short circuit current	I_{sc}	A		0.005	In detection state only
3	Valid test voltage	V_{valid}	V	2.80	10.0	—
4	Voltage difference between test points	ΔV_{test}	V	1.00		—
5	Slew rate	V_{slew}	V/µs		0.100	—

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33.2.5.2 Detection probe requirements

The detection voltage at the PSE PI shall be within the V_{valid} voltage range (as specified in Table 33–4) with a valid PD detection signature connected (as specified in Table 33–14).

In evaluating the presence of a valid PD, the PSE shall make at least two measurements with V_{PSE} values that create at least a ΔV_{test} difference as specified in Table 33–4. An effective resistance is calculated from two voltage/current measurements made during the detection process.

The resistance is calculated with Equation (33–2):

$$R = \left\{ \frac{(V_2 - V_1)}{(I_2 - I_1)} \right\}_{\Omega} \quad (33–2)$$

where

V_1 and V_2 are the first and second voltage measurements made at the PSE PI, respectively
I_1 and I_2 are the first and second current measurements made at the PSE PI, respectively
R is the effective resistance

Attached PI capacitance may be determined using these measurements and the port RC time-constant charging characteristics.

NOTE—Settling time before voltage or current measurement: the voltage or current measurement should be taken after V_{PSE} has settled to within 1% of its steady state condition with a valid PD detection signature connected (as specified in Table 33–14).

The PSE shall control the slew rate of the probing detection voltage when switching between detection voltages to be less than V_{slew} as specified in Table 33–4.

33.2.5.3 Detection criteria

A PSE shall accept as a valid signature a link section with both of the following characteristics between the powering pairs with an offset voltage up to V_{os} max and an offset current up to I_{os} max, as specified in Table 33–5:

a) Signature resistance R_{good}, and
b) Parallel signature capacitance C_{good}.

Table 33–5—Valid PD detection signature electrical characteristics

Item	Parameter	Symbol	Unit	Min	Max	Additional information
1	Accept signature resistance	R_{good}	kΩ	19.0	26.5	—
2	Accept signature capacitance	C_{good}	µF		0.150	—
3	Signature offset voltage tolerance	V_{os}	V	0	2.00	—
4	Signature offset current tolerance	I_{os}	µA	0	12.0	—

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CAUTION

In a multiport system, the implementer should maintain DC isolation through the termination circuitry to eliminate cross-port leakage currents.

33.2.5.4 Rejection criteria

The PSE shall reject link sections as having an invalid signature, when those link sections exhibit any of the following characteristics between the powering pairs, as specified in Table 33–6:

a) Resistance less than or equal to R_{bad} min, or
b) Resistance greater than or equal to R_{bad} max, or
c) Capacitance greater than or equal to C_{bad} min.

A PSE may accept or reject a signature resistance in the band between R_{good} min and R_{bad} min, and in the band between R_{good} max and R_{bad} max. A PSE may accept or reject a parallel signature capacitance in the band between C_{good} max and C_{bad} min.

In instances where the resistance and capacitance meet the detection criteria, but one or both of the offset tolerances are exceeded, the detection behavior of the PSE is undefined.

Table 33–6—Invalid PD detection signature electrical characteristics

Item	Parameter	Symbol	Unit	Min	Max	Additional information
1	Reject signature resistance	R_{bad}	kΩ	15.0	33.0	—
2	Reject signature capacitance	C_{bad}	µF	10.0		—
3	Open circuit resistance	R_{open}	MΩ	0.500		—

33.2.5.5 Open circuit criteria

If a PSE that is performing detection using Alternative B (see 33.2.3) determines that the impedance at the PI is greater than R_{open} as defined in Table 33–4, it may optionally consider the link to be open circuit and omit the tdbo timer interval.

33.2.6 PSE classification of PDs and mutual identification

The ability for the PSE to query the PD in order to determine the power requirements of that PD is called classification. The interrogation and power classification function is intended to establish mutual identification and is intended for use with advanced features such as power management.

Mutual identification is the mechanism that allows a Type 2 PD to differentiate Type 1 PSEs from Type 2 PSEs. Additionally, mutual identification allows Type 2 PSEs to differentiate between Type 1 and Type 2 PDs. PDs or PSEs that do not implement classification will not be able to complete mutual identification and can only perform as Type 1 devices.

There are two forms of classification: Physical Layer classification and Data Link Layer classification.

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Physical Layer classification occurs before a PSE supplies power to a PD when the PSE asserts a voltage onto the PI and the PD responds with a current representing a limited number of power classifications. Based on the response of the PD, the minimum power level at the output of the PSE is P_{Class} as shown in Equation (33–3). Physical Layer classification encompasses two methods, known as 1-Event Physical Layer classification (see 33.2.6.1) and 2-Event Physical Layer classification (see 33.2.6.2).

The minimum power output by the PSE for a particular PD class is defined by Equation (33–3). Alternatively, PSE implementations may use $V_{PSE} = V_{Port_PSE}$ min and $R_{Chan} = R_{Ch}$ max to arrive at over-margined values as shown in Table 33–7.

$$P_{Class} = \left\{ V_{PSE} \times \left(\frac{V_{PSE} - \sqrt{V_{PSE}^2 - 4 \times R_{Chan} \times P_{Class_PD}}}{2 \times R_{Chan}} \right) \right\}_W \quad (33\text{–}3)$$

where

V_{PSE} is the voltage at the PSE PI as defined in 1.4.426
R_{Chan} is the channel DC pair loop resistance
P_{Class_PD} is the PD's power classification (see Table 33–18)

Table 33–7—Physical Layer power classifications (P_{Class})

Class	Minimum power levels at output of PSE (P_{Class})
0	15.4 Watts
1	4.00 Watts
2	7.00 Watts
3	15.4 Watts
4	P_{Type} as defined in Table 33–11
NOTE 1—This is the minimum power at the PSE PI. For maximum power available to PDs, see Table 33–18. NOTE 2—Data Link Layer classification takes precedence over Physical Layer classification.	

With Data Link Layer classification, the PSE and PD communicate using the Data Link Layer Protocol (see 33.6) after the data link is established. The Data Link Layer classification has finer power resolution and the ability for the PSE and PD to participate in dynamic power allocation wherein allocated power to the PD may change one or more times during PD operation.

A PSE shall meet one of the allowable classification permutations listed in Table 33–8.

Subsequent to successful detection, a Type 1 PSE may optionally classify a PD using 1-Event Physical Layer classification. Valid classification results are Classes 0, 1, 2, 3, and 4, as listed in Table 33–7. If a Type 1 PSE does not implement classification, then the Type 1 PSE shall assign all PDs to Class 0. A Type 1 PSE may optionally implement Data Link Layer classification.

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Table 33–8—PSE and PD classification permutations

Permutations			PSE allowed?	PD allowed?
PSE/PD Type	Physical Layer classification	Data Link Layer classification		
Type 2	2-Event	No	Yes	No
		Yes	Yes	Yes
	1-Event	No	No	No
		Yes	Yes	No
	None	No	No	No
		Yes	No	No
Type 1	2-Event	No	No	Yes
		Yes	No	Yes
	1-Event	No	Yes	Yes
		Yes	Yes	Yes
	None	No	Yes	No
		Yes	Yes	No

Subsequent to successful detection, all Type 2 PSEs perform classification using at least one of the following: 2-Event Physical Layer classification; 2-Event Physical Layer classification and Data Link Layer classification; or 1-Event Physical Layer classification and Data Link Layer classification.

If a PSE successfully completes detection of a PD, but the PSE fails to complete classification of a PD, then a Type 1 PSE shall either return to the IDLE state or assign the PD to Class 0; a Type 2 PSE shall return to the IDLE state.

33.2.6.1 PSE 1-Event Physical Layer classification

When 1-Event Physical Layer classification is implemented, classification consists of the application of V_{Class} and the measurement of I_{Class} in a single classification event—1-EVENT_CLASS—as defined in the state diagram in Figure 33–9.

The PSE shall provide to the PI V_{Class} with a current limitation of I_{Class_LIM}, as defined in Table 33–10. Polarity shall be the same as defined for V_{Port_PSE} in 33.2.3 and timing specifications shall be as defined by T_{pdc} in Table 33–10.

The PSE shall measure the resultant I_{Class} and classify the PD based on the observed current according to Table 33–9. All measurements of I_{Class} shall be taken after the minimum relevant class event timing in Table 33–10. This measurement is referenced from the application of V_{Class} min to ignore initial transients.

If the result of the class event is Class 4, a Type 1 PSE shall assign the PD to Class 0; a Type 2 PSE treats the PD as a Type 2 PD but may provide Class 0 power until mutual identification is complete.

If the measured I_{Class} is within the range of I_{Class_LIM}, a Type 1 PSE shall either return to the IDLE state or classify the PD as Class 0; a Type 2 PSE shall return to the IDLE state.

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33.2.6.2 PSE 2-Event Physical Layer classification

When 2-Event Physical Layer classification is implemented, classification consists of the application of V_{Class} and the measurement of I_{Class} in a series of classification and mark events—CLASS_EV1, MARK_EV1, CLASS_EV2, and MARK_EV2—as defined in the state diagram in Figure 33–9.

The PSE in the state CLASS_EV1 shall provide to the PI V_{Class} as defined in Table 33–10. The timing specification shall be as defined by T_{CLE1} in Table 33–10. The PSE shall measure I_{Class} and classify the PD based on the observed current according to Table 33–9.

When the PSE is in the state MARK_EV1, the PSE shall provide to the PI V_{Mark} as defined in Table 33–10. The timing specification shall be as defined by T_{ME1} in Table 33–10.

When the PSE is in the state CLASS_EV2, the PSE shall provide to the PI V_{Class}, subject to the T_{CLE2} timing specification, as defined in Table 33–10. The PSE shall measure I_{Class} and classify the PD based on the observed current according to Table 33–9.

When the PSE is in the state MARK_EV2, the PSE shall provide to the PI V_{Mark} as defined in Table 33–10. The timing specification shall be as defined by T_{ME2} in Table 33–10.

The mark event states, MARK_EV1 and MARK_EV2, commence when the PI voltage falls below V_{Class} min and end when the PI voltage exceeds V_{Class} min. The V_{Mark} requirement is to be met with load currents in the range of I_{Mark} as defined in Table 33–17.

NOTE—In a properly operating system, the port may or may not discharge to the V_{Mark} range due to the combination of channel and PD capacitance and PD current loading. This is normal and acceptable system operation. For compliance testing, it is necessary to discharge the port in order to observe the V_{Mark} voltage. Discharge can be accomplished with a 2 mA load for 3 ms, after which V_{Mark} can be observed with minimum and maximum load current.

If any measured I_{Class} is equal to or greater than I_{Class_LIM} min as defined in Table 33–10, a Type 2 PSE shall return to the IDLE state. The class events shall meet the I_{Class_LIM} current limitation. The mark events shall meet the I_{Mark_LIM} current limitation. All measurements of I_{Class} shall be taken after the minimum relevant class event timing of Table 33–10. This measurement is referenced from the application of V_{Class} min to ignore initial transients.

All class event voltages and mark event voltages shall have the same polarity as defined for V_{Port_PSE} in 33.2.3. The PSE shall complete 2-Event Physical Layer classification and transition to the POWER_ON state without allowing the voltage at the PI to go below V_{Mark} min. If the PSE returns to the IDLE state, it shall maintain the PI voltage at V_{Reset} for a period of at least T_{Reset} min before starting a new detection cycle.

If the result of the first class event is Class 4, the PSE may omit the subsequent mark and class events only if the PSE implements Data Link Layer classification. In this case, a Type 2 PSE treats the PD as a Type 2 PD but may provide Class 0 power until mutual identification is complete.

If the result of the first class event is any of Classes 0, 1, 2, or 3, the PSE treats the PD as a Type 1 PD and may omit the subsequent mark and class events and classify the PD according to the result of the first class event.

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Table 33–9—PD classification

Measured I_{Class}	Classification
0 mA to 5.00 mA	Class 0
> 5.00 mA and < 8.00 mA	May be Class 0 or 1
8.00 mA to 13.0 mA	Class 1
> 13.0 mA and < 16.0 mA	Either Class 1 or 2
16.0 mA to 21.0 mA	Class 2
> 21.0 mA and < 25.0 mA	Either Class 2 or 3
25.0 mA to 31.0 mA	Class 3
> 31.0 mA and < 35.0 mA	Either Class 3 or 4
35.0 mA to 45.0 mA	Class 4
> 45.0 mA and < 51.0 mA	Either Class 4 or invalid class

NOTE—A Type 1 PSE may ignore I_{Class} and report Class 0.

Table 33–10—PSE Physical Layer classification electrical requirements

Item	Parameter	Symbol	Units	Min	Max	1- or 2-Event	Additional information
1	Class event voltage	V_{Class}	V	15.5	20.5	1, 2	
2	Class event current limitation	I_{Class_LIM}	A	0.051	0.100	1, 2	
3	Mark event voltage	V_{Mark}	V	7.00	10.0	2	
4	Mark event current limitation	I_{Mark_LIM}	A	0.005	0.100	2	
5	1st class event timing	T_{CLE1}	ms	6.00	30.0	2	
6	1st mark event timing	T_{ME1}	ms	6.00	12.0	2	
7	2nd class event timing	T_{CLE2}	ms	6.00	30.0	2	
8	2nd mark event timing	T_{ME2}	ms	6.00		2	Time from end of detection until power-on is limited by 33.2.7.12.
9	Classification reset voltage	V_{Reset}	V	0	2.80	2	
10	Classification reset timing	T_{Reset}	ms	15.0		2	
11	1-Event Physical Layer classification timing	T_{pdc}	ms	6.00	75.0	1	

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33.2.7 Power supply output

PSE behavior conforms to the state diagrams in Figure 33–9, Figure 33–9 continued, and Figure 33–10. When the PSE provides power to the PI, it shall conform with Table 33–11.

Table 33–11 limits show values that support worst-case operating limits. These ranges may be narrowed when additional information is known and applied in accordance with this specification.

Table 33–11—PSE output PI electrical requirements for all PD classes, unless otherwise specified

Item	Parameter	Symbol	Unit	Min	Max	PSE Type	Additional information
1	Output voltage in the POWER_ON state	V_{Port_PSE}	V	44.0	57.0	1	See 33.2.7.1.
				50.0	57.0	2	
2	Voltage transient below V_{Port_PSE} min	K_{Tran_lo}	%		7.6	2	See 33.2.7.2.
3	Power feeding ripple and noise:						
	f < 500 Hz		V_{pp}		0.500	1, 2	See 33.2.7.3.
	500 Hz to 150 kHz				0.200		
	150 kHz to 500 kHz				0.150		
	500 kHz to 1 MHz				0.100		
4	Continuous output current capability in POWER_ON state	I_{Con}	A	P_{Class} / V_{Port_PSE}		1, 2	See 33.2.7.4.
5	Output current in POWER_UP state	I_{Inrush}	A	0.400	See info	1, 2	See 33.2.7.5. Max value defined by Figure 33–13.
6	Inrush time	T_{Inrush}	s	0.050	0.075	1, 2	See 33.2.7.5
7	Overload current detection range	I_{CUT}	A	P_{Class} / V_{Port_PSE}	I_{LIM}	1,2	Optional limit; see 33.2.7.6, Table 33–7.
8	Overload time limit	T_{CUT}	s	0.050	0.075	1, 2	See 33.2.7.7.
9	Output current – at short circuit condition	I_{LIM}	A	0.400	See info	1	See 33.2.7.7. Max value defined by Figure 33–14.
				1.14 × I_{Cable}		2	
10	Short circuit time limit	T_{LIM}	s	0.050	See info	1	See 33.2.7.7.
				0.010		2	
11	Continuous output power capability in POWER_ON state	P_{Con}	W	P_{Class}		1, 2	See 33.2.7.10, Table 33–7.
12	PSE Type power minimum	P_{Type}	W	I_{Cable} × (V_{Port_PSE} min)		1, 2	See 33.1.4.
13	Power turn on time	T_{pon}	s		0.400	1, 2	See 33.2.7.12.

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Table 33–11—PSE output PI electrical requirements for all PD classes, unless otherwise specified *(continued)*

Item	Parameter	Symbol	Unit	Min	Max	PSE Type	Additional information
14	Turn on rise time	T_{Rise}	µs	15.0		1, 2	From 10 % to 90 % of the voltage difference at the PI in POWER_ON state from the beginning of POWER_UP.
15	Turn off time	T_{Off}	s		0.500	1, 2	See 33.2.7.8.
16	Turn off voltage	V_{Off}	V		2.80	1, 2	See 33.2.7.9.
17	DC MPS current	I_{Hold}	A	0.005	0.010	1, 2	See 33.2.9.1.2.
18	PD Maintain Power Signature dropout time limit	T_{MPDO}	s	0.300	0.400	1, 2	See 33.2.9.
19	PD Maintain Power Signature time for validity	T_{MPS}	s	0.060		1, 2	See 33.2.9.
20	Current unbalance	I_{unb}	A		3 % × I_{Cable}	1	See 33.2.7.11, 33.4.8. NOTE—For practical implementations, it is recommended that Type 1 PSEs support Type 2 I_{unb} requirements.
					3 % × I_{Peak}	2	
21	Alternative B detection backoff time	T_{dbo}	s	2.00		1, 2	
22	Output capacitance during detection state	C_{out}	µF		0.520	1, 2	
23	Detection timing	T_{det}	s		0.500	1, 2	Time to complete detection of a PD.
24	Error delay timing	T_{ed}	s	0.750		1, 2	Delay before PSE may attempt subsequent powering after power removal because of error condition.

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33.2.7.1 Output voltage in the POWER_ON state

The specification for V_{Port_PSE} in Table 33–11 shall be met with a (I_{Hold} max × V_{Port_PSE} min) to P_{Type} min load step at a rate of change of at least 15 mA/µs. The voltage transients as a result of load changes up to 35 mA/µs shall be limited to 3.5 V/µs max.

A PSE in the POWER_ON state may remove power from the PI when the PI voltage no longer meets the V_{Port_PSE} specification.

33.2.7.2 Voltage transients

A Type 2 PSE shall maintain an output voltage no less than K_{Tran_lo} below V_{Port_PSE} min for transient conditions lasting more than 30 µs and less than 250 µs, and meet the requirements of 33.2.7.7.

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Transients less than 30 µs in duration may cause the voltage at the PI to fall more than K_{Tran_lo}. The minimum PD input capacitance allows the PD to operate for any input voltage transient lasting less than 30 µs. Transients lasting more than 250 µs shall meet the V_{Port_PSE} specification.

33.2.7.3 Power feeding ripple and noise

The specification for power feeding ripple and noise in Table 33–11 shall be met for common-mode and/or pair-to-pair noise values for power outputs from (I_{Hold} max × V_{Port_PSE} min) to P_{Type} min for PSEs at static operating V_{Port_PSE}. The limits are meant to preserve data integrity. To meet EMI standards, lower values may be needed. For higher frequencies, see 33.4.4 and 33.4.5.

33.2.7.4 Continuous output current capability in the POWER_ON state

In addition to I_{Con} as specified in Table 33–11, the PSE shall support the following AC current waveform parameters, while within the operating voltage range of V_{Port_PSE}:

I_{Peak} minimum for T_{CUT} minimum and 5 % duty cycle minimum, where

$$I_{Peak} = \left\{ \frac{V_{PSE} - \sqrt{V_{PSE}^2 - 4(R_{Chan})(P_{Peak_PD})}}{2(R_{Chan})} \right\}_A \quad (33\text{–}4)$$

where

V_{PSE} is the voltage at the PSE PI as defined in 1.4.426

R_{Chan} is the channel loop resistance as defined in 33.1.4; this parameter has a worst-case value of R_{Ch}, defined in Table 33–1

P_{Peak_PD} is the peak power a PD may draw for its class; see Table 33–18

33.2.7.5 Output current in POWER_UP mode

POWER_UP mode occurs between the PSE's transition to the POWER_UP state and either the expiration of T_{Inrush} or the conclusion of PD inrush currents (see 33.3.7.3). However, for practical implementations, it is recommended that the POWER_UP mode persist for the complete duration of T_{Inrush}, as the PSE may not be able to correctly ascertain the conclusion of a PD's inrush behavior.

The PSE shall limit the maximum current sourced at the PI during POWER_UP. The maximum inrush current sourced by the PSE shall not exceed the PSE inrush template in Figure 33–13.

a) During POWER_UP, for PI voltages between 0 V and 10 V, the minimum I_{Inrush} requirement is 5 mA.
b) During POWER_UP, for PI voltages between 10 V and 30 V, the minimum I_{Inrush} requirement is 60 mA.
c) During POWER_UP, for PI voltages above 30 V, the minimum I_{Inrush} requirement is as specified in Table 33–11.
d) For Type 1 PSE, measurement of minimum I_{Inrush} requirement to be taken after 1 ms to allow startup transients. A Type 2 PSE that uses 1-Event physical layer classification, and requires the 1 ms settling time, shall power up a class 4 PD as if it used 2-Event physical layer classification.

The PSE inrush template, I_{PSEIT}, is defined by the following segments:

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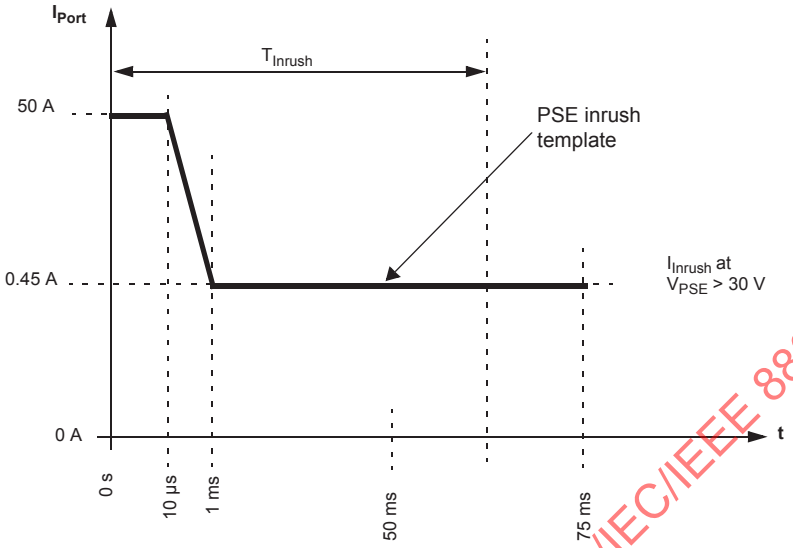

Figure 33–13—I_{Inrush} current and timing limits in POWER_UP state

$$I_{PSEIT}(t) = \begin{cases} 50.0 & \text{for } 0 < t < 10.0\times10^{-6} \\ 50.0 - \dfrac{(t - 10.0\times10^{-6})\times 49.6}{0.990\times10^{-6}} & \text{for } 10.0\times10^{-6} \le t < 0.001 \\ 0.450 & 0.001 \le t < 0.075 \end{cases} \quad (33\text{–}5)$$

where

t is the time in seconds

33.2.7.6 Overload current

If I_{Port}, the current supplied by the PSE to the PI, exceeds I_{CUT} for longer than T_{CUT}, the PSE may remove power from the PI. The cumulative duration of T_{CUT} is measured with a sliding window of at least 1 second width.

The I_{CUT} threshold may equal the I_{Peak} value determined by Equation (33–4).

33.2.7.7 Output current—at short circuit condition

A PSE may remove power from the PI if the PI current meets or exceeds the “PSE lowerbound template” in Figure 33–14. Power shall be removed from the PI of a PSE before the PI current exceeds the “PSE upperbound template” in Figure 33–14.

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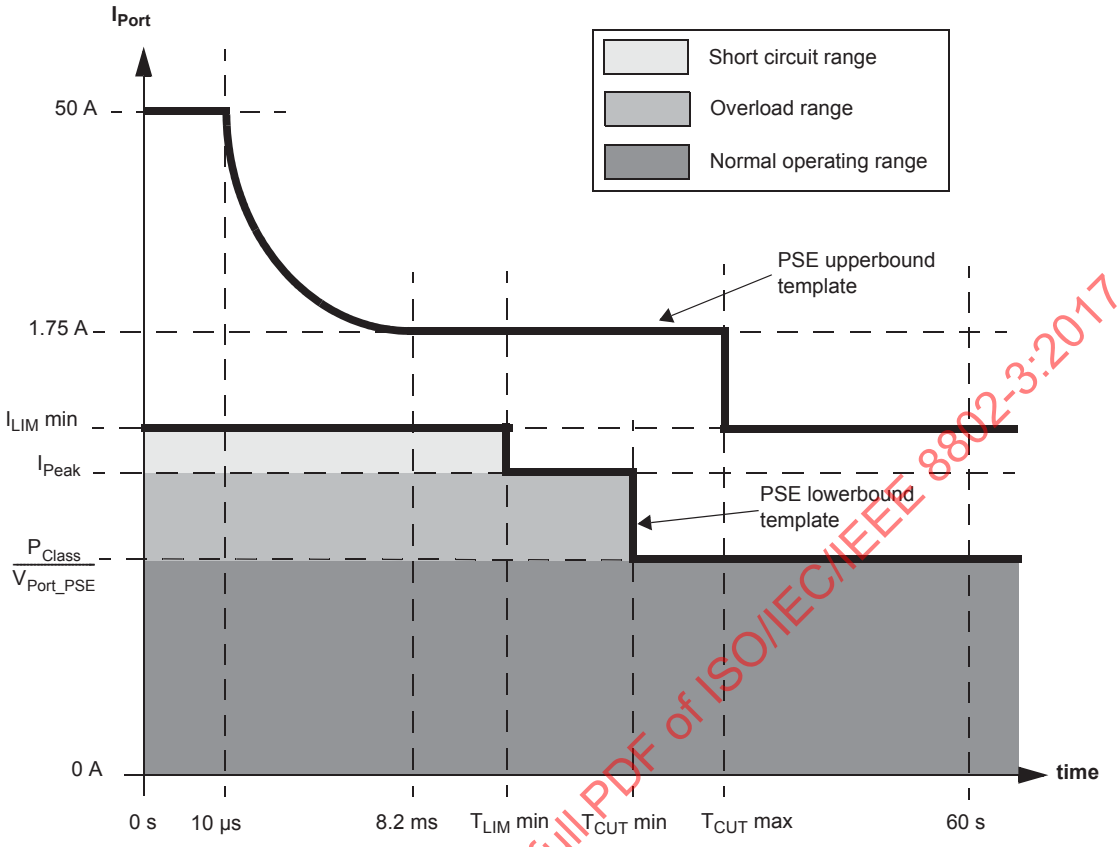

Figure 33–14—POWER_ON state PI operating current templates

The maximum value of I_{LIM} is the PSE upperbound template described by Equation (33–6) and Figure 33–14.

The PSE upperbound template, I_{PSEUT}, is defined by the following segments:

$$I_{PSEUT}(t) = \left\{ \begin{array}{ll} 50.0 & \text{for } (0 \le t < 10.0\times10^{-6}) \\ \sqrt{\frac{K}{t}} & \text{for } (10.0\times10^{-6} \le t < 8.20\times10^{-3}) \\ 1.75 & \text{for } \left(8.20\times10^{-3} \le t < T_{cutmax}\right) \\ I_{limmin} & \text{for } (T_{cutmax} \le t) \end{array} \right\}_{A} \quad (33\text{–}6)$$

where

t	is the duration in seconds that the PSE sources I_{Port}
K	is 0.025 A^2s, an energy limitation constant for the port current when it is not in steady state normal operation
T_{cutmax}	is T_{CUT} max, as defined in Table 33–11
I_{limmin}	is I_{LIM} min, as defined in Table 33–11

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The PSE shall limit the current to I_{LIM} for a duration of up to T_{LIM} in order to account for PSE dV/dt transients at the PI. The cumulative duration of T_{LIM} may be measured with a sliding window.

The PSE lowerbound template, I_{PSELT}, is defined by the following segments:

$$I_{PSELT}(t) = \left\{ \begin{array}{ll} I_{LIMmin} & \text{for } (0 \le t < T_{limmin}) \\ I_{Peak} & \text{for } (T_{limmin} \le t < T_{cutmin}) \\ \dfrac{P_{Class}}{V_{PSE}} & \text{for } (T_{cutmin} \le t) \end{array} \right\}_{A} \quad (33\text{–}7)$$

where

I_{LIMmin}	is the I_{LIM} min value for the PSE (see Table 33–11)
t	is the duration that the PI sources I_{Port}
T_{limmin}	is T_{LIM} min as defined in Table 33–11
T_{cutmin}	is T_{CUT} min, as defined in Table 33–11
I_{Peak}	is I_{Peak}, as defined in Equation (33–4)
P_{Class}	is P_{Class}, as defined in Table 33–7
V_{PSE}	is the voltage at the PSE PI

If a short circuit condition is detected, power removal from the PI shall begin within T_{LIM} as specified in Table 33–11. If I_{Port} exceeds the PSE lowerbound template, the PSE output voltage may drop below V_{Port_PSE} min.

33.2.7.8 Turn off time

The specification for T_{Off} in Table 33–11 shall apply to the discharge time from V_{Port_PSE} to V_{Off} with a test resistor of 320 kΩ attached to the PI. In addition, it is recommended that the PI be discharged when turned off. T_{Off} starts when V_{PSE} drops 1 V below the steady-state value after the pi_powered variable is cleared (see Figure 33–9). T_{Off} ends when $V_{PSE} \le V_{Off}$ max. The PSE remains in the IDLE state as long as the average voltage across the PI is V_{Off}. The IDLE state is the state when the PSE is not in detection, classification, or normal powering states.

33.2.7.9 Turn off voltage

The specification for V_{Off} in Table 33–11 shall apply to the PI voltage in the IDLE State.

33.2.7.10 Continuous output power capability in POWER_ON state

P_{Class} is the class power defined in 33.2.6 and Equation (33–3), or PSE allocated power (as defined in 79.3.2.6) added to the channel power loss.

P_{Con} is valid over the range of V_{Port_PSE} defined in Table 33–11. Measurement of P_{Con} should be averaged using any sliding window with a width of 1 s.

A PSE may remove power from a PD that causes the PSE to source more than P_{Class}.

33.2.7.11 Current unbalance

The specification for I_{unb} in Table 33–11 shall apply to the current unbalance between the two conductors of a power pair over the current load range.

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Type 2 Endpoint PSEs shall meet the requirements of 25.4.5 in the presence of (I_{unb} / 2).

33.2.7.12 Power turn on time

The specification for T_{pon} in Table 33–11 applies to the PSE power up time for a PD after completion of detection. If power is not applied as specified, a new detection cycle is initiated (see 33.2.4.1).

33.2.7.13 PSE stability

When connected together as a system, the PSE and PD might exhibit instability at the PSE side or the PD side or both due to the presence of negative impedance at the PD input. See Annex 33A for PSE design guidelines for stable operation.

33.2.8 Power supply allocation

A PSE does not initiate power provision to a link if the PSE is unable to provide the maximum power level requested by the PD based on the PD's class.

The PSE may manage the allocation of power based on additional information beyond the classification of the attached PD. Allocating power based on additional information about the attached PD, and the mechanism for obtaining that additional information, is beyond the scope of this standard with the exception that the allocation of power shall not be based solely on the historical data of the power consumption of the attached PD.

See 33.6 for a description of Data Link Layer classification.

If the system implements a power allocation algorithm, no additional behavioral requirement is placed on the system as it approaches or reaches its maximum power subscription. Specifically, the interaction between one PSE PI and another PSE PI in the same system is beyond the scope of this standard.

33.2.9 PSE power removal

Figure 33–10 shows the PSE monitor state diagrams. These state diagrams monitor for inrush current and the absence of the Maintain Power Signature (MPS).

If any of these conditions exist for longer than its related time limit, the power is removed from the PI.

33.2.9.1 PSE Maintain Power Signature (MPS) requirements

The MPS consists of two components, an AC MPS component and a DC MPS component.

The PSE shall monitor either the DC MPS component, the AC MPS component, or both.

33.2.9.1.1 PSE AC MPS component requirements

A PSE that monitors the AC MPS component shall meet the "AC Signal parameters" and "PSE PI voltage during AC disconnect detection" parameters in Table 33–12.

A PSE shall consider the AC MPS component to be present when it detects an AC impedance at the PI equal to or lower than $|Z_{ac1}|$ as defined in Table 33–12.

A PSE shall consider the AC MPS component to be absent when it detects an AC impedance at the PI equal to or greater than $|Z_{ac2}|$ as defined in Table 33–12. Power shall be removed from the PI when AC MPS has been absent for a time duration greater than T_{MPDO}.

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A PSE may consider the AC MPS component to be either present or absent when it detects a AC impedance between the values $|Z_{ac1}|$ max and $|Z_{ac2}|$ min.

33.2.9.1.2 PSE DC MPS component requirements

A PSE shall consider the DC MPS component to be present if I_{Port} is greater than or equal to I_{Hold} max for a minimum of T_{MPS}. A PSE shall consider the DC MPS component to be absent if I_{Port} is less than or equal to I_{Hold} min. A PSE may consider the DC MPS component to be either present or absent if I_{Port} is in the range of I_{Hold}.

Power shall be removed from the PI when DC MPS has been absent for a duration greater than T_{MPDO}.

The specification for T_{MPS} in Table 33–11 applies only to the DC MPS component. The PSE shall not remove power from the port when I_{Port} is greater than or equal to I_{Hold} max continuously for at least T_{MPS} every $T_{MPS} + T_{MPDO}$, as defined in Table 33–11. This allows a PD to minimize its power consumption.

Table 33–12—PSE PI parameters for AC disconnect-detection function

Item	Parameter	Symbol	Unit	Min	Max	Additional information
	AC signal parameters					
1a	PI probing AC voltage	V_open	V_{pp}	1.90	10% of the average value of V_{Port_PSE} within the limits of Table 33–11	Includes noise, ripple, etc. V_open is the AC voltage across the PI when the PD is not connected to the PI and before the detection of this condition by the PSE.
		V_open1	V_p		30.0 V, $V_{PSE} \leq$ 44.0 V	V_open1 is the AC voltage across the PI when the PD is not connected to the PI and after the detection of this condition by the PSE and the removal of power from the PI.
1b	AC probing signal frequency	F_p	kHz		0.500	
1c	AC probing signal slew rate	SR	V/µs		0.100	Positive or negative.
	AC source output impedance					
2a	Source output current during the operation of the AC disconnect detection function	I_sac	mA		5.00	During operation of the AC disconnect detection function.
2b	PSE PI impedance during PD detection when measured at the PSE PI	R_rev	kΩ	45.0		Specified in 33.2.5.1 and Figure 33–11. Shown here to clarify the difference in PI impedance during the signature detection function.
	PSE PI voltage during AC disconnect detection					
3a	PI AC voltage when PD is connected	V_{CLOSE}	V_{pp}			See Table 33–11, item 3.

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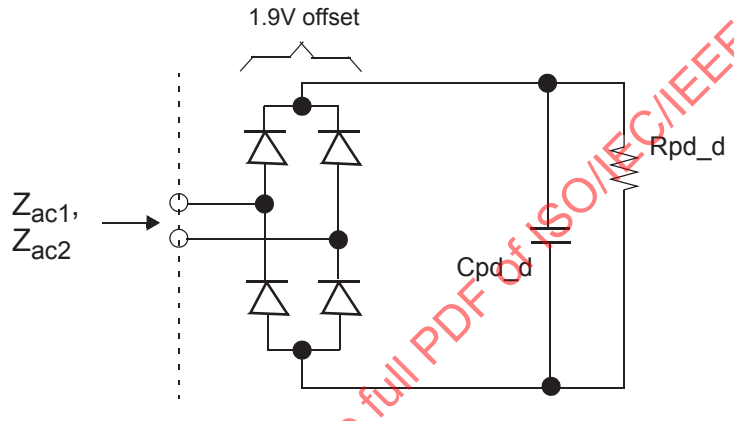
Table 33–12—PSE PI parameters for AC disconnect-detection function *(continued)*

Item	Parameter	Symbol	Unit	Min	Max	Additional information
3b	PI voltage when PD is disconnected	V_{PSE}	V_p		60.0	
	AC Maintain Power Signature					
4a	Valid impedance	$\lvert Z_{ac1} \rvert$	kΩ		27.0	F_p = 5 Hz, Testing voltage >2.5 V. See Figure 33–15.
4b	Invalid impedance	$\lvert Z_{ac2} \rvert$	kΩ	1980		See Figure 33–15.



NOTE—Rpd_d and Cpd_d are specified in Table 33–19. Cpd_d may be located either in parallel with Z_{ac1} or as shown above.

Figure 33–15—Z_{ac1} and Z_{ac2} definition as indicated in Table 33–12

33.3 Powered devices (PDs)

A PD is the portion of a device that is either drawing power or requesting power by participating in the PD detection algorithm. A device that is capable of becoming a powered device may or may not have the ability to draw power from an alternate power source and, if doing so, may or may not require power from the PI. PD capable devices that are neither drawing nor requesting power are also covered in this subclause.

A PD is specified at the point of the physical connection to the cabling. Characteristics such as the losses due to voltage correction circuits, power supply inefficiencies, separation of internal circuits from external ground or other characteristics induced by circuits after the PI connector are not specified. Limits defined for the PD are specified at the PI, not at any point internal to the PD, unless specifically stated.

33.3.1 PD PI

The PD shall be capable of accepting power on either of two sets of PI conductors. The two conductor sets are named Mode A and Mode B. In each four-wire connection, the two wires associated with a pair are at the same nominal average voltage. Figure 33–8 in conjunction with Table 33–13 illustrates the two power modes.

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Table 33–13—PD pinout

Conductor	Mode A	Mode B
1	Positive V_{PD}, Negative V_{PD}	
2	Positive V_{P}, Negative V_{PD}	
3	Negative V_{PD}, Positive V_{PD}	
4		Positive V_{PD}, Negative V_{PD}
5		Positive V_{PD}, Negative V_{PD}
6	Negative V_{PD}, Positive V_{PD}	
7		Negative V_{PD}, Positive V_{PD}
8		Negative V_{PD}, Positive V_{PD}

The PD shall be implemented to be insensitive to the polarity of the power supply and shall be able to operate per the PD Mode A column and the PD Mode B column in Table 33–13.

NOTE—PDs that implement only Mode A or Mode B are specifically not allowed by this standard. PDs that simultaneously require power from both Mode A and Mode B are specifically not allowed by this standard.

The PD shall not source power on its PI.

The PD shall withstand any voltage from 0 V to 57 V at the PI indefinitely without permanent damage.

33.3.2 PD type descriptions

PDs can be categorized as either Type 1 or Type 2.

Type 1 PDs implement a minimum of 1-Event Physical Layer classification and advertise a 1-Event class signature of 0, 1, 2, or 3.

Type 2 PDs implement both 2-Event Physical Layer classification (see 33.3.5.2) and Data Link Layer classification (see 33.6) and advertise a 2-Event class signature of 4.

The maximum power a PD expects to draw from a PSE is P_{Class_PD} max as defined in Table 33–18.

A Type 2 PD that does not successfully observe a 2-Event Physical Layer classification or Data Link Layer classification shall conform to Type 1 PD power restrictions and shall provide the user with an active indication if underpowered. The method of active indication is left to the implementer.

Type 2 PDs shall meet the requirements of 25.4.5 in the presence of (I_{unb} / 2).

33.3.3 PD state diagram

The PD state diagram specifies the externally observable behavior of a PD. The PD shall provide the behavior of the state diagram shown in Figure 33–16.

33.3.3.1 Conventions

The notation used in the state diagram follows the conventions of state diagrams as described in 21.5.

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33.3.3.2 Constants

The PD state diagram uses the following constants:

V_{Reset_th}
: Reset voltage threshold (see Table 33–17)

V_{Mark_th}
: Mark event voltage threshold (see Table 33–17)

class_sig
: PD classification, one of either 0, 1, 2, 3, or 4 (see Table 33–16)

33.3.3.3 Variables

The PD state diagram uses the following variables:

mdi_power_required
: A control variable indicating the PD is enabled and should request power from the PSE by applying a PD detection signature to the link, and when the PSE sources power to apply the MPS to keep the PSE sourcing power. A variable that is set in an implementation-dependent manner.
Values:FALSE:PD functionality is disabled.
TRUE:PD functionality is enabled.

pd_2-event
: A control variable indicating whether the PD presents a 2-Event class signature.
Values:FALSE:PD does not present a 2-Event class signature.
TRUE:PD does present a 2-Event class signature.

pd_dll_capable
: This variable indicates whether the PD implements Data Link Layer classification.
Values:FALSE:The PD does not implement Data Link Layer classification.
TRUE:The PD does implement Data Link Layer classification.

pd_dll_enabled
: A variable indicating whether the Data Link Layer classification mechanism is enabled.
Values:FALSE:Data Link Layer classification is not enabled.
TRUE:Data Link Layer classification is enabled.

pd_max_power
: A control variable indicating the max power that the PD may draw from the PSE. See power classifications in Table 33–18.
Values:0: PD may draw Class 0 power
1: PD may draw Class 1 power
2: PD may draw Class 2 power
3: PD may draw Class 3 power
4: PD may draw Class 4 power

pd_reset
: An implementation-specific control variable that unconditionally resets the PD state diagram to the OFFLINE state.
Values:FALSE:The device has not been reset (default).
TRUE:The device has been reset.

power_received
: An indication from the circuitry that power is present on the PD's PI.
Values:FALSE:The input voltage does not meet the requirements of V_{Port_PD} in Table 33–18.
TRUE:The input voltage meets the requirements of V_{Port_PD}.

present_class_sig
: Controls presenting the classification signature (see 33.3.5) by the PD.

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Values:FALSE:The PD classification signature is not to be applied to the link.
TRUE:The PD classification signature is to be applied to the link.

present_det_sig
Controls presenting the detection signature (see 33.3.4) by the PD.
Values:FALSE:A non-valid PD detection signature is to be applied to the link.
TRUE:A valid PD detection signature is to be applied to the link.

present_mark_sig
Controls presenting the mark event current and impedance (see 33.3.5.2.1) by the PD.
Values:FALSE:The PD does not present mark event behavior.
TRUE:The PD does present mark event behavior.

present_mps
Controls applying MPS (see 33.3.8) to the PD's PI.
Values:FALSE:The Maintain Power Signature (MPS) is not to be applied to the PD's PI.
TRUE:The MPS is to be applied to the PD's PI.

pse_dll_power_type
A control variable output by the PD power control state diagram (Figure 33–28) that indicates the type of PSE by which the PD is being powered.
Values:1: The PSE is a Type 1 PSE (default).
2: The PSE is a Type 2 PSE.

pse_power_type
A control variable that indicates to the PD the type of PSE by which it is being powered.
Values:1: The PSE is a Type 1 PSE.
2: The PSE is a Type 2 PSE.

V_{PD}
Voltage at the PD PI as defined in 1.4.425.

33.3.3.4 Timers

All timers operate in the manner described in 14.2.3.2 with the following addition. A timer is reset and stops counting upon entering a state where "stop x_timer" is asserted.

tpowerdly_timer
A timer used to prevent the Type 2 PD from drawing more than inrush current during the PSE's inrush period; see T_{delay} in Table 33–18.

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33.3.3.5 State diagrams

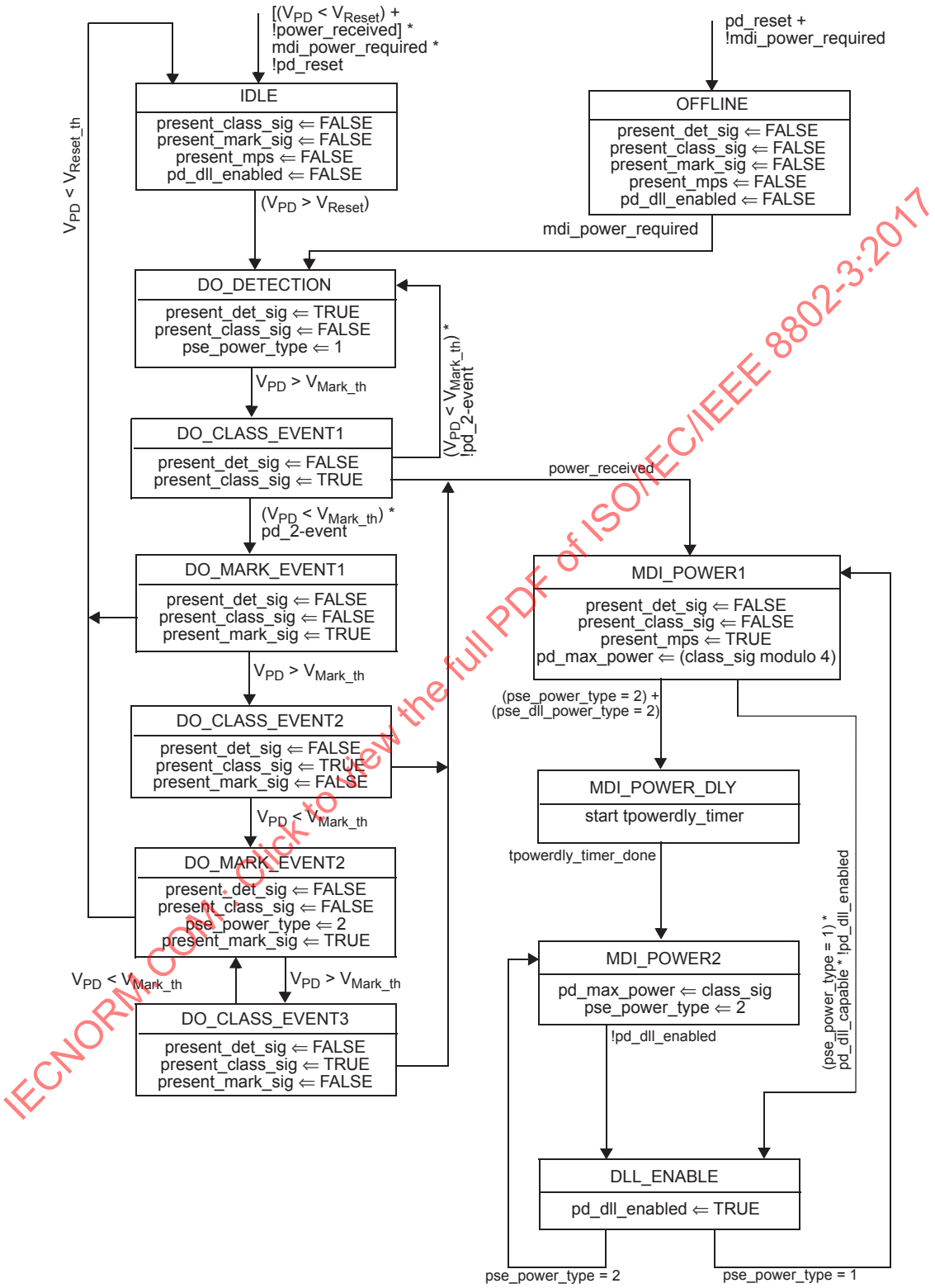

Figure 33–16—PD state diagram

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NOTE 1—DO_CLASS_EVENT3 creates a defined behavior for a Type 2 PD that is brought into the classification range repeatedly.

NOTE 2—In general, there is no requirement for a PD to respond with a valid classification signature for any DO_CLASS_EVENT duration less than T_{class}.

33.3.4 PD valid and non-valid detection signatures

A PD presents a valid detection signature while it is in a state where it accepts power via the PI, but is not powered via the PI per Figure 33–16.

A PD presents a non-valid detection signature at the PI while it is in a state where it does not accept power via the PI per Figure 33–16.

A Type 2 PD presents a non-valid detection signature when in a mark event state per Figure 33–16.

When a PD presents a valid or non-valid detection signature, it shall present the detection signature at the PI between Positive V_{PD} and Negative V_{PD} of PD Mode A and PD Mode B as defined in 33.3.1. When a PD becomes powered via the PI, it shall present a non-valid detection signature on the set of pairs from which it is not drawing power.

A PD may or may not present a valid detection signature when in the IDLE state.

The detection signature is a resistance calculated from two voltage/current measurements made during the detection process.

$$R_{\text{detect}} = \left\{ \frac{(V_2 - V_1)}{(I_2 - I_1)} \right\}_{\Omega} \tag{33–8}$$

where

V_1 and V_2	are the first and second voltage measurements made at the PD PI, respectively
I_1 and I_2	are the first and second current measurements made at the PD PI, respectively
R_{detect}	is the effective resistance

A valid PD detection signature shall have the characteristics of Table 33–14.

A non-valid detection signature shall have one or both of the characteristics in Table 33–15.

A PD that presents a signature outside of Table 33–14 is non-compliant, while a PD that present the signature of Table 33–15 is assured to fail detection.

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Table 33–14—Valid PD detection signature characteristics, measured at PD input connector

Parameter	Conditions	Minimum	Maximum	Unit
R_{detect} (at any 1 V or greater chord within the voltage range conditions)	2.70 V to 10.1 V	23.7	26.3	kΩ
V offset	See Figure 33–17	0	1.90	V
Voltage at the PI	I_{Port} = 124 µA	2.70		V
Input capacitance	2.70 V to 10.1 V	0.050	0.120	µF
Series input inductance	2.70 V to 10.1 V		0.100	mH

Table 33–15—Non-valid PD detection signature characteristics, measured at PD input connector

Parameter	Conditions	Range of values	Unit
R_{detect}	V < 10.1 V	Either greater than 45.0 or less than 12.0	kΩ
Input capacitance	V < 10.1 V	Greater than 10.0	µF

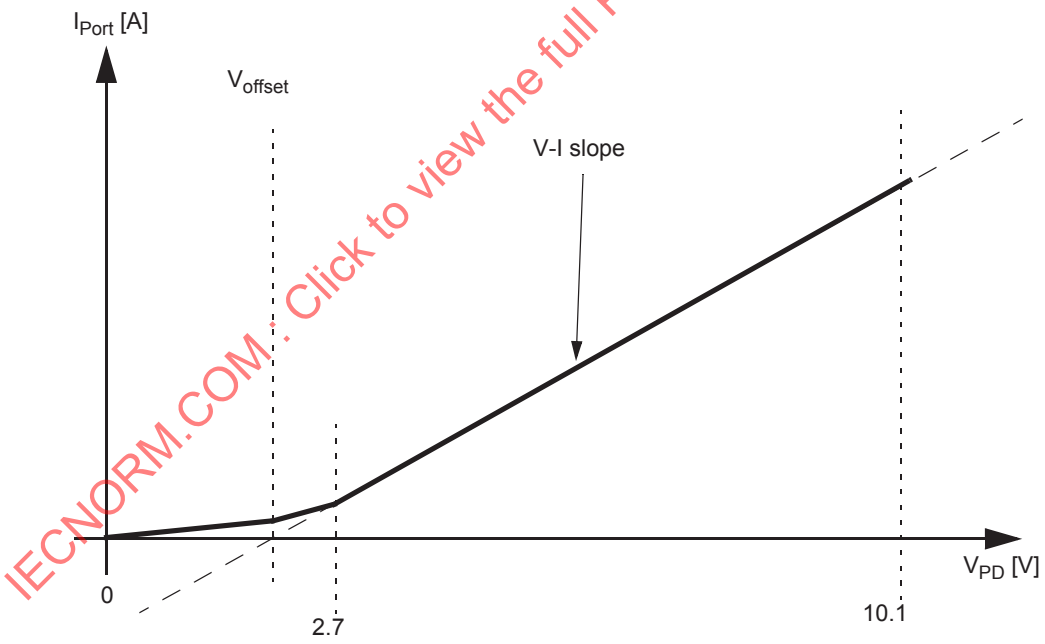

Figure 33–17—Valid PD detection signature offset

33.3.5 PD classifications

See 33.2.6 for a general description of classification mechanisms.

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A PD may be classified by the PSE based on the Physical Layer classification information, Data Link Layer classification, or a combination of both provided by the PD. The intent of PD classification is to provide information about the maximum power required by the PD during operation. Additionally, classification is used to establish mutual identification between Type 2 PSEs and Type 2 PDs.

The method of classification depends on the type of the PD and the type of the attached PSE.

A PD shall meet at least one of the allowable classification permutations listed in Table 33–8.

A Type 1 PD may implement any of the class signatures in 33.3.5 and 33.6.

Type 2 PDs implement both 2-Event class signature (see 33.3.5.2) and Data Link Layer classification (see 33.6).

PD classification behavior conforms to the state diagram in Figure 33–16.

33.3.5.1 PD 1-Event class signature

Class 0 is the default for PDs. However, to improve power management at the PSE, a Type 1 PD may opt to provide a signature for Class 1 to 3.

The PD is classified based on power. The Physical Layer classification of the PD is the maximum power that the PD draws across all input voltages and operational modes.

PDs implementing a 2-Event class signature shall return Class 4 in accordance with the maximum power draw, P_{Class_PD}, as specified in Table 33–18. Since 1-Event classification is a subset of 2-Event classification, Type 2 PDs respond to 1-Event classification with a Class 4 signature. Type 1 PDs may choose to implement a 2-Event class signature and return Class 0, 1, 2, or 3 in accordance with the maximum power draw, P_{Class_PD}. The Type 2 PD's classification behavior shall conform to the electrical specifications defined by Table 33–17.

In addition to a valid detection signature, PDs shall provide the characteristics of a classification signature as specified in Table 33–16. A PD shall present one, and only one, classification signature during classification.

Table 33–16—Classification signature, measured at PD input connector

Parameter	Conditions	Minimum	Maximum	Unit
Current for Class 0	14.5 V to 20.5 V	0	4.00	mA
Current for Class 1	14.5 V to 20.5 V	9.00	12.0	mA
Current for Class 2	14.5 V to 20.5 V	17.0	20.0	mA
Current for Class 3	14.5 V to 20.5 V	26.0	30.0	mA
Current for Class 4	14.5 V to 20.5 V	36.0	44.0	mA

33.3.5.2 PD 2-Event class signature

PDs implementing a 2-Event class signature shall return a Class 4 classification signature in accordance with the maximum power draw, P_{Class_PD}, as specified by Table 33–18. The PD's classification behavior shall conform to the electrical specifications defined by Table 33–17.

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Until successful 2-Event Physical Layer classification or Data Link Layer classification has completed, a Type 2 PD's pse_power_type state variable is set to '1.' A Type 2 PD shall conform to the electrical requirements as defined by Table 33–18 for the type defined in its pse_power_type state variable.

Table 33–17—2-Event Physical Layer classification electrical requirements

Item	Parameter	Symbol	Units	Min	Max	Additional information
1	Class event voltage	V_{Class}	V	14.5	20.5	
2	Mark event voltage	V_{Mark}	V	6.90	10.1	
3	Mark event current	I_{Mark}	mA	0.250	4.00	See 33.3.5.2.1
4	Mark event threshold	V_{Mark_th}	V	10.1	14.5	See 33.3.5.2.1
5	Classification reset threshold	V_{Reset_th}	V	2.81	6.90	See 33.3.5.2.1
6	Classification reset voltage	V_{Reset}	V	0	2.81	See 33.3.5.2.1

33.3.5.2.1 Mark Event behavior

When the PD is presenting a mark event signature as shown in the state diagram of Figure 33–16, the PD shall draw I_{Mark} as defined in Table 33–17 and present a non-valid detection signature as defined in Table 33–15.

The PD shall not exceed the I_{Mark} current limits when voltage at the PI enters the V_{Mark} specification as defined in Table 33–17.

V_{Mark_th} is the PI voltage threshold at which the PD implementing 2-Event class signature transitions into and out of the DO_CLASS_EVENT1 or DO_CLASS_EVENT2 states as shown in Figure 33–16.

The PD shall draw I_{Mark} until the PD transitions from a DO_MARK_EVENT state to the IDLE state.

V_{Reset_th} is the PI voltage threshold at which the PD implementing 2-Event class signature transitions from a DO_MARK_EVENT state to the IDLE state as shown in Figure 33–16.

33.3.6 PSE Type identification

A Type 2 PD shall identify the PSE Type as either Type 1 or Type 2 (see Figure 33–16).

The default value of pse_power_type is 1. After a successful 2-Event Physical Layer classification or Data Link Layer classification has completed, the pse_power_type is set to 2.

The PD resets the pse_power_type to '1' when the PD enters the DO_DETECTION state.

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33.3.7 PD power

The power supply of the PD shall operate within the characteristics in Table 33–18.

The PD may be capable of drawing power from a local power source. When a local power source is provided, the PD may draw some, none, or all of its power from the PI.

Table 33–18—PD power supply limits

Item	Parameter	Symbol	Unit	Min	Max	PD Type	Additional information
1	Input voltage	V_{Port_PD}	V	37.0	57.0	1	See 33.3.7.1, Table 33–1
				42.5	57.0	2	
2	Transient operating input voltage	V_{Tran_lo}	V	36.0		2	For time duration defined in 33.2.7.2
3	Input voltage range during overload	$V_{Overload}$	V	36.0	57.0	1	See 33.3.7.4, Table 33–1
				41.4	57.0	2	
4	Input average power, Class 0 and Class 3	P_{Class_PD}	W		13.0	1	See 33.3.7.2, Table 33–1
	Input average power, Class 1				3.84	1	
	Input average power, Class 2				6.49	1	
	Input average power, Class 4				25.5	2	
5	Input inrush current	I_{Inrush_PD}	A		0.400	1, 2	Peak value—See 33.3.7.3
6	Inrush to operating state delay	T_{delay}	s	0.080		2	See 33.3.7.3
7	Peak operating power, Class 0 and Class 3	P_{Peak_PD}	W		14.4	1	See 33.3.7.4
	Peak operating power, Class 1				5.00	1	
	Peak operating power, Class 2				8.36	1	
	Peak operating power, Class 4				$1.11 \times P_{Class_PD}$	2	
8	Input current transient (absolute value)		mA/µs		4.70	1, 2	See 33.3.7.5
9	PI capacitance during MDI_POWER states	C_{Port}	µF	5.00		1, 2	See 33.3.7.6, 33.3.7.3

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Table 33–18—PD power supply limits *(continued)*

Item	Parameter	Symbol	Unit	Min	Max	PD Type	Additional information
10	Ripple and noise, < 500 Hz		V_{PP}		0.500	1, 2	See 33.3.7.7. Balanced source impedance: R_{Ch}
	Ripple and noise, 500 Hz to 150 kHz				0.200		
	Ripple and noise, 150 kHz to 500 kHz				0.150		
	Ripple and noise, 500 kHz to 1 MHz				0.100		
11	a) PD Power supply turn on voltage	V_{On}	V		42.0	1, 2	See 33.3.7.1
	b) PD power supply turn off voltage	V_{Off}	V	30.0		1, 2	
12	PD classification stability time	T_{class}	s		0.005		See 33.3.7.8
13	Backfeed voltage	V_{bfd}	V		2.80		See 33.3.7.9

33.3.7.1 Input voltage

The specification for V_{Port_PD} in Table 33–18 is for the input voltage range after startup (see 33.3.7.3), and accounts for loss in the cabling plant. Note, $V_{PD} = V_{PSE} - (R_{Chan} \times I_{Port})$.

The PD shall turn on at a voltage less than or equal to V_{On}. After the PD turns on, the PD shall stay on over the entire V_{Port_PD} range. The PD shall turn off at a voltage less than V_{Port_PD} minimum and greater than or equal to V_{Off}.

The PD shall turn on or off without startup oscillation and within the first trial at any load value when fed by V_{Port_PSE} min to V_{Port_PSE} max (as defined in Table 33–11) with a series resistance within the range of valid Channel Resistance.

33.3.7.2 Input average power

The maximum average power, P_{Class_PD} in Table 33–18 or PDMaxPowerValue in 33.6.3.3, is calculated over a 1 second interval. PDs may dynamically adjust their maximum required operating power below P_{Class_PD} as described in 33.6.

NOTE—Average power is calculated using any sliding window with a width of 1 s.

33.3.7.2.1 System stability test conditions during startup and steady state operation

When the PD is fed by V_{Port_PSE} min to V_{Port_PSE} max with R_{Ch} (as defined in Table 33–1) in series, P_{Port_PD} shall be defined as shown in Equation (33–9):

$$P_{Port_PD} = \{V_{Port_PD} \times I_{Port}\}_W \quad (33–9)$$

where

P_{Port_PD} is the average input power at the PD PI

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V_{Port_PD} is the static input voltage at the PD PI
I_{Port} is the input current, either DC or RMS

NOTE—When connected together as a system, the PSE and PD might exhibit instability at the PSE side, the PD side, or both due to the presence of negative impedance at the PD input. See Annex 33A for PD design guidelines for stable operation.

33.3.7.3 Input inrush current

Inrush current is drawn during the startup period beginning with the application of input voltage at the PI compliant with V_{Port_PD} requirements as defined in Table 33–18, and ending when C_{Port} is charged to 99% of its final value. This period should be less than T_{Inrush} min per Table 33–11.

Type 2 PDs with pse_power_type state variable set to 2 prior to power-on shall behave like a Type 1 PD for at least T_{delay} min. T_{delay} starts when V_{PD} crosses the PD power supply turn on voltage, V_{On}. This delay is required so that the Type 2 PD does not enter a high power state before the PSE has had time to switch current limits from I_{Inrush} to I_{LIM}.

Input inrush current at startup is limited by the PSE if $C_{Port} < 180$ µF, as specified in Table 33–11.

If $C_{Port} \geq 180$ µF, input inrush current shall be limited by the PD so that I_{Inrush_PD} max is satisfied.

33.3.7.4 Peak operating power

$V_{Overload}$ is the PD PI voltage when the PD is drawing the permissible P_{Peak_PD}.

At any static voltage at the PI, and any PD operating condition, the peak power shall not exceed P_{Class_PD} max for more than T_{CUT} min, as defined in Table 33–11 and 5% duty cycle. Peak operating power shall not exceed P_{Peak} max.

Ripple current content (I_{Port_ac}) superimposed on the DC current level (I_{Port_dc}) is allowed if the total input power is less than or equal to P_{Class_PD} max.

The RMS, DC and ripple current shall be bounded by Equation (33–10):

$$I_{Port} = \left\{ \sqrt{(I_{Port_dc})^2 + (I_{Port_ac})^2} \right\}_A \quad (33\text{–}10)$$

where

I_{Port} is the RMS input current
I_{Port_dc} is the DC component of the input current
I_{Port_ac} is the RMS value of the AC component of the input current

The maximum I_{Port} value for all operating V_{Port_PD} range shall be defined by the following equation:

$$I_{portmax} = \left\{ \frac{P_{Class_PD}}{V_{Port_PD}} \right\}_A \quad (33\text{–}11)$$

where

$I_{portmax}$ is the maximum DC and RMS input current
V_{Port_PD} is the static input voltage at the PD PI
P_{Class_PD} is the maximum power, P_{Class_PD} max, as defined in Table 33–18

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Peak power, P_{Peak_PD}, for Class 4 is based on Equation (33–12), which approximates the ratiometric peak powers of Class 0 through Class 3. This equation may be used to calculate peak operating power for P_{Peak_PD} values obtained via Data Link Layer classification.

$$P_{Peak_PD} = \{1.11 \times P_{Class_PD}\}_{W} \quad (33–12)$$

where

P_{Peak_PD} is the peak operating power
P_{Class_PD} is the input average power

NOTE—The duty cycle of the peak current is calculated using any sliding window with a width of 1 s.

33.3.7.5 Peak transient current

When the input voltage at the PI is static and in the range of V_{Port_PD} defined by Table 33–18, the transient current drawn by the PD shall not exceed 4.70 mA/µs in either polarity. This limitation applies after inrush has completed (33.3.7.3) and before the PD has disconnected.

Under normal operating conditions when there are no transients applied at the PD PI, the PD shall operate below the PD upperbound template defined in Figure 33–18.

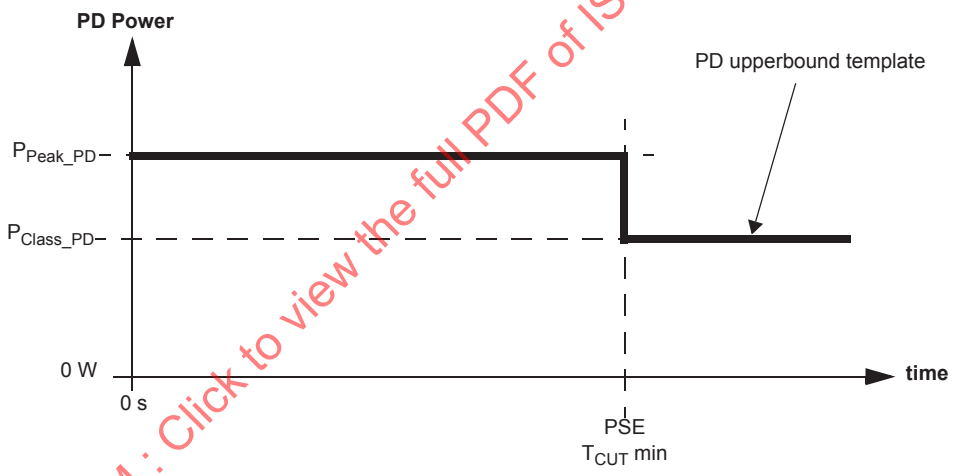

Figure 33–18—PD static operating mask

The PD upperbound template in Figure 33–18, P_{PDUT}, is described by Equation (33–13):

$$P_{PDUT}(t) = \left\{ \begin{array}{ll} P_{Peak_PD} & \text{for } (0 \le t < T_{cutmin}) \\ P_{Class_PD} & \text{for } (T_{cutmin} \le t) \end{array} \right\}_{W} \quad (33–13)$$

where

t is the duration in seconds that the PD sinks I_{Port}
P_{Peak_PD} is the peak operating power, P_{Peak_PD} max, as defined in Table 33–18
P_{Class_PD} is the maximum power, P_{Class_PD} max, as defined in Table 33–18
T_{cutmin} is T_{CUT} min, as defined in Table 33–11

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During PSE transient conditions in which the voltage at the PI is undergoing dynamic change, the PSE is responsible for limiting the transient current drawn by the PD for at least T_{LIM} min as defined in Table 33–11.

33.3.7.6 PD behavior during transients at the PSE PI

A Type 1 PD with input capacitance of 180 µF or less requires no special considerations with regard to transients at the PD PI. A Type 2 PD with peak power draw that does not exceed P_{Class_PD} max and has an input capacitance of 180 µF or less requires no special considerations with regard to transients at the PD PI. PDs that do not meet these requirements shall comply with the following:

— A Type 1 PD input current shall not exceed the PD upperbound template (see Figure 33–18) after T_{LIM} min (see Table 33–11 for a Type 1 PSE) when the following input voltage is applied: A current limited voltage source is applied to the PI through a R_{Ch} resistance (see Table 33–1). The current limit meets Equation (33–14) and the voltage ramps from V_{Port_PSE} min to V_{Port_PSE} max at 2250 V/s.

A Type 2 PD shall meet both of the following:

a) The PD input current spike shall not exceed 2.5 A and shall settle below the PD upperbound template (see Figure 33–18) within 4 ms. During this test, the PD PI voltage is driven from 50 V to 52.5 V at greater than 3.5 V/µs, a source impedance of 1.5 Ω, and a source that supports a current greater than 2.5 A.
b) The PD shall not exceed the PD upperbound template beyond T_{LIM} min under worst-case current draw under the following conditions. The input voltage source drives V_{PD} from V_{Port_PSE} min to 56 V at 2250 V/s, the source impedance is R_{Ch} (see Table 33–1), and the voltage source limits the current to MDI I_{LIM} per Equation (33–14).

The current limit at the MDI (MDI I_{LIM}) is defined by Equation (33–14):

$$\{pse_{\mathrm{ILIMmin}}\}_{\mathrm{mA}} < \{mdi_{\mathrm{ILIM}}\}_{\mathrm{mA}} \leq \{pse_{\mathrm{ILIMmin}}\}_{\mathrm{mA}} + 5.00 \qquad (33\text{–}14)$$

where

pse_{ILIMmin} is the PSE I_{LIM} min as defined in Table 33–11
mdi_{ILIM} is the current limit at the MDI (MDI I_{LIM})

33.3.7.7 Ripple and noise

The specification for ripple and noise in Table 33–18 shall be for the common-mode and/or differential pair-to-pair noise at the PD PI generated by the PD circuitry. The ripple and noise specification shall be for all operating voltages in the range of V_{Port_PD}, and over the range of input power of the device.

The PD shall operate correctly in the presence of ripple and noise generated by the PSE that appears at the PD PI. These levels are specified in Table 33–11, item 3.

Limits are provided to preserve data integrity. To meet EMI standards, lower values may be needed.

The system designer is advised to assume the worst-case condition in which both PSE and PD generate the maximum noise allowed by Table 33–11 and Table 33–18, which may cause a higher noise level to appear at the PI than the standalone case as specified by this clause.

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33.3.7.8 PD classification stability time

Following a valid detection and a rising voltage transition from V_{valid} to V_{Class}, the PD Physical Layer classification signature shall be valid within T_{class} as specified in Table 33–18 and remain valid for the duration of the classification period.

33.3.7.9 Backfeed voltage

When V_{Port_PD} max is applied across the PI at either polarity specified on the conductors for Mode A according to Table 33–13, the voltage measured across the PI for Mode B with a 100 kΩ load resistor connected shall not exceed V_{bfd} max as specified in Table 33–18. When V_{Port_PD} max is applied across the PI at either polarity specified on the conductors for Mode B according to Table 33–13, the voltage measured across the PI for Mode A with a 100 kΩ load resistor connected shall not exceed V_{bfd} max.

33.3.8 PD Maintain Power Signature

In order to maintain power, the PD shall provide a valid Maintain Power Signature (MPS) at the PI. The MPS shall be both:

a) Current draw equal to or above the minimum input current (I_{Port_MPS} min) as specified in Table 33–19 for a minimum duration of 75 ms followed by an optional MPS dropout for no longer than 250 ms, and
b) Input impedance with resistive and capacitive components as defined in Table 33–19.

A PD that does not maintain the MPS components in a) and b) above may have its power removed within the limits of T_{MPDO} as specified in Table 33–11.

Powered PDs that no longer require power shall remove both components a) and b) of the MPS. To cause PSE power removal, the impedance of the PI should rise above Z_{ac2} as specified in Table 33–12.

Table 33–19—PD Maintain Power Signature

Item	Parameter	Symbol	Unit	Min	Max	Additional information
1	Input current	I_{Port_MPS}	A	0.010		See 33.3.8
2	Input resistance	R_{pd_d}	kΩ		26.3	
3	Input capacitance	C_{pd_d}	µF	0.050		See Table 33–12

NOTE—A PD with C_{port} > 180 µF may not be able to meet the I_{Port_MPS} specification in Table 33–19 during the maximum allowed port voltage droop (V_{Port_PSE} max to V_{Port_PSE} min with series resistance R_{Ch}). Such a PD should increase its I_{Port} min or make other such provisions to meet the Maintain Power Signature.

33.4 Additional electrical specifications

This clause defines additional electrical specifications for both the PSE and PD. The specifications apply for all PSE and PD operating conditions at the cabling side of the mated connection of the PI. The requirements apply during data transmission only when specified as an operating condition.

The requirements of 33.4 are consistent with the requirements of the 10BASE-T MAU and the 100BASE-TX and 1000BASE-T PHYs.

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33.4.1 Isolation

PDs and PSEs shall provide isolation between all accessible external conductors, including frame ground (if any), and all MDI leads including those not used by the PD or PSE. Any equipment that can be connected to a PSE or PD through a non-MDI connector that is not isolated from the MDI leads needs to provide isolation between all accessible external conductors, including frame ground (if any), and the non-MDI connector. Accessible external conductors are specified in subclause 6.2.1 b) of IEC 60950-1:2001.

This electrical isolation shall withstand at least one of the following electrical strength tests:

a) 1500 V rms at 50 Hz to 60 Hz for 60 s, applied as specified in subclause 5.2.2 of IEC 60950-1:2001.
b) 2250 V dc for 60 s, applied as specified in subclause 5.2.2 of IEC 60950-1:2001.
c) An impulse test consisting of a 1500 V, 10/700 µs waveform, applied 10 times, with a 60 s interval between pulses. The shape of the impulses shall be 10/700 µs (10 µs virtual front time, 700 µs virtual time of half value), as defined in IEC 60950-1:2001 Annex N.

There shall be no insulation breakdown, as defined in subclause 5.2.2 of IEC 60950-1:2001, during the test. The resistance after the test shall be at least 2 MΩ, measured at 500 V dc.

Conductive link segments that have differing isolation and grounding requirements shall have those requirements provided by the port-to-port isolation of network interface devices (NID).

33.4.1.1 Electrical isolation environments

There are two electrical power distribution environments to be considered that require different electrical isolation properties. They are as follows:

— **Environment A:** When a LAN or LAN segment, with all its associated interconnected equipment, is entirely contained within a single low-voltage power distribution system and within a single building.
— **Environment B:** When a LAN crosses the boundary between separate power distribution systems or the boundaries of a single building.

33.4.1.1.1 Environment A requirements

Attachment of network segments via NIDs that have multiple instances of a twisted pair MDI requires electrical isolation between each segment and the protective ground of the NID.

For NIDs, the requirement for isolation is encompassed within the isolation requirements of the MAU or PHY (see 14.3.1.1, 25.4.6, and 40.6.1.1.). Equipment with multiple instances of PSE, PD, or both shall meet or exceed the isolation requirement of the MAU/PHY with which they are associated.

A multiport NID complying with Environment A requirements does not require electrical power isolation between link segments.

An Environment A PSE shall switch the more negative conductor. It is allowable to switch both conductors.

33.4.1.1.2 Environment B requirements

The attachment of network segments that cross Environment A boundaries requires electrical isolation between each segment and all other attached segments as well as to the protective ground of the NID.

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For NIDs, the requirement for isolation is encompassed within the isolation requirements of the MAU or PHY (see 14.3.1.1, 25.4.6, and 40.6.1.1.). Equipment with multiple instances of PSE, PD, or both shall meet or exceed the isolation requirement of the MAU/PHY with which each is associated.

The requirements for interconnected electrically conducting link segments that are partially or fully external to a single building environment may require additional protection against lightning strikes or other hazards. Protection requirements for such hazards are beyond the scope of this standard. Guidance on these requirements may be found in Section 6 of IEC 60950-1:2001, as well as any local and national codes related to safety.

33.4.2 Fault tolerance

Each wire pair of the PI, when it is also an MDI (e.g., an Endpoint PSE or PD), shall meet the fault tolerance requirements of the appropriate specifying clause. (See 14.3.1.2.7, 25.4, and 40.8.3.4.) When a PI is not an MDI (e.g., a Midspan PSE), the PSE PI shall meet the fault tolerance requirements of this subclause.

The PSE PI shall withstand without damage the application of short circuits of any wire to any other wire within the cable for an indefinite period of time. The magnitude of the current through such a short circuit shall not exceed I_{LIM} max as defined in Table 33–11.

Each wire pair shall withstand, without damage, a 1000 V common-mode impulse applied at E_{cm} of either polarity. The shape of the impulse shall be (0.3/50) µs (300 ns virtual front time, 50 µs virtual time of half value), as defined in IEC 60060, where E_{cm} is an externally applied AC voltage as shown in Figure 33–19.

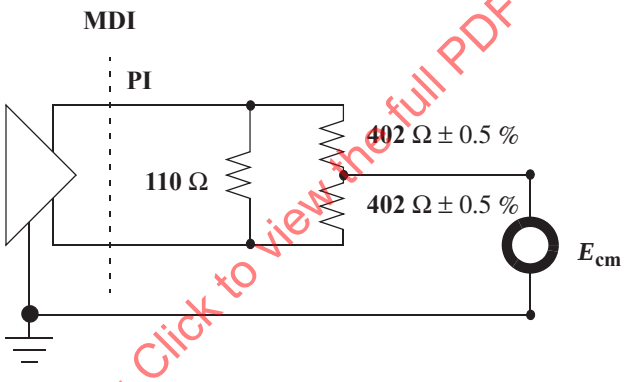

Figure 33–19—PI fault tolerance test circuit

33.4.3 Impedance balance

Impedance balance is a measurement of the common-mode-to-differential-mode offset of the PI. The common-mode-to-differential-mode impedance balance for the transmit and receive pairs shall exceed:

$$\left\{29.0 - 17.0 \times \log_{10}\left(\frac{f}{10.0}\right)\right\}_{dB} \qquad (33\text{–}15)$$

where

f is the frequency in MHz from 1.00 MHz to 20.0 MHz for a 10 Mb/s MAU

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$$\left\{34.0 - 19.2 \times \log_{10}\left(\frac{f}{50.0}\right)\right\}_{\text{dB}} \quad (33\text{–}16)$$

where

f is the frequency in MHz from 1.00 MHz to 100. MHz for a 100 Mb/s or greater PHY

The impedance balance is defined as shown in Equation (33–17):

$$\left\{20.0 \times \log_{10}\left(\frac{E_{\text{cm}}}{E_{\text{dif}}}\right)\right\}_{\text{dB}} \quad (33\text{–}17)$$

where

E_{cm} is an externally applied sinusoidal voltage as shown in Figure 33–20

E_{dif} is the voltage of the resulting waveform due only to the applied sine wave measured as shown in Figure 33–20

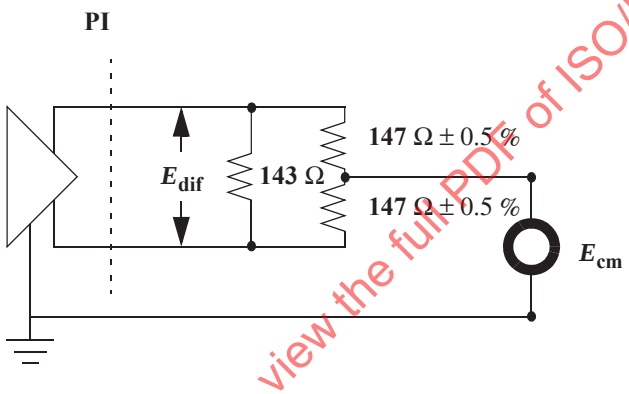

Figure 33–20—PI impedance balance test circuit

33.4.4 Common-mode output voltage

The magnitude of the common-mode AC output voltage measured according to Figure 33–21 and Figure 33–22 at the transmit PI while transmitting data and with power applied, $E_{\text{cm_out}}$, shall not exceed 50 mV peak when operating at 10 Mb/s, and 50 mV peak-to-peak when operating at 100 Mb/s or greater. The frequency of the measurement shall be from 1 MHz to 100 MHz.

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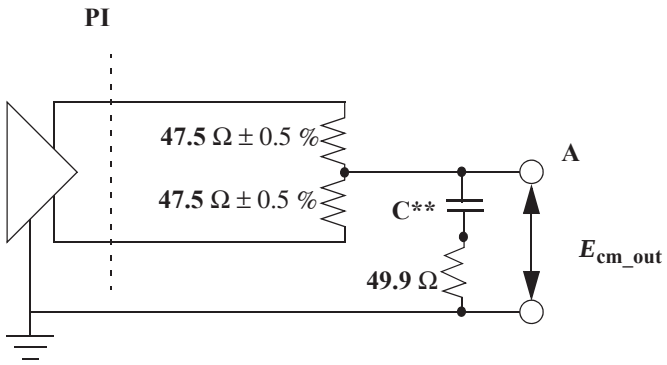

**Capacitor impedance less than 1 Ω
from 1 MHz to 100 MHz

Figure 33–21—Common-mode output voltage test

The common-mode AC output voltage shall be measured while the PHY is transmitting data, the PSE or PD is operating with the following PSE load or PD source:

1) For a PSE, the PI that supplies power is terminated as illustrated in Figure 33–22. The PSE load, R, in Figure 33–22 is adjusted so that the PSE output current, I_{out}, is 10 mA and then 350 mA, while measuring E_{cm_out} on the PI.
2) For a PD, the PI that requires power shall be terminated as illustrated in Figure 33–22. V_{source} in Figure 33–22 is adjusted to 36 Vdc and 57 Vdc, while measuring E_{cm_out} on the PI.

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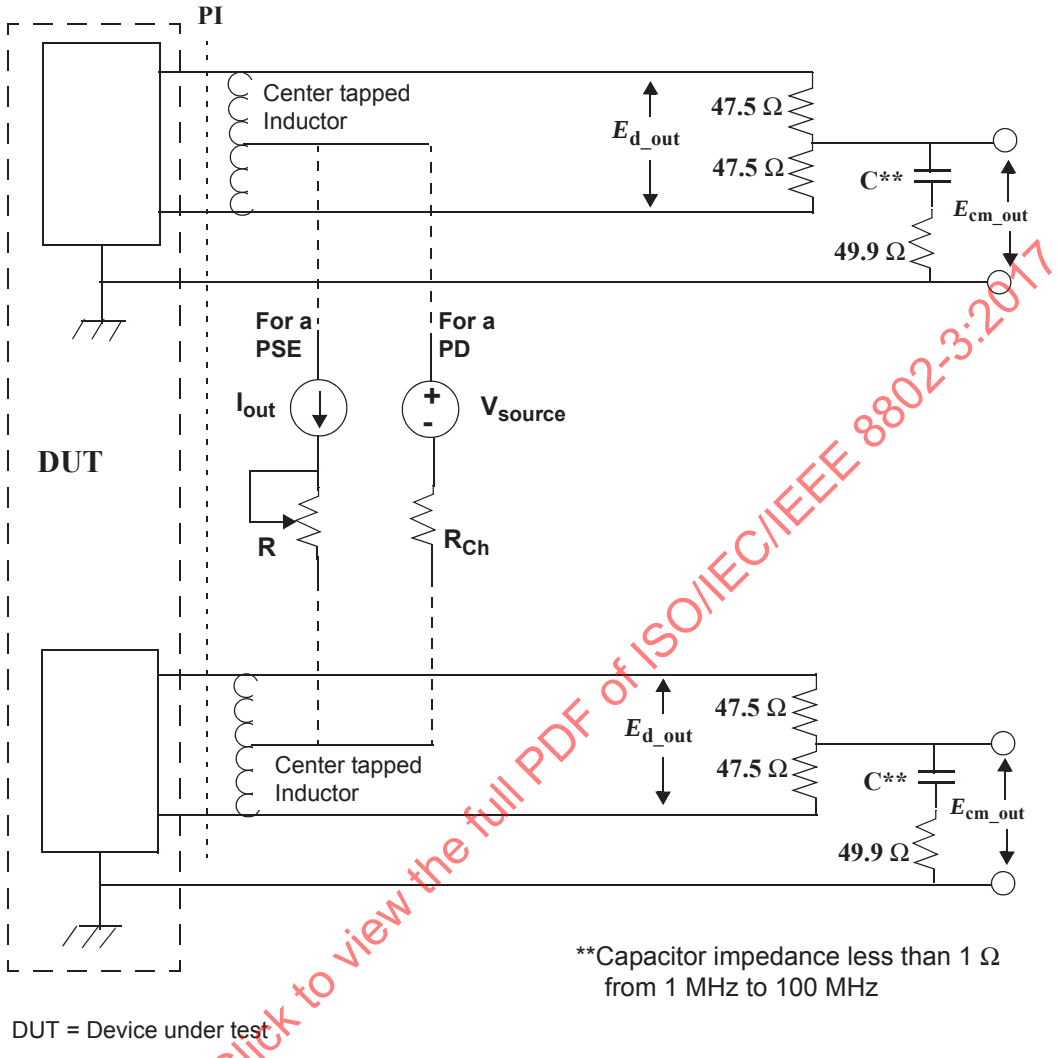

Figure 33–22—PSE and PD terminations for common-mode output voltage test

NOTE—The implementer should consider any applicable local, national, or international regulations that may require more stringent specifications. One such specification can be found in the European Standard EN 55022:1998.

33.4.5 Pair-to-pair output noise voltage

The pair-to-pair output noise voltage (see Figure 33–23) is limited by the resulting electromagnetic interference due to this AC voltage. This AC voltage can be ripple from the power supply (Table 33–11, item 3) or from any other source. A system integrating a PSE shall comply with applicable local and national codes for the limitation of electromagnetic interference.

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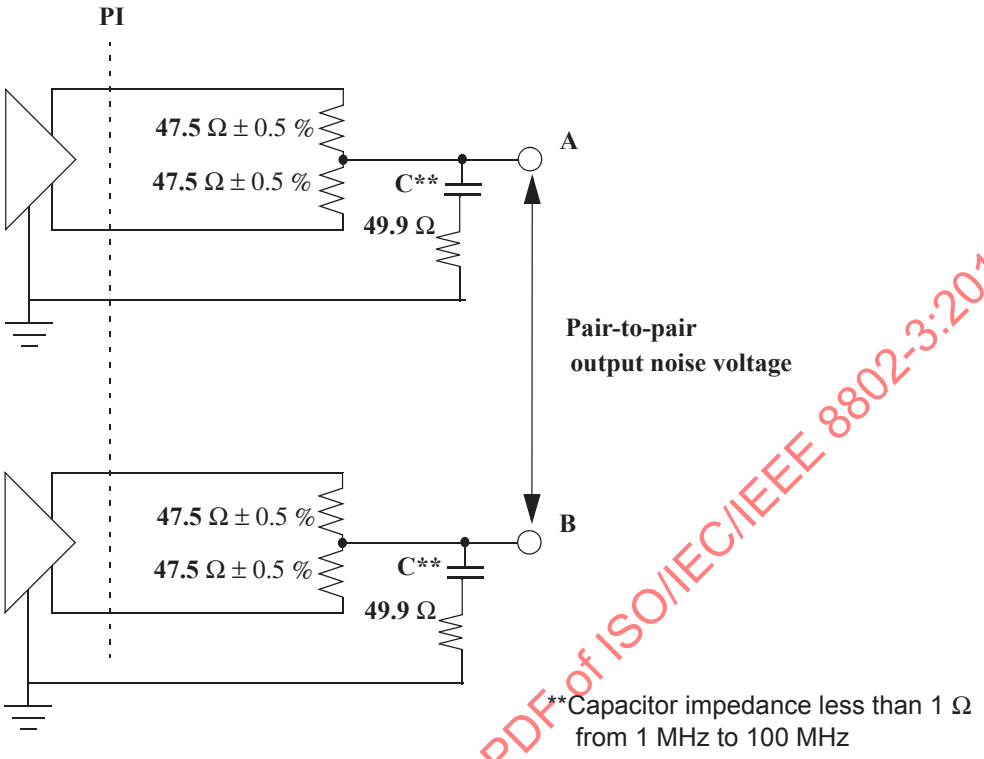

Figure 33–23—Pair-to-pair output noise voltage test

33.4.6 Differential noise voltage

The coupled noise, E_{d_out} in Figure 33–22, from a PSE or PD to the differential transmit and receive pairs shall not exceed 10 mV peak-to-peak when measured from 1 MHz to 100 MHz under the conditions specified in 33.4.4, item 1) and item 2).

33.4.7 Return loss

The differential impedance of the transmit and receive pairs at the PHY's MDI shall be such that any reflection shall meet the return loss requirements as specified in 14.3.1.3.4 for a 10 Mb/s PHY, in ANSI X3.263-1995 for a 100 Mb/s PHY, and 40.8.3.1 for a 1000 Mb/s PHY. In addition, all pairs terminated at an MDI should maintain a nominal common-mode impedance of 75 Ω. The common-mode termination is affected by the presence of the power supply, and this should be considered to determine proper termination.

33.4.8 100BASE-TX transformer droop

100BASE-TX systems may contain a legacy PHY receiver that expects to be connected to a PHY transmitter with 350 µH open circuit inductance (OCL). Alternative A Type 2 Midspan PSEs that support 100BASE-TX shall enforce channel unbalance currents less than or equal to Type 1 I_{unb} (see Table 33–11) or meet 33.4.9.2.

100BASE-TX Type 2 Endpoint PSEs and 100BASE-TX Type 2 PDs shall meet the requirements of Clause 25 in the presence of (I_{unb}/2).

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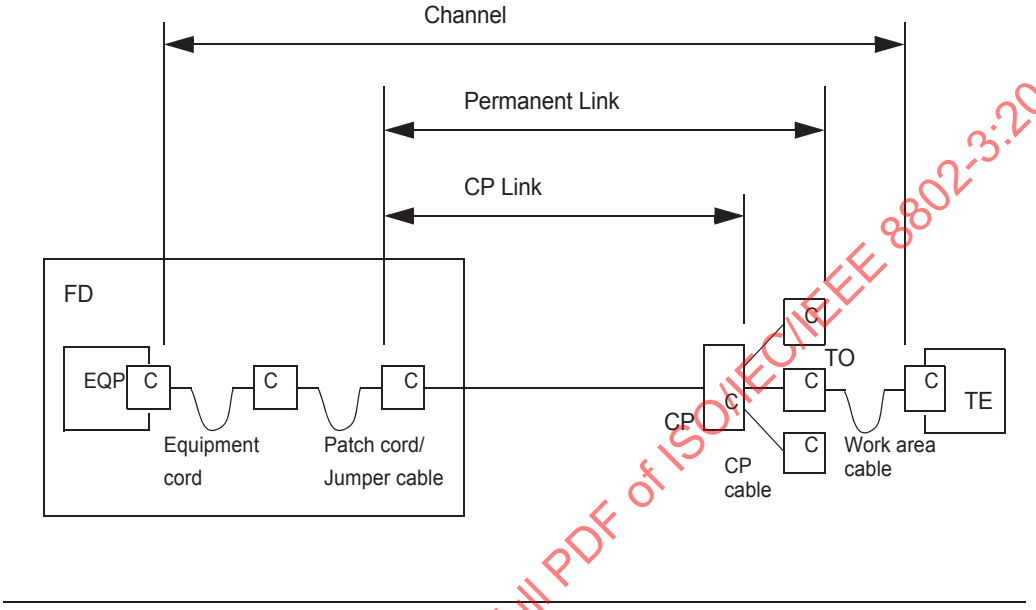
33.4.9 Midspan PSE device additional requirements

The cabling specifications for 100 Ω balanced cabling are described in ISO/IEC 11801-2002. Cable conforming to ANSI/TIA-568-C.2 also meets these requirements. Some cable category specifications that only appear in earlier editions are also supported. The configuration of "channel" and "permanent link" is defined in Figure 33–24. Type 2 Midspan PSE cabling system requirements are specified in 33.1.4.1.



FD = floor distributor; EQP = equipment; C = connection (mated pair);
CP = consolidation point; TO = telecommunications outlet;
TE = terminal equipment

Figure 33–24—Floor distributor channel configuration

ISO/IEC 11801 defines in 5.6.1 two types of Equipment interface to the cabling system: "Interconnect model" and the "cross-connect model." An equivalent "Interconnect model" and "cross-connect model" can be found in ANSI/TIA-568-C.0, 4.2. See Figure 33–25.

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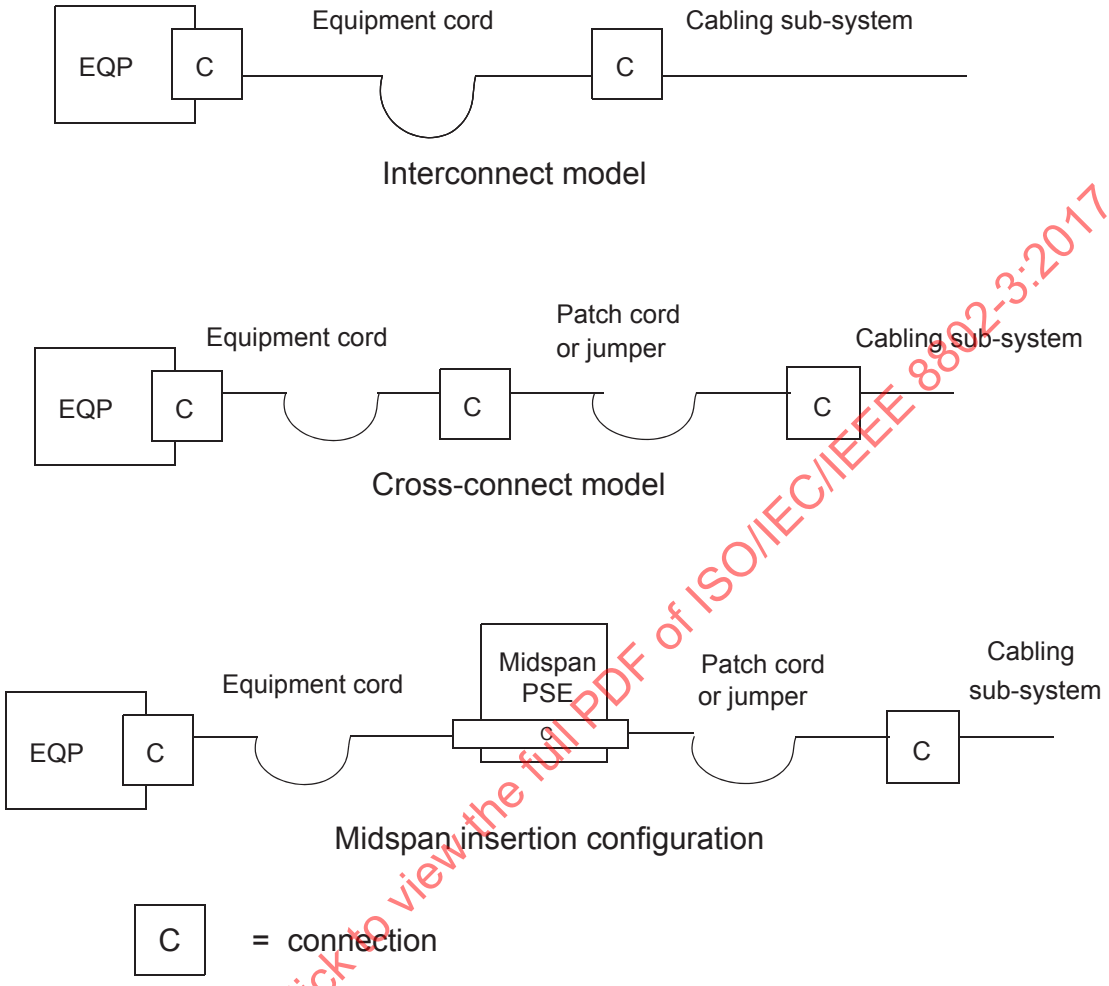

Figure 33–25—Interconnect model, cross-connect model, and midspan insertion configuration

The insertion of a Midspan PSE at the Floor Distributor (FD) shall comply with the following guidelines:

a) If the existing FD configuration is of the “Interconnect model” type, the Midspan PSE can be added, provided it does not increase the length of the resulting “channel” to more than specified 100 m as defined in ISO/IEC 11801 or ANSI/TIA-568-C.0.

b) If the existing FD configuration is of the “Cross-connect model” type, the Midspan PSE needs to be installed instead of one of the connection pairs in the FD. In addition, the installation of the Midspan PSE shall not increase the length of the resulting “channel” to more than specified 100 m as defined in ISO/IEC 11801 or ANSI/TIA-568-C.0.

Configurations with the Midspan PSE in the cabling channel shall not alter the transmission requirements of the “permanent link.” A Midspan PSE shall not provide DC continuity between the two sides of the segment for the pairs that inject power.

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The requirements for the two pair Category 5 channel are found in 25.4.9. The specification of Midspan PSE operation on a two pair cable is beyond the scope of this document.

NOTE—Appropriate terminations may be applied to the interrupted pairs on both sides of the Midspan device.

33.4.9.1 "Connector" or "telecom outlet" Midspan PSE device transmission requirements

The Midspan PSE equipment to be inserted as "connector" or "telecom outlet" shall meet the following transmission parameters. These parameters should be measured using the test procedures of ISO 11801:2002 or ANSI/TIA-568-C.2 for connecting hardware.

There are four types of Midspan PSEs defined with respect to transmission requirements:

1) 10BASE-T/100BASE-TX connector or telecom outlet Midspan PSE
2) 10BASE-T/100BASE-TX work area or equipment cable Midspan PSE
3) 1000BASE-T connector or telecom outlet Midspan PSE
4) 1000BASE-T work area of equipment cable Midspan PSE

33.4.9.1.1 Near End Crosstalk (NEXT)

NEXT loss is a measure of the unwanted signal coupling from a transmitter at the near-end into neighboring pairs measured at the near-end. NEXT loss is expressed in dB relative to the received signal level. NEXT loss for Midspan PSE devices shall meet the values determined by Equation (33–18) when measured for the transmit and receive pairs from 1 MHz to 100 MHz. However, for frequencies that correspond to calculated values greater than 65 dB, the requirement reverts to the minimum requirement of 65 dB.

$$\{NEXTconn\}_{\text{dB}} \geq 40.0 - 20.0 \times \log_{10}\left(\frac{f}{100}\right) \qquad (33\text{–}18)$$

where

NEXTconn	is the Near End Crosstalk loss
f	is the frequency expressed in MHz

33.4.9.1.2 Insertion loss

Insertion loss is a measure of the signal loss between the transmitter and receiver, expressed in dB relative to the received signal level. Insertion loss for Midspan PSE devices shall meet the values determined by Equation (33–19) when measured for the transmit and receive pairs from 1 MHz to 100 MHz. However, for frequencies that correspond to calculated values less than 0.1 dB, the requirement reverts to the maximum requirement of 0.1 dB.

$$\{ILconn\}_{\text{dB}} \leq 0.040 \times \sqrt{f} \qquad (33\text{–}19)$$

where

ILconn	is the insertion loss
f	is the frequency expressed in MHz

33.4.9.1.3 Return loss

Return loss is a measure of the reflected energy caused by impedance mismatches in the cabling system and is expressed in dB relative to the reflected signal level. Return loss for Midspan PSE devices shall meet or exceed the values specified in Table 33–20 when measured for the transmit and receive pairs from 1 MHz to 100 MHz.

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Table 33–20—Connector return loss

Frequency	Return loss
1 MHz ≤ f < 20 MHz	23 dB
20 MHz ≤ f ≤ 100 MHz	14 dB

33.4.9.1.4 Work area or equipment cable Midspan PSE

Replacing the work area or equipment cable with a cable that includes a Midspan PSE should not alter the requirements of the cable. This cable shall meet the requirements of this clause and the specifications for a Category 5 (jumper) cord as specified in ISO/IEC 11801:2002 or ANSI/TIA-568-C.2 for insertion loss, NEXT, and return loss for the transmit and receive pairs.

33.4.9.2 Midspan signal path requirements

An Alternative A Midspan PSE transfer function gain shall be greater than that expressed by Equation (33–20) for the frequency range from 0.1 MHz to 1 MHz, at the pins of the PI used as 100BASE-TX transmit pins.

$$\left\{ -0.100 + 37.5 \times \log_{10}\left(\frac{22.4 \times f}{\sqrt{1.00 + 521 \times f^2}} \right) \right\} \text{dB} \qquad (33\text{–}20)$$

where

f is the frequency expressed in MHz.

The requirements shall be met with a DC bias current, I_{bias}, between 0 mA and (I_{unb}/2) mA (I_{unb} is defined in Table 33–11).

33.4.9.2.1 Alternative A Midspan PSE signal path transfer function

The transfer function is measured by applying a test signal to the Midspan PSE signal input through a source impedance of 100 Ω ± 1 %. The Midspan PSE signal input and output may be connected to a 0.5 m maximum length of cable, meeting the requirements of 25.4.9, terminated with 100 Ω ± 1 %.

The transfer function is defined from the output termination to the Midspan PSE input. See Figure 33–26.

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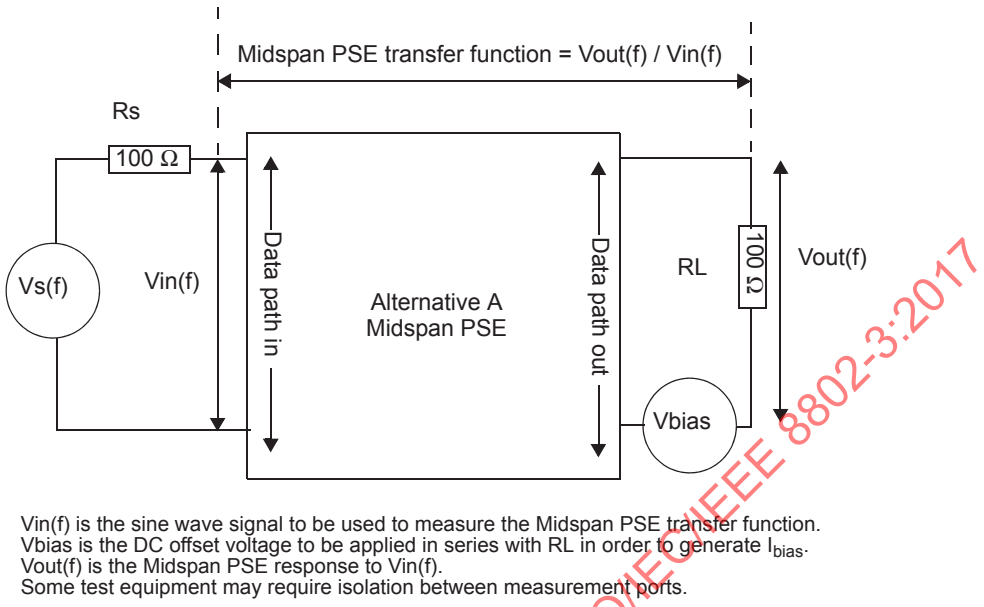

Vin(f) is the sine wave signal to be used to measure the Midspan PSE transfer function.
Vbias is the DC offset voltage to be applied in series with RL in order to generate I_{bias}.
Vout(f) is the Midspan PSE response to Vin(f).
Some test equipment may require isolation between measurement ports.

Figure 33–26—Measurement setup for Alternative A Midspan PSE transfer function

33.5 Management function requirements

If the PSE is implemented with a management interface described in 22.2.4 or 45.2 (MDIO), then the management access shall use the PSE register definitions shown in 33.5.1. Where no physical embodiment of the Clause 22 or Clause 45 management is supported, equivalent management capability shall be provided. Managed objects corresponding to PSE and PD control parameters and states are described in Clause 30.

33.5.1 PSE registers

A PSE implementing either Clause 22 or Clause 45 management interface shall use register address 11 for its control and register address 12 for its status functions. The full set of management registers is listed in Table 22–6.

Some of the bits within registers are defined as latching high (LH). When a bit is defined as latching high and the condition for the bit to be high has occurred, the bit shall remain high until after it has been read via the management interface. Once such a read has occurred, the bit shall assume a value based on the current state of the condition it monitors.

33.5.1.1 PSE Control register (Register 11) (R/W)

The assignment of bits in the PSE Control register is shown in Table 33–21. The default value for each bit of the PSE Control register should be chosen so that the initial state of the PSE upon power up or reset is a normal operational state without management intervention.

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Table 33–21—PSE Control register bit definitions

Bit(s)	Name	Description	R/W[a]
11.15:6	Reserved	Ignore when read	RO
11.5	Data Link Layer Classification Capability	1 = Data Link Layer classification capability enabled 0 = Data Link Layer classification capability disabled	R/W
11.4	Enable Physical Layer Classification	1 = Physical Layer classification enabled 0 = Physical Layer classification disabled	R/W
11.3:2	Pair Control	(11.3) (11.2) 1 1 = Reserved 1 0 = PSE pinout Alternative B 0 1 = PSE pinout Alternative A 0 0 = Reserved	R/W
11.1:0	PSE Enable	(11.1) (11.0) 1 1 = Reserved 1 0 = Force Power Test Mode 0 1 = PSE Enabled 0 0 = PSE Disabled	R/W

[a]R/W = Read/Write, RO = Read Only

33.5.1.1.1 Reserved bits (11.15:6)

Bits 11.15:6 are reserved for future standardization. They shall not be affected by writes and shall return a value of zero when read. For compatibility with future use of reserved bits and registers, if the management entity writes to a reserved bit, it should use a value of zero. If it reads a reserved bit, it should ignore the results.

33.5.1.1.2 Data Link Layer Classification capability (11.5)

Bit 11.5 controls a PSEs capability of performing Data Link Layer classification as specified in 33.6.

A PSE that does not support Data Link Layer classification shall ignore writes to bit 11.5 and shall return a value of zero when read. A PSE that supports Data Link Layer classification, but does not allow the capability to be disabled, shall ignore writes to bit 11.5 and shall return a value of one when read.

A PSE that supports Data Link Layer classification and supports the ability to enable and disable it shall enable Data Link Layer classification by setting bit 11.5 to one and disable it by setting bit 11.5 to zero.

33.5.1.1.3 Enable Physical Layer classification (11.4)

Bit 11.4 controls Physical Layer classification as specified in 33.2.6. A PSE that indicates support for Physical Layer classification in register 12.13 may also provide the option of disabling Physical Layer classification through bit 11.4.

A PSE that does not support Physical Layer classification shall ignore writes to bit 11.4 and shall return a value of zero when read. A PSE that supports Physical Layer classification, but does not allow the function to be disabled, shall ignore writes to bit 11.4 and shall return a value of one when read.

The Physical Layer classification function shall be enabled by setting bit 11.4 to one and disabled by setting bit 11.4 to zero.

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33.5.1.1.4 Pair Control (11.3:2)

Bits 11.3:2 report the supported PSE Pinout Alternative specified in 33.2.1. A PSE may also provide the option of controlling the PSE Pinout Alternative through these bits. Provision of this option is indicated through the Pair Control Ability (12.0) bit. A PSE that does not support this option shall ignore writes to these bits and shall return the value that reports the supported PSE Pinout Alternative.

When read as '01', bits 11.3:2 indicate that only PSE Pinout Alternative A is supported by the PSE. When read as '10', bits 11.3:2 indicate that only PSE Pinout Alternative B is supported by the PSE.

Where the option of controlling the PSE Pinout Alternative through these bits is provided, setting bits 11.3:2 to '01' shall force the PSE to use only PSE Pinout Alternative A and setting bits 11.3:2 to '10' shall force the PSE to use only PSE Pinout Alternative B.

If bit 12.0 is one, writing to these register bits shall set mr_pse_alternative to the corresponding value: '01' = A and '10' = B. The combinations '00' and '11' for bits 11.3:2 are reserved and will never be assigned. Reading bits 11.3:2 returns an unambiguous result of '01' or '10' that may be used to determine the presence of the PSE Control register.

33.5.1.1.5 PSE enable (11.1:0)

The PSE function shall be disabled by setting bit 11.1 to zero and bit 11.0 to zero. When the PSE function is disabled, the MDI shall function as it would if it had no PSE function. The PSE function shall be enabled by setting bits 11.1 to a zero and 11.0 to a one. When bit 11.1 is a one, and bit 11.0 is a zero, a test mode is enabled. This test mode supplies power without regard to PD detection.

Writing to these register bits shall set mr_pse_enable to the corresponding value: '00' = disable, '01' = enable and '10' = force power. The combination '11' for bits 11.1:0 has been reserved for future use.

> **CAUTION**
>
> Test mode may damage connected non-PD legacy, twisted pair Ethernet devices, or other non-Ethernet devices, especially in split application wiring schemes.

33.5.1.2 PSE Status register (Register 12) (R/W)

The assignment of bits in the PSE Status register is shown in Table 33–22.

Table 33–22—PSE Status register bit definitions

Bit(s)	Name	Description	R/W[a]
12.15	PSE Type Electrical Parameters	1 = PSE is using Type 2 PSE electrical parameters 0 = PSE is using Type 1 PSE electrical parameters	RO
12.14	Data Link Layer Classification Enabled	1 = Data Link Layer classification is enabled 0 = Data Link Layer classification is not supported or is not enabled	RO
12.13	Physical Layer Classification Supported	1 = PSE supports Physical Layer classification 0 = PSE does not support Physical Layer classification	RO

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Table 33–22—PSE Status register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
12.12	Power Denied or Removed	1 = Power has been denied or removed due to fault 0 = Power has not been denied or removed	RO/ LH
12.11	Valid Signature	1 = Valid PD signature detected 0 = No valid PD signature detected	RO/ LH
12.10	Invalid Signature	1 = Invalid PD signature detected 0 = No invalid PD signature detected	RO/ LH
12.9	Short Circuit	1 = Short circuit condition detected 0 = No short circuit condition detected	RO/ LH
12.8	Overload	1 = Overload condition detected 0 = No overload condition detected	RO/ LH
12.7	MPS Absent	1 = MPS absent condition detected 0 = No MPS absent condition detected	RO/ LH
12.6:4	PD Class	(12.6) (12.5) (12.4) 1 1 1 = Reserved 1 1 0 = Reserved 1 0 1 = Invalid Class 1 0 0 = Class 4 0 1 1 = Class 3 0 1 0 = Class 2 0 0 1 = Class 1 0 0 0 = Class 0	RO
12.3:1	PSE Status	(12.3) (12.2) (12.1) 1 1 1 = Reserved 1 1 0 = Reserved 1 0 1 = implementation-specific fault 1 0 0 = Test error 0 1 1 = Test mode 0 1 0 = Delivering power 0 0 1 = Searching 0 0 0 = Disabled	RO
12.0	Pair Control Ability	1 = PSE pinout controllable by Pair Control bits 0 = PSE Pinout Alternative fixed	RO

[a]RO = Read Only, LH = Latched High

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33.5.1.2.1 PSE Type electrical parameters (12.15)

When read as a zero, bit 12.15 indicates that the PSE is operating with Type 1 PSE electrical parameters. When read as a one, bit 12.15 indicates that the PSE is operating with Type 2 PSE electrical parameters. This bit shall be set to zero when the PSE state diagram sets the state variable set_parameter_type to 1. This bit shall be set to one when the PSE state diagram sets set_parameter_type to 2.

33.5.1.2.2 Data Link Layer Classification Enabled (12.14)

When read as a one, bit 12.14 indicates the PSE supports Data Link Layer classification as defined in 33.2.6 and that it is enabled. When read as a zero, bit 12.14 indicates that the PSE lacks support for Data Link Layer classification or that Data Link Layer classification is not enabled. If supported, the Data Link Layer classification may be enabled or disabled through the state diagram variable pse_dll_enabled (see 33.2.4.4).

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This bit shall be set to one when the PSE state diagram (Figure 33–9) sets true the state variable pse_dll_enabled. This bit shall be set to zero when the PSE state diagram sets false the state variable pss_dll_enabled.

33.5.1.2.3 Physical Layer Classification Supported (12.13)

When read as a one, bit 12.13 indicates that the PSE supports Physical Layer classification as defined in 33.2.6. When read as a zero, bit 12.13 indicates that the PSE lacks support for Physical Layer classification. If supported, the function may be enabled or disabled through the Enable Physical Layer Classification bit (11.4).

33.5.1.2.4 Power Denied or Removed (12.12)

When read as a one, bit 12.12 indicates that power has been denied or has been removed due to a fault condition. This bit shall be set to one when the PSE state diagram (Figure 33–9) enters the states 'POWER_DENIED' or 'ERROR_DELAY.' The Power Denied bit shall be implemented with latching high behavior as defined in 33.5.1.

33.5.1.2.5 Valid Signature (12.11)

When read as a one, bit 12.11 indicates that a valid signature has been detected. This bit shall be set to one when mr_valid_signature transitions from FALSE to TRUE. The Valid Signature bit shall be implemented with latching high behavior as defined in 33.5.1.

33.5.1.2.6 Invalid Signature (12.10)

When read as a one, bit 12.10 indicates that an invalid signature has been detected. This bit shall be set to one when the PSE state diagram (Figure 33–9) enters the state 'SIGNATURE_INVALID'. The Invalid Signature bit shall be implemented with latching high behavior as defined in 33.5.1.

33.5.1.2.7 Short Circuit (12.9)

When read as a one, bit 12.9 indicates that a short circuit condition has been detected. This bit shall be set to one when the PSE state diagram (Figure 33–9) enters the state 'ERROR_DELAY.' The Short Circuit bit shall be implemented with latching high behavior as defined in 33.5.1.

33.5.1.2.8 Overload (12.8)

When read as a one, bit 12.8 indicates that an overload condition has been detected. This bit shall be set to one when the PSE state diagram (Figure 33–9) enters the state 'ERROR_DELAY_OVER'. The Overload bit shall be implemented with latching high behavior as defined in 33.5.1.

33.5.1.2.9 MPS Absent (12.7)

When read as a one, bit 12.7 indicates that an MPS Absent condition has been detected. The MPS Absent bit shall be set to one when the PSE state diagram (Figure 33–9) transitions directly from the state POWER_ON to IDLE due to tmpdo_timer_done being asserted. The MPS Absent bit shall be implemented with latching high behavior as defined in 33.5.1.

33.5.1.2.10 PD Class (12.6:4)

Bits 12.6:4 report the PD Class of a detected PD as specified in 33.2.5 and 33.2.6. The value in this register is valid while a PD is connected, i.e., while the PSE Status (12.3:1) bits are reporting "delivering power." The combinations '110' and '111' for bits 12.6:4 have been reserved for future use.

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33.5.1.2.11 PSE Status (12.3:1)

Bits 12.3:1 report the current status of the PSE. When read as '000', bits 12.3:1 indicate that the PSE state diagram (Figure 33–9) is in the state DISABLED. When read as '010', bits 12.3:1 indicate that the PSE state diagram is in the state POWER_ON. When read as '011', bits 12.3:1 indicate that the PSE state diagram is in the state TEST_MODE. When read as '100', bits 12.3:1 indicate that the PSE state diagram is in the state TEST_ERROR. When read as '101', bits 12.3:1 indicate that the PSE state diagram is in the state IDLE due to the variable error_condition = true. When read as '001', bits 12.3:1 indicate that the PSE state diagram is in a state other than those listed above.

The combinations '111' and '110' for bits 12.3:1 have been reserved for future use.

33.5.1.2.12 Pair Control Ability (12.0)

When read as a one, bit 12.0 indicates that the PSE supports the option to control which PSE Pinout Alternative (see 33.2.1) is used for PD detection and power through the Pair Control (11.3:2) bits. When read as a zero, bit 12.0 indicates that the PSE lacks support of the option to control which PSE Pinout Alternative is used for PD detection and power through the Pair Control (11.3:2) bits.

33.6 Data Link Layer classification

Additional control and classification functions are supported using Data Link Layer classification using frames based on the IEEE 802.3 Organizationally Specific TLVs defined in Clause 79. Type 2 PDs that require more than 13.0 W support Data Link Layer classification (see 33.3.5). Data Link Layer classification is optional for all other devices.

All reserved fields in transmitted Power via MDI TLVs shall contain zero, and all reserved fields in received Power via MDI TLVs shall be ignored.

33.6.1 TLV frame definition

Implementations that support Data Link Layer classification shall comply with all mandatory parts of IEEE Std 802.1AB-2009; shall support the Power via MDI Type, Length, Value (TLV) defined in 79.3.2; and shall support the control state diagrams defined in 33.6.3.

33.6.2 Data Link Layer classification timing requirements

A Type 2 PSE shall send an LLDPDU containing a Power via MDI TLV within 10 seconds of Data Link Layer classification being enabled in the PSE as indicated by the variable pse_dll_enabled (33.2.4.4, 33.6.3.3).

A Type 1 PSE that implements Data Link Layer classification shall send an LLDPDU containing a Power via MDI TLV when the PSE Data Link Layer classification engine is ready as indicated by the variable pse_dll_ready (33.6.3.3).

All Type 1 PDs that implement Data Link Layer classification and Type 2 PDs shall set the state variable pd_dll_ready within 5 minutes of Data Link Layer classification being enabled in a PD as indicated by the variable pd_dll_enabled (33.3.3.3, 33.6.3.3).

Under normal operation, an LLDPDU containing a Power via MDI TLV with an updated value for the "PSE allocated power value" field shall be sent within 10 seconds of receipt of an LLDPDU containing a Power via MDI TLV where the "PD requested power value" field is different from the previously communicated value.

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Under normal operation, an LLDPDU containing a Power via MDI TLV with an updated value for the "PD requested power value" field shall be sent within 10 seconds of receipt of an LLDPDU containing a Power via MDI TLV where the "PSE allocated power value" field is different from the previously communicated value.

33.6.3 Power control state diagrams

The power control state diagrams for PSEs and PDs specify the externally observable behavior of a PSE and PD Data Link Layer classification respectively. PSE Data Link Layer classification shall provide the behavior of the state diagram as shown in Figure 33–27. PD Data Link Layer classification shall provide the behavior of the state diagram as shown in Figure 33–28.

33.6.3.1 Conventions

The body of this subclause is comprised of state diagrams, including the associated definitions of variables, constants, and functions. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

The notation used in the state diagrams follows the conventions of state diagrams as described in 21.5.

33.6.3.2 Constants

PD_DLLMAX_VALUE

This value is derived from pd_max_power variable (33.3.3.3) described as follows:

pd_max_power	PD_DLLMAX_VALUE
0	130
1	39
2	65
3	130
4	255

PD_INITIAL_VALUE

This value is derived as follows from the pd_max_power (33.3.3.3) variable used in the PD state diagram (Figure 33–16):

pd_max_power	PD_INITIAL_VALUE
0	≤ 130
1	≤ 39
2	≤ 65
3	≤ 130
4	≤ 255

PSE_INITIAL_VALUE

This value is derived as follows from parameter_type and the mr_pd_class_detected (33.2.4.6) variable used in the PSE state diagram (Figure 33–9):

parameter_type	mr_pd_class_detected	PSE_INITIAL_VALUE
1	0	130
1	1	39
1	2	65
1	3	130
1	4	130
2	4	255

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33.6.3.3 Variables

The PSE power control state diagram (Figure 33–27) and PD power control state diagram (Figure 33–28) use the following variables:

MirroredPDRequestedPowerValue
: The copy of PDRequestedPowerValue that the PSE receives from the remote system. This variable is mapped from the aLldpXdot3RemPDRequestedPowerValue attribute (30.12.3.1.17). Actual power numbers are represented using an integer value that is encoded according to Equation (79–1), where *X* is the decimal value of MirroredPDRequestedPowerValue.
Values:0 through 255

MirroredPDRequestedPowerValueEcho
: The copy of PDRequestedPowerValueEcho that the PD receives from the remote system. This variable is mapped from the aLldpXdot3RemPDRequestedPowerValue attribute (30.12.3.1.17).

MirroredPSEAllocatedPowerValue
: The copy of PSEAllocatedPowerValue that the PD receives from the remote system. This variable is mapped from the aLldpXdot3RemPSEAllocatedPowerValue attribute (30.12.3.1.18). Actual power numbers are represented using an integer value that is encoded according to Equation (79–2), where *X* is the decimal value of MirroredPSEAllocatedPowerValue.
Values:0 through 255

MirroredPSEAllocatedPowerValueEcho
: The copy of PSEAllocatedPowerValue that the PSE receives from the remote system. This variable is mapped from the aLldpXdot3RemPSEAllocatedPowerValue attribute (30.12.3.1.18).

PDRequestedPowerValueEcho
: This variable is updated by the PSE state diagram. This variable maps into the aLldpXdot3LocPDRequestedPowerValue attribute (30.12.2.1.17).
Values:0 through 255

PDMaxPowerValue
: Integer that indicates the actual PD power value of the local system. The actual PD power value for a PD is the maximum input average power (see 33.3.7.2) the PD ever draws under the current power allocation. Actual power numbers are represented using an integer value that is encoded according to Equation (79–1), where *X* is the decimal value of PDMaxPowerValue.

PDRequestedPowerValue
: Integer that indicates the PD requested power value in the PD. The value is the maximum input average power (see 33.3.7.2) the PD requests. This power value is encoded according to Equation (79–1), where *X* is the decimal value of PDRequestedPowerValue. This variable is mapped from the aLldpXdot3LocPDRequestedPowerValue attribute (30.12.2.1.17).
Values:0 through PD_DLLMAX_VALUE

PSEAllocatedPowerValue
: Integer that indicates the PSE allocated power value in the PSE. The value is the maximum input average power (see 33.3.7.2) the PD ever draws. The power value for a PSE is the maximum input average power the PD may ever draw. This power value is encoded according to Equation (79–2), where *X* is the decimal value of PSEAllocatedPowerValue. This variable is mapped from the aLldpXdot3LocPSEAllocatedPowerValue attribute (30.12.2.1.18).
Values:0 through 255

PSEAllocatedPowerValueEcho
: This variable is updated by the PD state diagram. This variable maps into the aLldpXdot3LocPSEAllocatedPowerValue attribute (30.12.2.1.18).
Values:0 through 255

TempVar
: A temporary variable used to store Power Value. Actual power numbers are represented using an integer value that is encoded according to Equation (79–1) or Equation (79–2), where *X* is the decimal value of TempVar.

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local_system_change
: An implementation-specific control variable that indicates that the local system wants to change the allocated power value. In a PSE, this indicates it is going to change the power allocated to the PD. In a PD, this indicates it is going to request a new power allocation from the PSE.
Values:FALSE:The local system does not wants to change the power allocation.
TRUE:The local system wants to change the power allocation.

parameter_type
: A control variable output by the PSE state diagram (Figure 33–9) used by a Type 2 PSE to choose operation with Type 1 or Type 2 PSE output PI electrical requirement parameter values defined in Table 33–11.
Values: 1: Type 1 PSE parameter values (default).
2: Type 2 PSE parameter values.

pd_dll_enabled
: A variable output by the PD state diagram (Figure 33–16) to indicate if the PD Data Link Layer classification mechanism is enabled.
Values: FALSE:PD Data Link Layer classification is not enabled.
TRUE:PD Data Link Layer classification is enabled.

pd_dll_power_type
: A control variable that indicates the type of PD that is connected to the PSE as advertised through Data Link Layer classification.
Values: 1: PD is a Type 1 PD (default).
2: PD is a Type 2 PD.

pd_dll_ready
: An implementation-specific control variable that indicates that the PD has initialized Data Link Layer classification. This variable maps into the aLldpXdot3LocReady attribute (30.12.2.1.20).
Values:FALSE:Data Link Layer classification has not completed initialization.
TRUE:Data Link Layer classification has completed initialization.

pse_dll_enabled
: A variable output by the PSE state diagram (Figure 33–9) to indicate if the PSE Data Link Layer classification mechanism is enabled.
Values: FALSE:PSE Data Link Layer classification is not enabled.
TRUE:PSE Data Link Layer classification is enabled.

pse_dll_power_type
: A control variable that indicates the type of the PSE by which the PD is being powered.
Values: 1: PSE is a Type 1 PSE (default).
2: PSE is a Type 2 PSE.

pse_dll_ready
: An implementation-specific control variable that indicates that the PSE has initialized Data Link Layer classification. This variable maps into the aLldpXdot3LocReady attribute (30.12.2.1.20).
Values:FALSE:Data Link Layer classification has not completed initialization.
TRUE:Data Link Layer classification has completed initialization.

pse_power_type
: A control variable output by the PD state diagram (Figure 33–16) to indicate the type of PSE by which it is being powered.

A summary cross-references between the DTE Power via MDI classification local and remote object class attributes and the PSE and PD power control state diagrams, including the direction of the mapping, is provided in Table 33–23.

33.6.3.4 Functions

pse_power_review
: This function evaluates the power allocation or budget of the PSE based on local system changes. The function returns the following variables:

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PSE_NEW_VALUE:

The new max power value that the PSE expects the PD to draw. Actual power numbers are represented using an integer value that is encoded according to Equation (79–2), where *X* is the decimal value of PSE_NEW_VALUE.

pd_power_review

This function evaluates the power requirements of the PD based on local system changes and/or changes in the PSE allocated power value. The function returns the following variables:

PD_NEW_VALUE:

The new max power value that the PD wants to draw. Actual power numbers are represented using an integer value that is encoded according to Equation (79–1), where *X* is the decimal value of PD_NEW_VALUE.

Table 33–23—Attribute to state diagram variable cross-reference

Entity	Attribute	Mapping	State diagram variable
oLldpXdot3LocSystemsGroup Object Class			
PSE	aLldpXdot3LocPDRequestedPowerValue	⇐	PDRequestedPowerValueEcho
	aLldpXdot3LocPSEAllocatedPowerValue	⇐	PSEAllocatedPowerValue
	aLldpXdot3LocReady	⇐	pse_dll_ready
PD	aLldpXdot3LocPDRequestedPowerValue	⇐	PDRequestedPowerValue
	aLldpXdot3LocPSEAllocatedPowerValue	⇐	PSEAllocatedPowerValueEcho
	aLldpXdot3LocReady	⇐	pd_dll_ready
oLldpXdot3RemSystemsGroup Object Class			
PSE	aLldpXdot3RemPDRequestedPowerValue	⇒	MirroredPDRequestedPowerValue
	aLldpXdot3RemPSEAllocatedPowerValue	⇒	MirroredPSEAllocatedPowerValueEcho
	aLldpXdot3RemPowerType Value[a] 11 01	 ⇒ ⇒	pd_dll_power_type Value[a] 01 10
PD	aLldpXdot3RemPSEAllocatedPowerValue	⇒	MirroredPSEAllocatedPowerValue
	aLldpXdot3RemPDRequestedPowerValue	⇒	MirroredPDRequestedPowerValueEcho
	aLldpXdot3RemPowerType Value[a] 10 00	 ⇒ ⇒	pse_dll_power_type Value[a] 01 10

[a]Other value combinations mapping from aLldpXdot3RemPowerType to pd_dll_power_type or pse_dll_power_type are not possible.

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33.6.3.5 State diagrams

The general state change procedure for PSEs is shown in Figure 33–27.

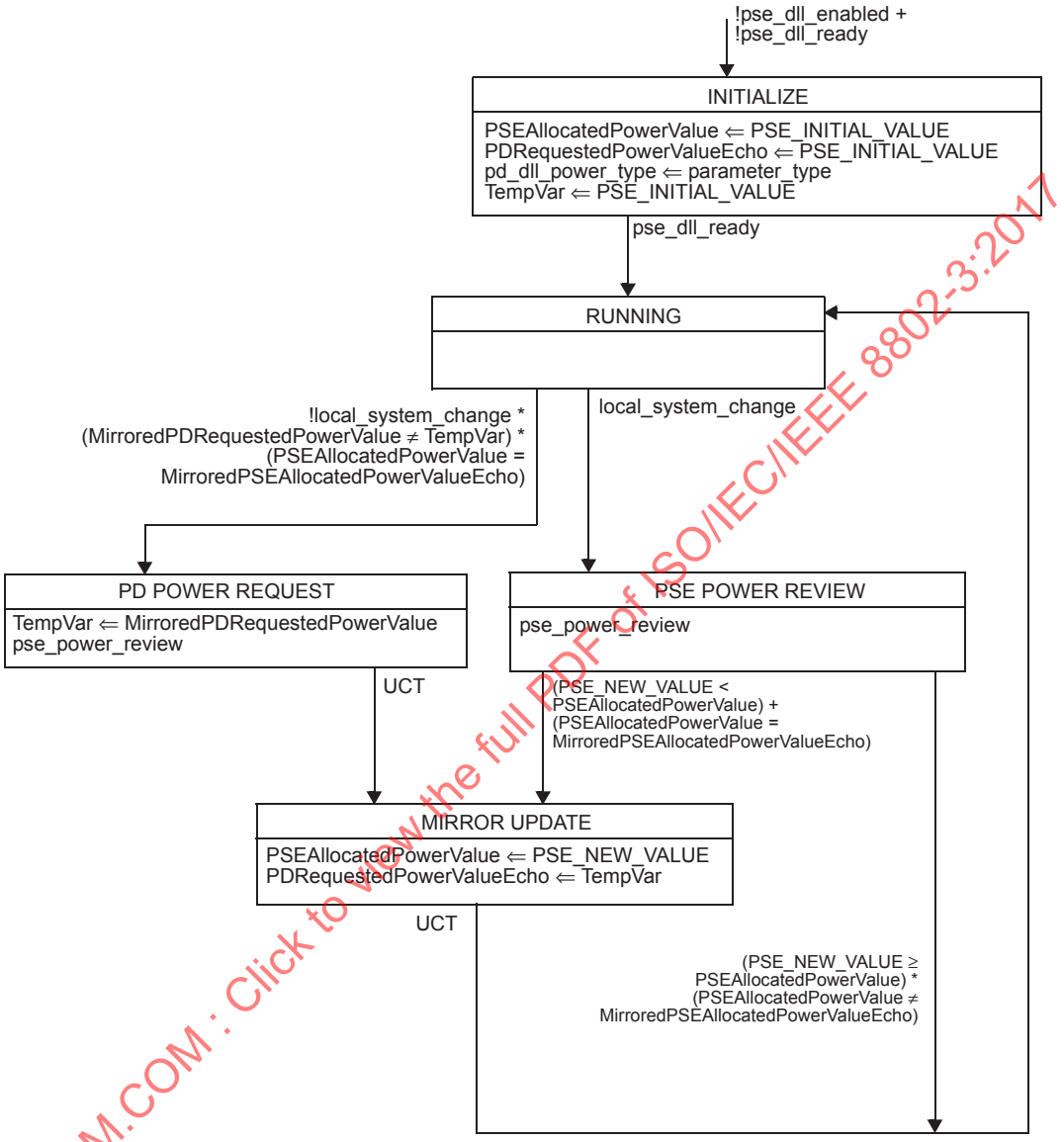

Figure 33–27—PSE power control state diagram

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The general state change procedure for PDs is shown in Figure 33–28.

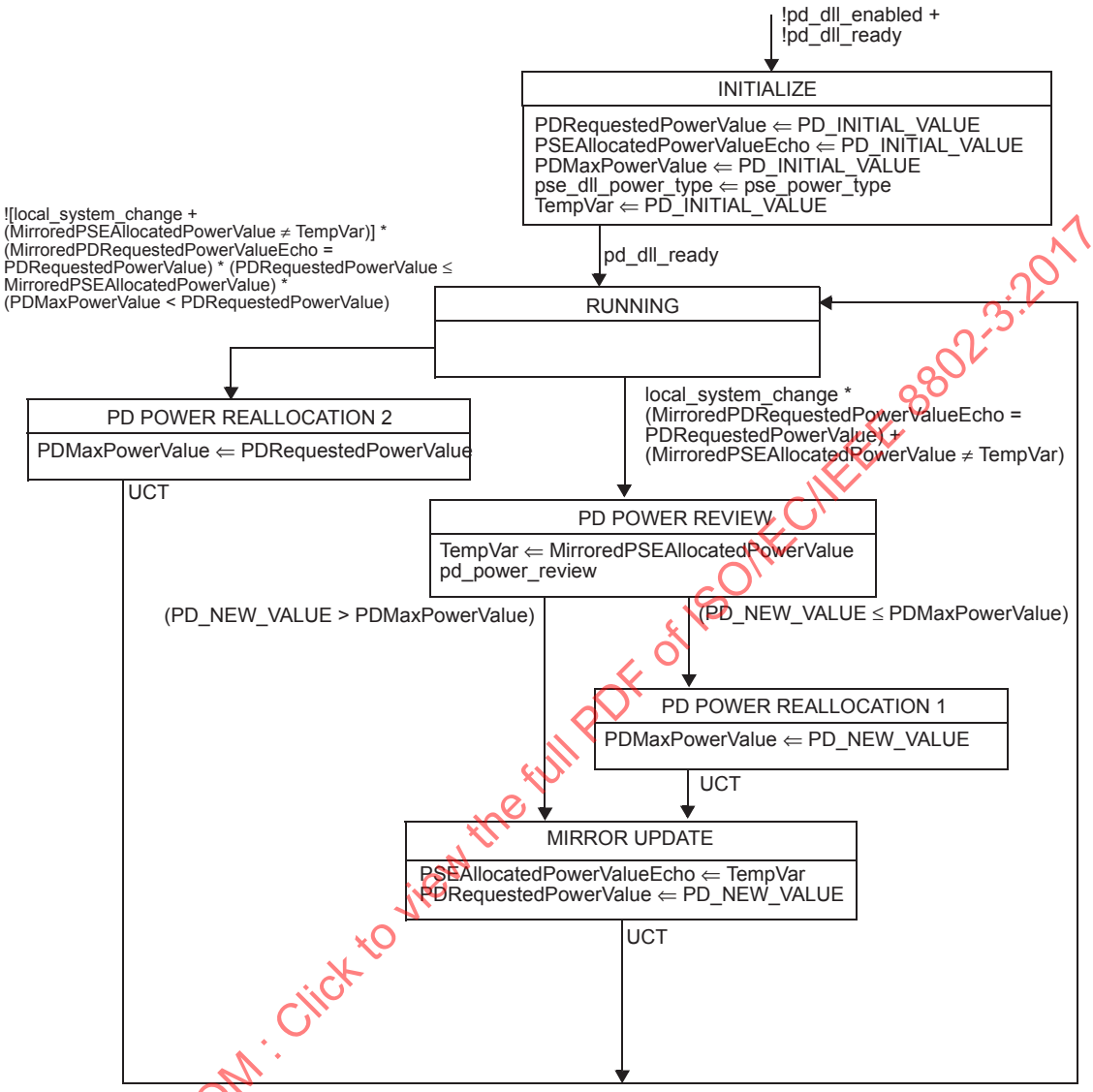

Figure 33–28—PD power control state diagram

33.6.4 State change procedure across a link

The PSE and PD utilize the LLDPDUs to advertise their various attributes to the other entity.

The PD may request a new power value through the aLldpXdot3LocPDRequestedPowerValue (30.12.2.1.17) attribute in the oLldpXdot3LocSystemsGroup object class. The request appears to the PSE as a change to the aLldpXdot3RemPDRequestedPowerValue (30.12.3.1.17) attribute in the oLldpXdot3RemSystemsGroup object class.

The PSE responds to the PD's request through the aLldpXdot3LocPSEAllocatedPowerValue (30.12.2.1.18) attribute in the oLldpXdot3LocSystemsGroup object class. The PSE also copies the value of the aLldpXdot3RemPDRequestedPowerValue (30.12.3.1.17) in the oLldpXdot3RemSystemsGroup object class

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to the aLldpXdot3LocPDRequestedPowerValue (30.12.2.1.17) in the oLldpXdot3LocSystemsGroup object class. This appears to the PD as a change to the aLldpXdot3RemPSEAllocatedPowerValue (30.12.3.1.18) attribute in the oLldpXdot3RemSystemsGroup object class.

The PSE may allocate a new power value through the aLldpXdot3LocPSEAllocatedPowerValue (30.12.2.1.18) attribute in the oLldpXdot3LocSystemsGroup object class. The request appears to the PD as a change to the aLldpXdot3RemPSEAllocatedPowerValue (30.12.3.1.18) attribute in the oLldpXdot3RemSystemsGroup object class. The PD responds to a PSE's request through the aLldpXdot3LocPDRequestedPowerValue (30.12.2.1.17) attribute in the oLldpXdot3LocSystemsGroup object class. The PD also copies the value of the aLldpXdot3RemPSEAllocatedPowerValue (30.12.3.1.18) attribute in the oLldpXdot3RemSystemsGroup object class to the aLldpXdot3LocPSEAllocatedPowerValue (30.12.2.1.18) attribute in the oLldpXdot3LocSystemsGroup object class. This appears to the PSE as a change to the aLldpXdot3RemPDRequestedPowerValue (30.12.3.1.17) attribute in the oLldpXdot3RemSystemsGroup object class.

The state diagrams describe the behavior above.

33.6.4.1 PSE state change procedure across a link

A PSE is considered to be in sync with the PD when the value of PSEAllocatedPowerValue matches the value of MirroredPSEAllocatedPowerValueEcho. When the PSE is not in sync with the PD, the PSE is only allowed to decrease its power allocation.

During normal operation, the PSE is in the RUNNING state. If the PSE wants to initiate a change in the PD allocation, the local_system_change is asserted and the PSE enters the PSE POWER REVIEW state, where a new power allocation value, PSE_NEW_VALUE, is computed. If the PSE is in sync with the PD or if PSE_NEW_VALUE is smaller than PSEAllocatedPowerValue, it enters the MIRROR UPDATE state where PSE_NEW_VALUE is assigned to PSEAllocatedPowerValue. It also updates PDRequestedPowerValueEcho and returns to the RUNNING state.

If the PSE sees a change to the previously stored MirroredPDRequestedPowerValue, it recognizes a request by the PD to change its power allocation. It entertains this request only when it is in sync with the PD. The PSE examines the request by entering the PD POWER REQUEST state. A new power allocation value, PSE_NEW_VALUE, is computed. It then enters the MIRROR UPDATE state where PSE_NEW_VALUE is assigned to PSEAllocatedPowerValue. It also updates PDRequestedPowerValueEcho and returns to the RUNNING state.

33.6.4.2 PD state change procedure across a link

A PD is considered to be in sync with the PSE when the value of PDRequestedPowerValue matches the value of MirroredPDRequestedPowerValueEcho. The PD is not allowed to change its maximum power draw or the requested power value when it is not in sync with the PSE.

During normal operation, the PD is in the RUNNING state. If the PD sees a change to the previously stored MirroredPSEAllocatedPowerValue or local_system_change is asserted by the PD so as to change its power allocation, it enters the PD POWER REVIEW state. In this state, the PD evaluates the change and generates an updated power value called PD_NEW_VALUE. If PD_NEW_VALUE is less than PDMaxPowerValue, it updates PDMaxPowerValue in the PD POWER REALLOCATION 1 state. The PD finally enters the MIRROR UPDATE state where PD_NEW_VALUE is assigned to PDRequestedPowerValue. It also updates PSEAllocatedPowerValueEcho and returns to the RUNNING state.

In the above flow, if PD_NEW_VALUE is greater than PDMaxPowerValue, the PD waits until it is in sync with the PSE and the PSE grants the higher power value. When this condition arises, the PD enters the PD

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POWER REALLOCATION 2 state. In this state, the PD assigns PDMaxPowerValue to PDRequestedPowerValue and returns to the RUNNING state.

33.7 Environmental

33.7.1 General safety

All equipment subject to this clause shall conform to IEC 60950-1. In particular, the PSE shall be classified as a Limited Power Source in accordance with IEC 60950-1.

Equipment shall comply with all applicable local and national codes related to safety.

33.7.2 Network safety

This subclause sets forth a number of recommendations and guidelines related to safety concerns. The list is neither complete nor does it address all possible safety issues. The designer is urged to consult the relevant local, national, and international safety regulations to verify compliance with the appropriate requirements. LAN cabling systems described in this clause are subject to at least four direct electrical safety hazards during their installation and use. These hazards are as follows:

a) Direct contact between LAN components and power, lighting, or communications circuits.
b) Static charge buildup on LAN cabling and components.
c) High-energy transients coupled onto the LAN cabling system.
d) Voltage potential differences between safety grounds to which various LAN components are connected.

Such electrical safety hazards should be avoided or appropriately protected against for proper network installation and performance. In addition to provisions for proper handling of these conditions in an operational system, special measures should be taken to verify that the intended safety features are not negated during installation of a new network or during modification of an existing network.

33.7.3 Installation and maintenance guidelines

It is a mandatory requirement that sound installation practice, as defined by applicable local codes and regulations, be followed in every instance in which such practice is applicable.

It is a mandatory requirement that, during installation of the cabling plant, care be taken to verify that non-insulated network cabling conductors do not make electrical contact with unintended conductors or ground.

33.7.4 Patch panel considerations

It is possible that the current carrying capability of a cabling cross-connect may be exceeded by a PSE. The designer should consult the manufacturers' specifications to verify compliance with the appropriate requirements.

33.7.5 Telephony voltages

The use of building wiring brings with it the possibility of wiring errors that may connect telephony voltages to a PSE or PD. Other than voice signals, the primary voltages that may be encountered are the "battery" and ringing voltages. Although there is no universal standard, the following maximums generally apply:

Battery voltage to a telephone line is generally 56 Vdc, applied to the line through a balanced 400 Ω source impedance. Ringing voltage is a composite signal consisting of an AC component and a DC component. The

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AC component is up to 175 Vp at 20 Hz to 60 Hz with a 100 Ω source resistance. The DC component is 56 Vdc with 300 Ω to 600 Ω source resistance. Large reactive transients can occur at the start and end of each ring interval.

Application of any of the above voltages to the PI of a PSE or a PD shall not result in any safety hazard.

33.7.6 Electromagnetic emissions

The PD and PSE powered cabling link shall comply with applicable local and national codes for the limitation of electromagnetic interference.

33.7.7 Temperature and humidity

The PD and PSE powered cabling link segment is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling. Specific requirements and values for these parameters are beyond the scope of this standard.

33.7.8 Labeling

It is recommended that the PSE or PD (and supporting documentation) be labeled in a manner visible to the user with at least the following parameters:

a) Power classification and power level in terms of maximum current drain over the operating voltage range, 36 V to 57 V, applies for PD only
b) Port type (e.g., 100BASE-TX, TIA Category, or ISO Class)
c) Any applicable safety warnings
d) “PSE” or “PD” as appropriate
e) Type (e.g., “Type 1” or “Type 2”)

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33.8 Protocol implementation conformance statement (PICS) proforma for Clause 33, DTE Power via MDI[21]

33.8.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 33, DTE Power via MDI, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

33.8.2 Identification

33.8.2.1 Implementation identification

Supplier[1]	
Contact point for inquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1,3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

33.8.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 33, DTE Power via MDI
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	
Date of Statement	

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[21] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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33.8.2.3 PD Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*PDT2	Type 2 PD implementation	33.3.2	PD is Type 2	O	Yes [ ] No [ ]
*PDCL	PD Classification	33.3.5	PD supports classification	PDT2:M	Yes [ ] No [ ]
*PDCL2	Implementation supports 2-Event class signature	33.3.5	PD supports 2-Event class signature	PDT2:M	Yes [ ] No [ ]
*DLLC	Implementation supports Data Link Layer classification	33.6	PD supports Data Link Layer classification	PDT2:M	Yes [ ] No [ ]

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33.8.2.4 PSE Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*PSET1	Type 1 PSE implementation	33.1.4	Optional	O	Yes [ ] No [ ]
*PSET2	Type 2 PSE implementation	33.1.4	Optional	O	Yes [ ] No [ ]
*MID	Midspan PSE	33.2.1	PSE implemented as a midspan device	O/1	Yes [ ] No [ ]
*MIDA	Alternative A Midspan PSE	33.2.2	Midspan PSE implements Alternative A	MID:O:2	Yes [ ] No [ ]
*MAN	PSE supports management registers accessed through MII Management Interface	33.5	Optional	O	Yes [ ] No [ ]
*CL	Implementation supports Physical Layer classification	33.2.6	Optional	O/1	Yes [ ] No [ ]
*DLLC	Implementation supports Data Link Layer classification	33.6	PSE supports Data Link Layer classification	O	Yes [ ] No [ ]
*1EPLC	Implementation supports 1-Event Physical Layer classification	33.2.6.1	Optional	O	Yes [ ] No [ ]
*2EPLC	Implementation supports 2-Event Physical Layer classification	33.2.6.2	Optional	O	Yes [ ] No [ ]
*PA	Power Allocation	33.2.8	PSE implements power supply allocation	O	Yes [ ] No [ ]
*PCA	Pair control ability—PSE supports the option to control which PSE Pinout is used	33.5.1.1.5	Optional	O	Yes [ ] No [ ]
*AC	Monitor AC MPS	33.2.9.1.1	PSE monitors for AC MPS	O.3	Yes [ ] No [ ]
*DC	Monitor DC MPS	33.2.9.1.2	PSE monitors for DC MPS	O.3	Yes [ ] No [ ]

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33.8.3 PICS proforma tables for DTE Power via MDI

33.8.3.1 Common device features

Item	Feature	Subclause	Value/Comment	Status	Support
COM1	Compatibility considerations.	33.1.2	PDs and PSEs compatible at their PIs	M	Yes [ ]
COM2	Type 2 operation cabling	33.1.4.1	DC loop resistance 25 Ω or less. Requirement satisfied by category 5e components (cables, cords, and connectors)	M	Yes [ ]
COM3	Resistance unbalance	33.1.4.2	3 % or less	M	Yes [ ]

33.8.3.2 Power sourcing equipment

Item	Feature	Subclause	Value/Comment	Status	Support
PSE1	PSE location	33.2.1	Requirements apply equally to Endpoint and Midspan PSE unless otherwise stated	M	Yes [ ]
PSE2	Alternative A and Alternative B	33.2.3	Implement either Alternative A or Alternative B or both but not operate on same link segment simultaneously	M	Yes [ ] N/A [ ]
PSE3	PSE behavior	33.2.4	In accordance with state diagrams shown in Figure 33–9, Figure 33–9 continued, and Figure 33–10	M	Yes [ ]
PSE4	Detection, classification, and turn on timing	33.2.4.1	In accordance with Table 33–4, Table 33–10, and Table 33–11	M	Yes [ ]
PSE5	Backoff voltage	33.2.4.1	Not greater than V_{Off}	M	Yes [ ]
PSE6	PSE variable definition permutations	33.2.4.4	Meet at least one allowable definition described in Table 33–3	M	Yes [ ]
PSE7	Type 2 PSE mutual identification	33.2.4.6	When powering a Type 2 PD, assigns a value of '2' to parameter_type if mutual identification is complete	PSET2: M	Yes [ ] N/A [ ]
PSE8	Type 2 PSE powering a Type 1 PD	33.2.4.6	Meets the PI electrical requirements of a Type 1 PSE, but may choose to meet the electrical requirements of a Type 2 PSE for I_{Con}, I_{LIM}, T_{LIM}, and P_{Type}	PSET2: M	Yes [ ] N/A [ ]
PSE9	Applying power	33.2.5	Not until a PD requesting power has been successfully detected	M	Yes [ ]
PSE10	Power pairs	33.2.5	Power supplied on the same pairs as those used for detection	M	Yes [ ]
PSE11	Detecting PDs	33.2.5.1	Performed via the PSE PI	M	Yes [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
PSE12	PSE presents non-valid signature	33.2.5.1	As defined in Table 33–15	M	Yes [ ]
PSE13	Open circuit voltage and short circuit current	33.2.5.1	Meet specifications for V_{oc} and I_{sc} in Table 33–4	M	Yes [ ]
PSE14	Backdriven current	33.2.5.1	Not be damaged by up to 5 mA over the range of V_{Port_PSE}	M	Yes [ ]
PSE15	Output capacitance	33.2.5.1	C_{out} in Table 33–11	M	Yes [ ]
PSE16	Detection voltage with a valid PD signature connected	33.2.5.2	Meets V_{valid} in Table 33–4	M	Yes [ ]
PSE17	Detection voltage measurements	33.2.5.2	At least two that create at least ΔV_{test} difference	M	Yes [ ]
PSE18	Control slew rate when switching detection voltages	33.2.5.2	Less than V_{slew} in Table 33–4	M	Yes [ ]
PSE19	Accept as a valid signature	33.2.5.3	R_{good} and C_{good}, with up to V_{os} max and I_{os} max as defined in Table 33–5	M	Yes [ ]
PSE20	Reject as an invalid signature	33.2.5.4	Resistance less than R_{bad} min, resistance greater than R_{bad} max, or capacitance greater than C_{bad} min	M	Yes [ ]
PSE21	Classification permutations	33.2.6	Meet one allowable permutation in Table 33–8	M	Yes [ ]
PSE22	Type 1 PSE does not implement Physical Layer classification	33.2.6	Assign all PDs to Class 0	PSET1: M	Yes [ ] N/A [ ]
PSE23	Type 1 PSE failure to complete classification	33.2.6	Return to IDLE state or assign PD to Class 0	PSET1: M	Yes [ ] N/A [ ]
PSE24	Type 2 PSE failure to complete classification	33.2.6	Return to IDLE state	PSET2: M	Yes [ ] N/A [ ]
PSE25	Provide V_{Class} for 1-Event Physical Layer classification	33.2.6.1	Limited to I_{Class_LIM} as defined by Table 33–10	1EPLC: M	Yes [ ] N/A [ ]
PSE26	Classification polarity for 1-Event Physical Layer classification	33.2.6.1	Same as V_{Port_PSE}	1EPLC: M	Yes [ ] N/A [ ]
PSE27	Classification timing for 1-Event Physical Layer classification	33.2.6.1	In accordance with T_{pdc} in Table 33–10	1EPLC: M	Yes [ ] N/A [ ]
PSE28	Measurement result of 1-Event Physical Layer classification I_{Class}	33.2.6.1	Classify PD according to observed current based on Table 33–9	1EPLC: M	Yes [ ] N/A [ ]
PSE29	Measurement timing of 1-Event Physical Layer classification I_{Class}	33.2.6.1	Measurement taken after the minimum relevant class event timing in Table 33–10	1EPLC: M	Yes [ ] N/A [ ]
PSE30	Class 4 result for 1-Event Physical Layer classification with a Type 1 PSE	33.2.6.1	Assign the PD to Class 0	PSET1: M	Yes [ ] N/A [ ]
PSE31	Type 1 PSE 1-Event Physical Layer classification if I_{Class} is in the range of I_{Class_LIM}	33.2.6.1	Return to IDLE state or assign PD to Class 0	PSET1: M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
PSE32	Type 2 PSE 1-Event Physical Layer classification if I_{Class} is in the range of I_{Class_LIM}	33.2.6.1	Return to IDLE state	PSET2: M	Yes [ ] N/A [ ]
PSE33	In the CLASS_EV1 and CLASS_EV2 states, provide V_{Class}	33.2.6.2	As defined in Table 33–10	2EPLC: M	Yes [ ] N/A [ ]
PSE34	Classification timing in CLASS_EV1 state	33.2.6.2	In accordance with T_{CLE1} in Table 33–10	2EPLC: M	Yes [ ] N/A [ ]
PSE35	In the CLASS_EV1 and CLASS_EV2 states, measurement result I_{Class}	33.2.6.2	Classify PD according to Table 33–9	2EPLC: M	Yes [ ] N/A [ ]
PSE36	In the MARK_EV1 and MARK_EV2 states, provide V_{Mark}	33.2.6.2	In accordance with Table 33–10	2EPLC: M	Yes [ ] N/A [ ]
PSE37	Classification timing in MARK_EV1	33.2.6.2	In accordance with T_{ME1} in Table 33–10	2EPLC: M	Yes [ ] N/A [ ]
PSE38	Classification timing in CLASS_EV2 state	33.2.6.2	In accordance with T_{CLE2} in Table 33–10	2EPLC: M	Yes [ ] N/A [ ]
PSE39	Classification timing in MARK_EV2 state	33.2.6.2	In accordance with T_{ME2} in Table 33–10	2EPLC: M	Yes [ ] N/A [ ]
PSE40	Type 2 PSE 2-Event Physical Layer classification if I_{Class} is greater than or equal to I_{Class_LIM} min	33.2.6.2	Returns to IDLE state	2EPLC: M	Yes [ ] N/A [ ]
PSE41	Current limitation during class events	33.2.6.2	Meet I_{Class_LIM}	2EPLC: M	Yes [ ] N/A [ ]
PSE42	Current limitation during mark events	33.2.6.2	Meet I_{Mark_LIM}	2EPLC: M	Yes [ ] N/A [ ]
PSE43	Measurement timing of 2-Event Physical Layer classification I_{Class}	33.2.6.2	Taken after the minimum relevant class event timing in Table 33–10	2EPLC: M	Yes [ ] N/A [ ]
PSE44	Class event and mark event voltages polarity	33.2.6.2	Same as V_{Port_PSE}	2EPLC: M	Yes [ ] N/A [ ]
PSE45	Voltage level at PI when transition to POWER_ON state	33.2.6.2	Completes 2-Event classification and transitions to POWER_ON with PI voltage greater than or equal to V_{Mark} min	2EPLC: M	Yes [ ] N/A [ ]
PSE46	Return to IDLE state	33.2.6.2	Maintains PI voltage at V_{Reset} for at least T_{Reset} min before starting new detection cycle	2EPLC: M	Yes [ ] N/A [ ]
PSE47	Power supply output	33.2.7	When the PSE provides power to the PI, conforms with Table 33–11	M	Yes [ ]
PSE48	Load regulation	33.2.7.1	Met with (I_{Hold} max × V_{Port_PSE} min) to P_{Type} min load step at a rate of change of at least 15 mA/µs max	M	Yes [ ]
PSE49	Voltage transients	33.2.7.1	Limited to 3.5 V/µs max for load changes up to 35 mA/µs	M	Yes [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
PSE50	Voltage transients (30 µs to 250 µs)	33.2.7.2	No less than K_{Tran_lo} below V_{Port_PSE} min and meet requirements of 33.2.7.7.	PSET2: M	Yes [ ]
PSE51	Voltage transients (greater than 250 µs)	33.2.7.2	Meet V_{Port_PSE} specification	M	Yes [ ]
PSE52	Power feeding ripple and noise	33.2.7.3	Met for common-mode and/or pair-to-pair noise values for power outputs from (I_{Hold} max × V_{Port_PSE} min) to P_{Type} min at static operating V_{Port_PSE}	M	Yes [ ]
PSE53	AC current waveform parameters	33.2.7.4	I_{Peak} minimum equals Equation (33–4) for T_{CUT} minimum and 5% duty cycle minimum.	M	Yes [ ]
PSE54	Inrush current limit	33.2.7.5	PSE limits the maximum current sourced at the PI	M	Yes [ ]
PSE55	Inrush current template	33.2.7.5	Current sourced does not exceed the PSE inrush template in Figure 33–13	M	Yes [ ]
PSE56	Short circuit condition	33.2.7.7	Remove power from PI before I_{PSEUT} is exceeded. Equation (33–6) and Figure 33–14.	M	Yes [ ]
PSE57	Short circuit current and time	33.2.7.7	In accordance with I_{LIM} and T_{LIM} in Table 33–11	M	Yes [ ]
PSE58	Short circuit power removal	33.2.7.7	Begins within T_{LIM} in Table 33–11	M	Yes [ ]
PSE59	Turn off time	33.2.7.8	Applies to the discharge time from V_{Port_PSE} to V_{Off} with a test resistor of 320 kΩ attached to the PI.	M	Yes [ ]
PSE60	Turn off voltage	33.2.7.9	Applies to the PI voltage in the IDLE state	M	Yes [ ]
PSE61	Current unbalance	33.2.7.11	Applies to the two conductors of a power pair over the current load range in accordance with I_{unb} in Table 33–11.	M	Yes [ ]
PSE62	Type 2 PSEs in the presence of (I_{unb} / 2)	33.2.7.11	Meet the requirements of 25.4.5	PSET2: M	Yes [ ]
PSE63	Power allocation	33.2.8	Not be based solely on historical data of power consumption of the attached PD	PA:M	Yes [ ] N/A [ ]
PSE64	PSE monitoring AC MPS component	33.2.9.1.1	Meets “AC Signal parameters” and “PSE PI voltage during AC disconnect detection” parameters in Table 33–12	AC:M	Yes [ ] N/A [ ]
PSE65	PSE AC MPS component present	33.2.9.1.1	When AC impedance at the PI is equal to or lower than $\|Z_{ac1}\|$ in Table 33–12	AC:M	Yes [ ] N/A [ ]
PSE66	PSE AC MPS component absent	33.2.9.1.1	When AC impedance at the PI equal to or greater than $\|Z_{ac2}\|$ in Table 33–12	AC:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
PSE67	Power removal	33.2.9.1.1	When AC MPS has been absent for a time duration greater than T_{MPDO}	AC:M	Yes [ ] N/A [ ]
PSE68	PSE DC MPS component present	33.2.9.1.2	I_{Port} is greater than or equal to I_{Hold} max for at least T_{MPS} min as specified in Table 33–11	DC:M	Yes [ ] N/A [ ]
PSE69	PSE DC MPS component absent	33.2.9.1.2	I_{Port} is less than or equal to I_{Hold} min as specified in Table 33–11	DC:M	Yes [ ] N/A [ ]
PSE70	Power removal	33.2.9.1.2	When DC MPS has been absent for a time duration greater than T_{MPDO}	DC:M	Yes [ ] N/A [ ]
PSE71	Not remove power	33.2.9.1.2	When the DC current is greater than or equal to I_{Hold} max continuously for at least T_{MPS} every $T_{MPS} + T_{MPDO}$	DC:M	Yes [ ] N/A [ ]

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33.8.3.3 Powered devices

Item	Feature	Subclause	Value/Comment	Status	Support
PD1	Accept power	33.3.1	On either set of PI conductors	M	Yes [ ]
PD2	Polarity insensitive	33.3.1	Both Mode A and Mode B per Table 33–13	M	Yes [ ]
PD3	Source power	33.3.1	The PD does not source power on its PI	M	Yes [ ]
PD4	Voltage tolerance	33.3.1	Withstand 0 V to 57 V at the PI indefinitely without permanent damage	M	Yes [ ]
PD5	Underpowered Type 2 PD	33.3.2	If PD does not successfully observe 2-Event Physical Layer classification or Data Link Layer classification, conforms to Type 1 PD power restrictions and provides the user with an active indication if underpowered	PDT2:M	Yes [ ] N/A [ ]
PD6	Current unbalance	33.3.2	Type 2 PDs meet the requirements of 25.4.5 in presence of (I_{unb}/2)	PDT2:M	Yes [ ] N/A [ ]
PD7	PD behavior	33.3.3	According to state diagram shown in Figure 33–16	M	Yes [ ]
PD8	Valid and non-valid detection signatures	33.3.4	Presented between positive V_{PD} and negative V_{PD} on each set of pairs defined in 33.3.1	M	Yes [ ]
PD9	Non-valid detection signature	33.3.4	When powered, present an invalid signature on the set of pairs not drawing power	M	Yes [ ]
PD10	Valid detection signature	33.3.4	Characteristics defined in Table 33–14	M	Yes [ ]
PD11	Non-valid detection signature	33.3.4	Exhibit one or both of the characteristics described in Table 33–15	M	Yes [ ]
PD12	PD classifications	33.3.5	Meets at least one permutation listed in Table 33–8	PDCL:M	Yes [ ]
PD13	PD implementing 2-Event class signature	33.3.5.1	Returns Class 4	PDCL2:M	Yes [ ] N/A [ ]
PD14	Type 2 PD classification behavior	33.3.5.1	Conforms to electrical specifications in Table 33–17	PDT2:M	Yes [ ] N/A [ ]
PD15	Classification signature	33.3.5.1	As defined in Table 33–16	PDCL:M	Yes [ ] N/A [ ]
PD16	Classification signature	33.3.5.1	One classification signature during classification	PDCL:M	Yes [ ] N/A [ ]
PD17	2-Event class signature	33.3.5.2	Class 4 in accordance with the maximum power draw as specified in Table 33–18	PDCL2:M	Yes [ ] N/A [ ]
PD18	2-Event class signature behavior	33.3.5.2	As defined in Table 33–17	PDCL2:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
PD19	Type 2 PD electrical requirements	33.3.5.2	As defined by Table 33–18 of the Type defined in its pse_power_type state variable	PDT2:M	Yes [ ] N/A [ ]
PD20	Mark event current and 2-Event class signature	33.3.5.2.1	Draw I_{Mark} and present a non-valid detection signature as defined in Table 33–15	PDCL2:M	Yes [ ] N/A [ ]
PD21	Mark event current limits	33.3.5.2.1	Not exceed I_{Mark} when voltage at the PI enters V_{Mark} as defined in Table 33–17	PDCL2:M	Yes [ ] N/A [ ]
PD22	PD current draw	33.3.5.2.1	I_{Mark} until the PD transitions from DO_MARK_EVENT state to the IDLE state	PDCL2:M	Yes [ ] N/A [ ]
PD23	PSE identification	33.3.6	Identify as Type 1 or Type 2 (see Figure 33–16)	PDT2:M	Yes [ ]
PD24	PD power supply	33.3.7	Operate within the characteristics in Table 33–18	M	Yes [ ]
PD25	PD turn on voltage	33.3.7.1	PD turns on at a voltage less than or equal to V_{On}	M	Yes [ ]
PD26	PD stay on voltage	33.3.7.1	Stay on for all voltages in the range of V_{Port_PD}	M	Yes [ ]
PD27	PD turn off voltage	33.3.7.1	Turn off at a voltage less than V_{Port_PD} min and greater than V_{Off}	M	Yes [ ]
PD28	Startup oscillations	33.3.7.1	Shall turn on or off without startup oscillations and within the first trial at any load value	M	Yes [ ]
PD29	P_{Port_PD} definition	33.3.7.2.1	When PD is fed by V_{Port_PD} min to V_{Port_PD} max with R_{Ch} (as defined in Table 33–1) in series	M	Yes [ ]
PD30	Type 2 PD input inrush current	33.3.7.3	With pse_power_type state set to 2 prior to power-on, operate as a Type 1 PD for at least T_{delay} min	PDT2:M	Yes [ ] N/A [ ]
PD31	Input inrush current	33.3.7.3	Limited by the PD if C_{port} is greater than or equal to 180 µF so that I_{Inrush_PD} max is satisfied.	M	Yes [ ]
PD32	Peak power	33.3.7.4	Not to exceed P_{Class_PD} max for more than T_{CUT} min and 5% duty cycle	M	Yes [ ]
PD33	Peak operating power	33.3.7.4	Not to exceed P_{Peak} max	M	Yes [ ]
PD34	RMS, DC, and ripple current	33.3.7.4	Bounded by Equation (33–10)	M	Yes [ ]
PD35	Maximum I_{Port} for all operating V_{Port_PD}	33.3.7.4	Defined by Equation (33–11)	M	Yes [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
PD36	Peak transient current	33.3.7.5	Not to exceed 4.70 mA/µs in either polarity	M	Yes [ ]
PD37	Specifications for I_{PDUT}	33.3.7.5	Operate below upperbound template defined in Figure 33–18	M	Yes [ ]
PD38	Behavior during transients at the PSE PI	33.3.7.6	As specified in 33.3.7.6	M	Yes [ ]
PD39	Ripple and noise	33.3.7.7	As specified in Table 33–18 for the common-mode and/or differential pair-to-pair noise at the PD PI	M	Yes [ ]
PD40	Ripple and noise specification	33.3.7.7	For all operating voltages in the range defined by V_{Port_PD} in Table 33–18	M	Yes [ ]
PD41	Ripple and noise presence	33.3.7.7	Operates in the presence of ripple and noise generated by the PSE that appears at the PD PI	M	Yes [ ]
PD42	Classification stability	33.3.7.8	Class signature valid within T_{class} and remains valid for the duration of the classification period	M	Yes [ ]
PD43	Backfeed voltage	33.3.7.9	Mode A and Mode B per 33.3.7.9	M	Yes [ ]
PD44	Maintain power signature	33.3.8	PD provides a valid MPS at the PI as defined in 33.3.8	M	Yes [ ]
PD45	No longer require power	33.3.8	Remove both components of the Maintain Power Signature	M	Yes [ ]

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33.8.3.4 Electrical specifications applicable to the PSE and PD

Item	Feature	Subclause	Value/Comment	Status	Support
EL1	Conductor isolation	33.4.1	Provided between accessible external conductors including frame ground and all MDI leads	M	Yes [ ]
EL2	Strength tests for electrical isolation	33.4.1	Withstand at least one of the electrical strength tests specified in 33.4.1	M	Yes [ ]
EL3	Insulation breakdown	33.4.1	No breakdown of insulation during electrical isolation tests	M	Yes [ ]
EL4	Isolation resistance	33.4.1	At least 2 MΩ, measured at 500 Vdc after electrical isolation tests	M	Yes [ ]
EL5	Isolation and grounding requirements	33.4.1	Conductive link segments that have different requirements have those requirements provided by the port-to-port isolation of the NID	M	Yes [ ]
EL6	Environment A requirements for multiple instances of PSE and/or PD	33.4.1.1.1	Meet or exceed the isolation requirement of the MAU/PHY with which they are associated	!MID:M	Yes [ ] N/A [ ]
EL7	Environment A requirement	33.4.1.1.1	Switch more negative conductor	M	Yes [ ] N/A [ ]
EL8	Environment B requirements for multiple instances of PSE and/or PD	33.4.1.1.2	Meet or exceed the isolation requirement of the MAU/PHY with which they are associated	!MID:M	Yes [ ] N/A [ ]
EL9	Fault tolerance for PIs encompassed within the MDI	33.4.2	Meet requirements of the appropriate specifying clause	!MID:M	Yes [ ] N/A [ ]
EL10	Fault tolerance for PSE PIs not encompassed within an MDI	33.4.2	Meet the requirements of 33.4.2	M	Yes [ ] N/A [ ]
EL11	Common-mode fault tolerance	33.4.2	Each wire pair withstands without damage a 1000 V common-mode impulse applied at E_{cm} of either polarity	M	Yes [ ]
EL12	The shape of the impulse for item common-mode fault tolerance	33.4.2	0.3/50 µs (300 ns virtual front time, 50 µs virtual time of half value)	M	Yes [ ]
EL13	Common-mode to differential-mode impedance balance for transmit and receive pairs	33.4.3	Exceeds Equation (33–15) for 10 Mb/s PHYs and Equation (33–16) for 100Mb/s or greater PHYs	M	Yes [ ]
EL14	Common-mode AC output voltage	33.4.4	Magnitude while transmitting data and with power applied does not exceed 50 mV peak when operating at 10 Mb/s and 50 mV peak-to-peak when operating at 100 Mb/s or greater	M	Yes [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
EL15	Frequency range for common-mode AC output voltage measurement	33.4.4	From 1 MHz to 100 MHz	M	Yes [ ]
EL16	Common-mode AC output voltage measurement	33.4.4	While the PHY is transmitting data, the PSE or PD is operating, and with the enumerated PSE load or PD source	M	Yes [ ]
EL17	Noise from an operating PSE or PD to the differential transmit and receive pairs	33.4.6	Does not exceed 10 mV peak-to-peak measured from 1 MHz to 100 MHz under the conditions specified in 33.4.4	M	Yes [ ]
EL18	Return loss requirements	33.4.7	Specified in 14.3.1.3.4 for a 10 Mb/s PHY, in ANSI X3.263:1995 for a 100 Mb/s PHY, and 40.8.3.1 for a 1000 Mb/s PHY	M	Yes [ ]
EL19	100BASE-TX Type 2 Endpoint PSE and PD channel unbalance	33.4.8	Meet requirements of Clause 25 in the presence of (I_{unb}/2)	M	Yes [ ] N/A [ ]

33.8.3.5 Electrical specifications applicable to the PSE

Item	Feature	Subclause	Value/Comment	Status	Support
PSEEL1	Short circuit fault tolerance	33.4.2	Any wire pair withstands any short circuit to any other pair for an indefinite amount of time	M	Yes [ ]
PSEEL2	Magnitude of short circuit current	33.4.2	Does not exceed I_{LIM} max	M	Yes [ ]
PSEEL3	Limitation of electromagnetic interference.	33.4.5	PSE complies with applicable local and national codes	M	Yes [ ]
PSEEL4	Alternative A Type 2 Midspan PSEs that support 100BASE-TX	33.4.8	Enforce channel unbalance currents less than or equal to Type 1 Iunb (see Table 33–11) or meet 33.4.9.2.	MIDA: M	Yes [ ] N/A [ ]
PSEEL5	Insertion of Midspan at FD	33.4.9	Comply with the guidelines specified in 33.4.9 items a) and b)	MID:M	Yes [ ] N/A [ ]
PSEEL6	Resulting “channel”	33.4.9	Installation of a Midspan PSE does not increase the length to more than 100 m as defined in ISO/IEC 11801.	MID:M	Yes [ ] N/A [ ]
PSEEL7	Configurations with Midspan PSE	33.4.9	Not alter transmission requirements of the “permanent link”	MID:M	Yes [ ] N/A [ ]
PSEEL8	DC continuity in power injecting pairs	33.4.9	Does not provide DC continuity between the two sides of the segment for the pairs that inject power	MID:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
PSEEL9	Midspan PSE inserted as a "connector" or "telecom outlet"	33.4.9.1	Meet transmission parameters NEXT, insertion loss, and return loss	MID:M	Yes [ ] N/A [ ]
PSEEL10	Midspan PSE NEXT	33.4.9.1.1	Meet values detemined by Equation (33–18) from 1 MHz to 100 MHz, but not greater than 65 dB	MID:M	Yes [ ] N/A [ ]
PSEEL11	Midspan PSE Insertion Loss	33.4.9.1.2	Meet values determined by Equation (33–19) from 1 MHz to 100 MHz, but not less than 0.1 dB	MID:M	Yes [ ] N/A [ ]
PSEEL12	Midspan PSE Return Loss	33.4.9.1.3	Meet or exceed values in Table 33–20 for transmit and receive pairs from 1 MHz to 100 MHz	MID:M	Yes [ ] N/A [ ]
PSEEL13	Work area or equipment cable Midspan PSE	33.4.9.1.4	Meet the requirements of this clause and the specifications for a Category 5 (jumper) cord as specified in ISO/IEC 11801-2002 or ANSI/TIA-568-C.2 for insertion loss, NEXT, and return loss for transmit and receive pairs	MID:M	Yes [ ] N/A [ ]
PSEEL14	Alternative A Midspan PSE signal path requirements	33.4.9.2	Exceed transfer function gain expressed in Equation (33–20) from 0.10 MHz to 1 MHz at the pins of the PI used as 100BASE-TX transmit pins	MIDA: M	Yes [ ] N/A [ ]
PSEEL15	Alternative A Midspan PSE signal path requirements bias current	33.4.9.2	Met with DC bias current between 0 mA and (I_{unb}/2)	MIDA: M	Yes [ ] N/A [ ]

33.8.3.6 Electrical specifications applicable to the PD

Item	Feature	Subclause	Value/Comment	Status	Support
PDEL1	PD common-mode test requirement	33.4.4	The PIs that require power terminated as illustrated in Figure 33–22	M	Yes [ ]

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33.8.3.7 Management function requirements

Item	Feature	Subclause	Value/Comment	Status	Support
MF1	Management capability	33.5	Access to register definitions defined in 33.5.1 via interface described in 22.2.4 or 45.2 or equivalent	MAN:M	Yes [ ] N/A [ ]
MF2	PSE registers	33.5.1	Register address 11 for control functions and register address 12 for status functions	MAN:M	Yes [ ] N/A [ ]
MF3	Register bits latching high (LH)	33.5.1	Remain high until read via the management interface	MAN:M	Yes [ ] N/A [ ]
MF4	Latching register bit after read	33.5.1	Assumes a value based on the current state of the condition it monitors	MAN:M	Yes [ ] N/A [ ]
MF5	PSE Control register reserved bits (11.15:6)	33.5.1.1.1	Not affected by writes and return a value of zero when read	MAN:M	Yes [ ] N/A [ ]
MF6	Data Link Layer classification not supported	33.5.1.1.2	Ignore writes to bit 11.5 and return a value of zero when read	MAN* !DLLC: M	Yes [ ] N/A [ ]
MF7	Data Link Layer classification supported	33.5.1.1.2	Ignore writes to bit 11.5 and return a value of one when function cannot be disabled	MAN* DLLC: M	Yes [ ] N/A [ ]
MF8	Enable/disable Data Link Layer classification capability	33.5.1.1.2	Capability enabled by setting bit 11.5 to one and disabled by setting bit 11.5 to zero	MAN* DLLC: M	Yes [ ] N/A [ ]
MF9	Physical Layer classification not supported	33.5.1.1.3	Ignore writes to bit 11.4 and return a value of zero when read	MAN* !CL:M	Yes [ ] N/A [ ]
MF10	Physical Layer classification supported	33.5.1.1.3	Ignore writes to bit 11.4 and return a value of one when function cannot be disabled	MAN* CL:M	Yes [ ] N/A [ ]
MF11	Enable/disable Physical Layer classification	33.5.1.1.3	Function enabled by setting bit 11.4 to one and disabled by setting bit 11.5 to zero	MAN* CL:M	Yes [ ] N/A [ ]
MF12	Pair Control Ability not supported	33.5.1.1.4	Ignore writes to bits 11.3:2	MAN* !PCA:M	Yes [ ] N/A [ ]
MF13	Writes to 11.3:2 when Pair Control Ability not supported	33.5.1.1.4	Return the value that reports the supported PSE Pinout Alternative	MAN* !PCA:M	Yes [ ] N/A [ ]
MF14	Bits 11.3:2 set to '01'	33.5.1.1.4	Forces the PSE to use Alternative A	MAN* PCA:M	Yes [ ] N/A [ ]
MF15	Bits 11.3:2 set to '10'	33.5.1.1.4	Forces the PSE to use Alternative B	MAN* PCA:M	Yes [ ] N/A [ ]
MF16	Pair control ability bit (12.0)	33.5.1.1.4	A value of one sets the mr_pse_alternative variable	MAN* PCA:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
MF17	PSE function disabled	33.5.1.1.5	Setting PSE Enable bits 11.1:0 to a '00', also the MDI shall function as it would if it had no PSE function	MAN:M	Yes [ ] N/A [ ]
MF18	PSE function enabled	33.5.1.1.5	Setting PSE Enable bits 11.1:0 to a '01'	MAN:M	Yes [ ] N/A [ ]
MF19	PSE enable bits (11.1:0)	33.5.1.1.5	Writing to these register bits shall set mr_pse_enable to the corresponding value: '00' = disable, '01' = enable and '10' = force power	MAN:M	Yes [ ] N/A [ ]
MF20	PSE Type electrical parameters bit (12.15)	33.5.1.2.1	Set to zero when the PSE state diagram sets the state variable set_parameter_type to 1. Set to one when set_parameter_type is set to 2	MAN:M	Yes [ ] N/A [ ]
MF21	Data Link Layer classification enabled bit (12.14)	33.5.1.2.2	Set to one when the PSE state diagram sets true pse_dll_enabled. Set to zero when the PSE state diagram sets false pss_dll_enabled	MAN:M	Yes [ ] N/A [ ]
MF22	Power denied bit (12.12)	33.5.1.2.4	A value of one indicates power has been denied or removed due to an error condition	MAN:M	Yes [ ] N/A [ ]
MF23	Power denied bit implementation	33.5.1.2.4	Implemented with a latching high behavior as defined in 33.5.1	MAN:M	Yes [ ] N/A [ ]
MF24	Valid signature bit (12.11)	33.5.1.2.5	One indicates a valid signature has been detected. Set to one when mr_valid_signature transitions from FALSE to TRUE.	MAN:M	Yes [ ] N/A [ ]
MF25	Valid signature bit implementation	33.5.1.2.5	Implemented with a latching high behavior as defined in 33.5.1	MAN:M	Yes [ ] N/A [ ]
MF26	Invalid signature bit (12.10)	33.5.1.2.6	One indicates an invalid signature has been detected. Set to one entering SIGNATURE_INVALID state	MAN:M	Yes [ ] N/A [ ]
MF27	Invalid signature bit implementation	33.5.1.2.6	Implemented with a latching high behavior as defined in 33.5.1	MAN:M	Yes [ ] N/A [ ]
MF28	Short circuit bit (12.9)	33.5.1.2.7	Bit indicates a short circuit condition has been detected. Set to one entering ERROR_DELAY state.	MAN:M	Yes [ ] N/A [ ]
MF29	Short circuit bit implementation	33.5.1.2.7	Implemented with a latching high behavior as defined in 33.5.1	MAN:M	Yes [ ] N/A [ ]
MF30	Overload bit (12.8)	33.5.1.2.8	Bit indicates an overload condition has been detected. Set to one when entering the ERROR_DELAY_OVER state	MAN:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
MF31	Overload bit implementation	33.5.1.2.8	Implemented with a latching high behavior as defined in 33.5.1	MAN:M	Yes [ ] N/A [ ]
MF32	MPS absent bit (12.7)	33.5.1.2.9	Bit indicates an MPS Absent condition has been detected. Set to one when transitions directly from POWER_ON to IDLE state when MPS is absent for a duration greater than T_{MPDO} as specified in 33.2.9	MAN:M	Yes [ ] N/A [ ]
MF33	MPS Absent bit implementation	33.5.1.2.9	Implemented with a latching high behavior as defined in 33.5.1	MAN:M	Yes [ ] N/A [ ]

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33.8.3.8 Data Link Layer classification requirements

Item	Feature	Subclause	Value/Comment	Status	Support
DLL1	Reserved fields	33.6	Reserved fields in Power via MDI TLV transmitted as zeroes and ignored upon receipt	M	Yes [ ] N/A [ ]
DLL2	Data Link Layer classification standards compliance	33.6.1	Meet mandatory parts of IEEE Std 802.1AB-2009	DLLC:M	Yes [ ] N/A [ ]
DLL3	TLV frame definitions	33.6.1	Meet requirements for Type, Length, and Value (TLV) defined in 79.3.2	DLLC:M	Yes [ ] N/A [ ]
DLL4	Control state diagrams	33.6.1	Meet state diagrams defined in 33.6.3	DLLC:M	Yes [ ] N/A [ ]
DLL5	Type 2 PSE LLDPDU	33.6.2	Transmitted within 10 seconds of Data Link Layer classification being enabled as indicated by pse_dll_enabled	DLLC:M	Yes [ ] N/A [ ]
DLL6	Type 1 PSE LLDPDU	33.6.2	Transmitted when Data Link Layer classification is ready as indicated by pse_dll_ready	DLLC:M	Yes [ ] N/A [ ]
DLL7	PD Data Link Layer classification ready	33.6.2	Set state variable pd_dll_ready within 5 min of Data Link Layer classification being enabled as indicated by pd_dll_enabled	DLLC:M	Yes [ ] N/A [ ]
DLL8	PD requested power value change	33.6.2	LLDPDU with updated “PSE allocated power value” sent within 10 seconds	DLLC:M	Yes [ ] N/A [ ]
DLL9	PSE allocated power value change	33.6.2	LLDPDU with updated “PD requested power value” sent within 10 seconds	DLLC:M	Yes [ ] N/A [ ]
DLL10	PSE power control state diagrams	33.6.3	Meet the behavior shown in Figure 33–27	DLLC:M	Yes [ ] N/A [ ]
DLL11	PD power control state diagrams	33.6.3	Meet the behavior shown in Figure 33–28	DLLC:M	Yes [ ] N/A [ ]

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33.8.3.9 Environmental specifications applicable to PSEs and PDs

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	Safety	33.7.1	Conforms to IEC 60950-1:2001	M	Yes [ ]
ES2	PSE classified as a limited power source	33.7.1	In accordance with IEC 60950-1:2001	M	Yes [ ]
ES3	Safety	33.7.1	Comply with all applicable local and national codes	M	Yes [ ]
ES4	Telephony voltages	33.7.5	Application thereof described in 33.7.5 not result in any safety hazard	M	Yes [ ]
ES5	Limitation of electromagnetic interference	33.7.6	PD and PSE powered cabling comply with applicable local and national codes	M	Yes [ ]

33.8.3.10 Environmental specifications applicable to the PSE

Item	Feature	Subclause	Value/Comment	Status	Support
PSEES1	Safety	33.7.1	Limited Power Source in accordance with IEC 60950-1:2001	M	Yes [ ]

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NOTE—The remaining annexes in the standard are numbered in correspondence to their associated clauses; e.g., Annexes 22A, 22B, 22C, and 22D correspond to Clause 22.

Annex 22A

(informative)

MII output delay, setup, and hold time budget

22A.1 System model

The discussion of signal timing characteristics that follows will refer to the system model depicted in Figure 22A–1, Figure 22A–2, and Figure 22A–3. This system model can be applied to each of the three application environments defined in 22.2.1.

Figure 22A–1 depicts a simple system model in which the MII is used to interconnect two integrated circuits on the same circuit assembly. In this model the Reconciliation sublayer comprises one integrated circuit, and the PHY comprises the other. A Reconciliation sublayer or a PHY may actually be composed of several separate integrated circuits. The system model in Figure 22A–1 includes two unidirectional signal transmission paths, one from the Reconciliation sublayer to the PHY and one from the PHY to the Reconciliation sublayer. The path from the Reconciliation sublayer to the PHY is separated into two sections, labeled A1 and B1. The path from the PHY to the Reconciliation sublayer is separated into two sections, labeled C1 and D1.

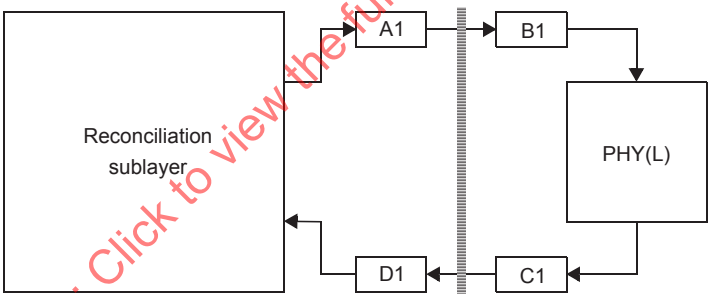

Figure 22A–1—Model for integrated circuit to integrated circuit connection

Figure 22A–2 depicts a system model for the case where the MII is used to interconnect two circuit assemblies. The circuit assemblies may be physically connected in a motherboard/daughterboard arrangement, or they may be physically connected with the cable defined in 22.4.5 and the line interface connector defined in 22.6. The system model in Figure 22A–2 includes two unidirectional signal transmission paths, one from the Reconciliation sublayer to the PHY and one from the PHY to the Reconciliation sublayer. The path from the Reconciliation sublayer to the PHY is separated into two sections, labeled A2 and B2. The path from the PHY to the Reconciliation sublayer is separated into two sections, labeled C2 and D2.

Figure 22A–3 depicts a system model in which the MII is used to interconnect both integrated circuits and circuit assemblies. This system model allows for separate signal transmission paths to exist between the Reconciliation sublayer and a local PHY(L), and between the Reconciliation sublayer and a remote PHY(R). The unidirectional paths between the Reconciliation sublayer and the PHY(L) are composed of sections A1,

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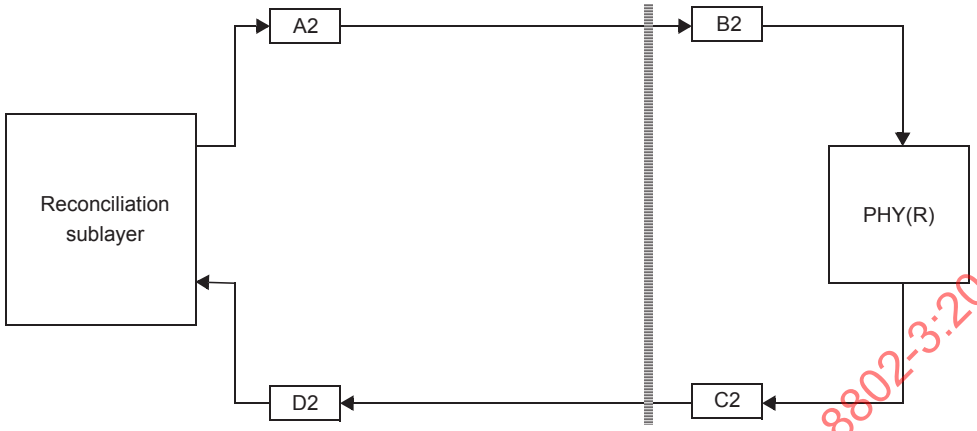

Figure 22A–2—Model for circuit assembly to circuit assembly connection

B1, C1, and D1. The unidirectional paths between the Reconciliation sublayer and the remote PHY(R) are composed of sections A2, B2, C2, and D2.

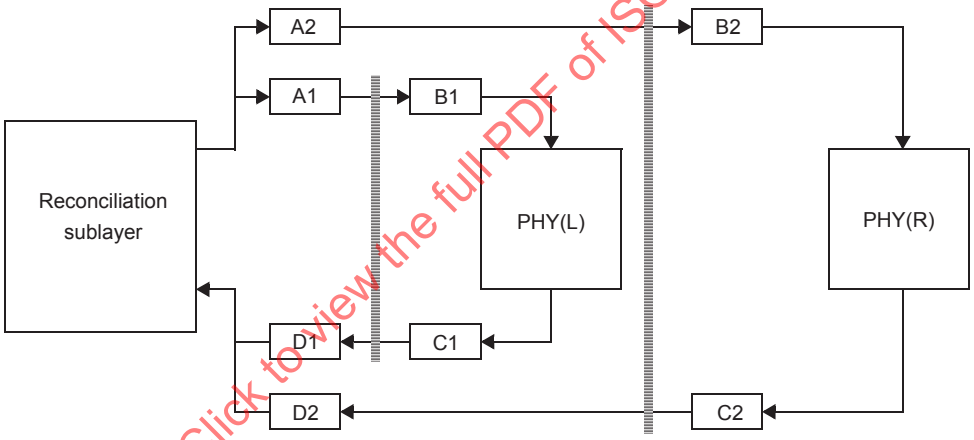

Figure 22A–3—Combined model

Each of these system models assumes a set of common timing and electrical characteristics that shall be met at the input and output ports of the Reconciliation sublayer and PHY devices. The characteristics of the signal transmission paths are identified for each of the sections A1, B1, C1, D1, A2, B2, C2, and D2.

22A.2 Signal transmission path characteristics

The signal transmission path characteristics are specified for each of the path sections defined in 22A.1. The characteristics for these sections are specified so as to allow sections A1, B1, C1, and D1 to be implemented in the form of printed circuit board traces, while sections A2, B2, C2, and D2 may be implemented with a combination of printed circuit board traces and wire conductors in a cable assembly.

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The signal transmission path characteristics are stated in terms of their maximum delay and their characteristic impedance. These values are summarized in Table 22A–1.

Table 22A–1—Signal transmission path characteristics

Section	Maximum delay (ns)	Impedance (Ω)
A1, D1	5	68 ± 15%
B1, C1	2.5	68 ± 15%
A2, D2	5	68 ± 10%
B2, C2	2.5	68 ± 10%

The driver characteristics specified in 22.4.3, the receiver characteristics specified in 22.4.4, and the signal transmission path characteristics specified in Table 22A–1 can be applied to the system models shown in Figure 22A–1 or Figure 22A–2. The combination of loads presented in Figure 22A–3 cannot be adequately driven by an output buffer that meets the driver characteristics specified in 22.4.3 while being sampled by an input buffer that meets the receiver characteristics specified in 22.4.4.

To address the system model depicted in Figure 22A–3, it is permissible to incorporate an additional stage of buffering into path sections A1, A2, D1, and D2, provided that the resulting maximum delay characteristic for those path sections does not exceed the value stated in Table 22A–1. The delay characteristic for transmission path sections A2 and D2 includes an allowance for the delay that results from the presence of a lumped capacitive load at the end of the path. For a transmission path section with a characteristic impedance Z_o, with a lumped capacitive load C_L, this delay is nominally Z_oC_L. In the case of a maximum transmission path section impedance of 78 Ω with a lumped load of 8 pF, the nominal delay is 0.6 ns. Thus the allowable delay for a buffer inserted into transmission path section A2 or D2 is 4.4 ns.

22A.3 Budget calculation

A recommended timing budget is shown in Table 22A–2. This budget assumes that the combined system model shown in Figure 22A–3 represents a worst case.

Table 22A–2—Round-trip delay budget

Description	Incremental delay (ns)	Cumulative delay (ns)
TX_CLK output at PHY(R)	0.0	0.0
Transmission path section C2	2.5	2.5
Transmission path section D2	5.0	7.5
Clock to output in Reconciliation sublayer	15.0	22.5

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Table 22A–2—Round-trip delay budget *(continued)*

Description	Incremental delay (ns)	Cumulative delay (ns)
Transmission path section A2	5.0	27.5
Transmission path section B2	2.5	30.0
Setup time at PHY(R)	10.0	40.0

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Annex 22B

(informative)

MII driver ac characteristics

22B.1 Implications of CMOS ASIC processes

For MII drivers that drive rail to rail, such as those commonly used in CMOS ASICs (complimentary metal oxide semiconductor application-specific integrated circuits), the ac characteristic performance requirements of 22.4.3.2 can be met if the V_{oh} vs. I_{oh} and V_{ol} vs. I_{ol} dc characteristics of the driver stay within the unshaded areas of Figure 22B–1.

The variation in output resistance of a field effect transistor (FET) due to variations in supply voltage, temperature, and process may require that a resistance be placed in series with the output of the FETs to meet this specification. The series resistance can be part of the driver circuit, or external to the driver. If the series resistance is not part of the driver circuit, the driver vendor shall specify the value of series resistance required to meet the specification. A series resistor used to meet this specification is conceptually part of the driver regardless of whether it is physically internal or external to the driver.

The propagation delay of the path between the driver and an external series resistor used to meet the specification shall not exceed 10% of the 10–90% rise/fall time of the driver.

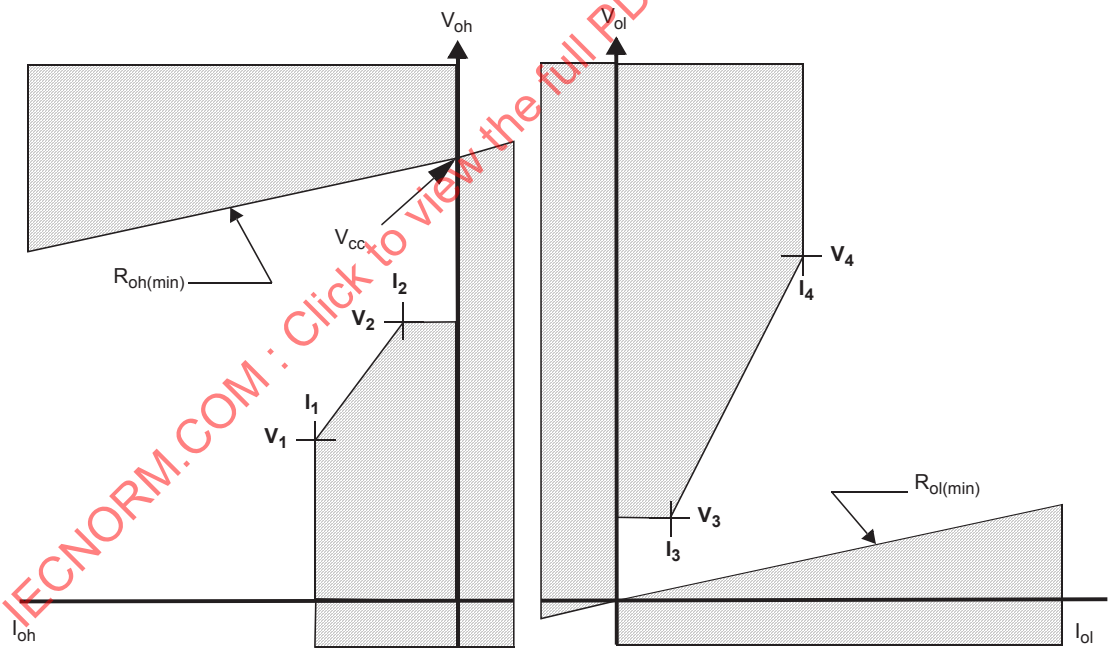

Figure 22B–1—Driver output V–I curve

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22B.2 $R_{o(min)}$ and V, I values for operation from 5 V ± 10% supply

Referring to Figure 22B–1, $R_{oh(min)}$ and $R_{ol(min)}$ both equal 40 Ω, and the values for the V-I points on the curve are given in Table 22B–1 for MII drivers that drive rail to rail from a +5 V ± 10% power supply.

Table 22B–1—Values for driver output V-I curve (5 V supply)

V–I point	I (mA)	V (V)
I_1, V_1	–20	1.10
I_2, V_2	–4	2.4
I_3, V_3	4	0.40
I_4, V_4	43	3.05

22B.3 $R_{o(min)}$ and V, I values for operation from 3.3 V ± 0.3 V supply

Referring to Figure 22B–1, $R_{oh(min)}$ and $R_{ol(min)}$ both equal 33 Ω, and the values for the V–I points on the curve are given in Table 22B–2 for MII drivers that drive rail to rail from a +3.3 V ± 0.3 V power supply.

Table 22B–2—Values for driver output V-I curve (3.3 V supply)

V-I point	I (mA)	V (V)
I_1,V_1	–20	1.10
I_2,V_2	–4	2.4
I_3,V_3	4	0.40
I_4,V_4	26	2.10

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Annex 22C

(informative)

Measurement techniques for MII signal timing characteristics

22C.1 Measuring timing characteristics of source terminated signals

The measurement of timing relationships between MII signals at the MII connector is complicated by the use of driver output impedance to control transmission line reflections on point-to-point transmission paths passing through the connector. The voltage waveforms on point-to-point transmission paths can be different at the MII connector and at the end of the paths. A clean transition (or step) from one logic state to the other at the end of a point to point path can appear as two half-steps at the MII connector.

To eliminate ambiguity as to where on a two half-step state transition to measure timing, all timing measurements on point-to-point transmission paths will be at the end of the path. In some cases, an end of path must be artificially created.

22C.2 Measuring timing characteristics of transmit signals at the MII

The timing of TX_EN, TX_ER, and TXD<3:0> relative to TX_CLK at the MII connector is measured as follows.

Use the time base for TX_CLK as a timing reference. Break the TX_CLK path at the MII connector, forcing the TX_CLK point-to-point transmission path to end at the connector. Measure when the rising edge of TX_CLK passes through $V_{ih(min)}$ at the MII connector. Call this time T_{clk}. Reconnect the TX_CLK path at the MII connector and break the paths of TX_EN, TX_ER, and TXD<3:0> at the MII connector, forcing the paths to end at the connector. Measure when TX_EN, TX_ER, and TXD<3:0> exit the switching region at the MII connector. Call these times T_{en}, T_{er}, and $T_{<3:0>}$, respectively.

The timing relationships at the MII connector for TX_EN, TX_ER, and TXD<3:0> relative to TX_CLK are met if ($T_{en} - T_{clk}$), ($T_{er} - T_{clk}$), ($T_3 - T_{clk}$), ($T_2 - T_{clk}$), ($T_1 - T_{clk}$), and ($T_0 - T_{clk}$), respectively, meet the timing relationships specified in 22.3.1.

22C.3 Measuring timing characteristics of receive signals at the MII

The timing of RX_DV, RX_ER, and RXD<3:0> relative to RX_CLK at the MII connector is measured as follows.

Break the paths of RX_CLK, RX_DV, RX_ER, and RXD<3:0> at the MII connector, forcing the paths to end at the connector. Measure when RX_DV, RX_ER, and RXD<3:0> exit the switching region at the MII connector relative to when the rising edge of RX_CLK passes through $V_{il(max)}$. Also measure when RX_DV, RX_ER, and RXD<3:0> reenter the switching region relative to when the rising edge of RX_CLK passes through $V_{ih(min)}$.

The timing relationships at the MII connector for RX_DV, RX_ER, and RXD<3:0> relative to RX_CLK are met if the times measured in the previous step meet the timing relationships specified in 22.3.2.

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22C.4 Measuring timing characteristics of MDIO

The MDIO and MDC signal timing characteristics cannot be measured using the techniques defined for the transmit and receive signals since MDIO and MDC may connect a single station management entity to multiple PHY devices. The MDIO and MDC timing characteristics are measured with a PHY connected to the MII connector. The signal timing characteristics for MDC and MDIO must be met over the range of conditions which occur when from one to 32 PHYs are connected to an STA. When 32 PHYs are connected to an STA, the total capacitance can be as large as 390 pF on MDC, and as large as 470 pF on MDIO.

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Annex 22D

(informative)

Clause 22 access to Clause 45 MMD registers

Clause 22 provides access to registers in a Clause 45 MMD using Registers 13 and 14. This informative annex provides users with some insight how these registers can be utilized to access Clause 45 MMD registers. Accesses to Registers 13 and 14, for the purpose of accessing registers in a Clause 45 MMD, should be performed atomically to avoid the chance of another process changing the Function, DEVAD or address fields within the MMD. This is the same requirement of Clause 45 accesses.

22D.1 Write operation

To write a Clause 45 register using the Clause 22 access mechanism, perform the following accesses using the appropriate PHY address for the PHY of interest:

a) To Register 13, write the Function field to 00 (address) and DEVAD field to the device address value for the desired MMD;
b) To Register 14, write the desired address value to the MMD's address register;
c) To Register 13, write the Function field to 01 (Data, no post increment) and DEVAD field to the same device address value for the desired MMD;
d) To Register 14, write the content of the MMD's selected register.

Step a) and Step b) can be skipped if the MMD's address register was previously configured.

22D.2 Read operation

To read a Clause 45 register using the Clause 22 access mechanism, perform the following accesses using the appropriate PHY address for the PHY of interest:

a) To Register 13, write the Function field to 00 (address) and DEVAD field to the device address value for the desired MMD;
b) To Register 14, write the desired address value to the MMD's address register;
c) To Register 13, write the Function field to 01 (Data, no post increment) and DEVAD field to the same device address value for the desired MMD;
d) From Register 14, read the content of the MMD's selected register.

Step a) and Step b) can be skipped if the MMD's address register was previously configured.

22D.3 MMD address operations

22D.3.1 Address

While the Function field contains the value 00 (address):

a) subsequent writes to Register 14 continue to rewrite MMD DEVAD's address register;
b) subsequent reads from Register 14 continue to reread MMD DEVAD's address register.

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22D.3.2 Data, no post increment

While the Function field contains the value 01 (Data, no post increment):

a) subsequent writes to Register 14 continue to rewrite the data register selected by the value in MMD DEVAD's address register;
b) subsequent reads from Register 14 continue to reread the data register selected by the value in MMD DEVAD's address register.

22D.3.3 Data, post increment on reads and writes

While the Function field contains the value 10 (Data, post increment on reads and writes):

a) subsequent writes to Register 14 write the next higher addressed data register selected by the value in MMD DEVAD's address register, i.e. MMD DEVAD's address register is incremented after each access;
b) subsequent reads from Register 14 read the next higher addressed data register selected by the value in MMD DEVAD's address register, i.e. MMD DEVAD's address register is incremented after each access.

22D.3.4 Data, post increment on writes only

While the Function field contains the value 11 (Data, post increment on writes only):

a) subsequent writes to Register 14 write the next higher addressed data register selected by the value in MMD DEVAD's address register, i.e. MMD DEVAD's address register is incremented after each access;
b) subsequent reads from Register 14 continue to reread the data register selected by the value in MMD DEVAD's address register.

This Function enables a read-modify-write capability for successively addressed registers within a MMD.

22D.4 PHY Coexistence and bus conflict avoidance

There are multiple levels of coexistence on the MDIO bus:

a) PHYs accessible via the Clause 22 access mechanism can coexist on the same bus using different PHY address values;
b) Ports accessible via the Clause 45 access mechanism can coexist on the same bus using different port address values;
c) PHYs accessible via the Clause 22 access mechanism can coexist on the same bus with ports accessible via the Clause 45 access mechanism, even with identical PHY/port address values due to the different ST (start of frame) encodings of the frame structures (see 45A.3 and 45A.4, which discuss the need for protocol aware voltage translators for this type of coexistence);
d) MMDs accessible via the Clause 45 access mechanism with the same port address can coexist on the same bus using different device address values.

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Annex 23A

(normative)

6T codewords

The *leftmost* ternary symbol of each 6T Code group shown in Table 23A–1 (broken into 23A–1a and 23A–1b for pagination) shall be transmitted *first*. The *leftmost* nibble of each data octet is the *most significant*.

Table 23A–1a—100BASE-T4 8B6T code table

Data octet	6T code group	Data octet	6T code group	Data octet	6T code group	Data octet	6T code group
00	+ - 0 0 + -	20	0 0 - + + -	40	+ 0 + 0 0 -	60	0 - 0 + + 0
01	0 + - + - 0	21	- - + 0 0 +	41	+ + 0 0 - 0	61	0 0 - + 0 +
02	+ - 0 + - 0	22	+ + - 0 + -	42	+ 0 + 0 - 0	62	0 - 0 + 0 +
03	- 0 + + - 0	23	+ + - 0 - +	43	0 + + 0 - 0	63	- 0 0 + 0 +
04	- 0 + 0 + -	24	0 0 + 0 - +	44	0 + + 0 0 -	64	- 0 0 + + 0
05	0 + - - 0 +	25	0 0 + 0 + -	45	+ + 0 - 0 0	65	0 0 - 0 + +
06	+ - 0 - 0 +	26	0 0 - 0 0 +	46	+ 0 + - 0 0	66	0 - 0 0 + +
07	- 0 + - 0 +	27	- - + + + -	47	0 + + - 0 0	67	- 0 0 0 + +
08	- + 0 0 + -	28	- 0 - + + 0	48	0 0 0 + 0 0	68	- + - + + 0
09	0 - + + - 0	29	- - 0 + 0 +	49	0 0 0 - + +	69	- - + + 0 +
0A	- + 0 + - 0	2A	- 0 - + 0 +	4A	0 0 0 + - +	6A	- + - + 0 +
0B	+ 0 - + - 0	2B	0 - - + 0 +	4B	0 0 0 + + -	6B	+ - - + 0 +
0C	+ 0 - 0 + -	2C	0 - - + + 0	4C	0 0 0 - + 0	6C	+ - - + + 0
0D	0 - + - 0 +	2D	- - 0 0 + +	4D	0 0 0 - 0 +	6D	- - + 0 + +
0E	- + 0 - 0 +	2E	- 0 - 0 + +	4E	0 0 0 + - 0	6E	- + - 0 + +
0F	+ 0 - - 0 +	2F	0 - - 0 + +	4F	0 0 0 + 0 -	6F	+ - - 0 + +
10	+ 0 + - - 0	30	+ - 0 0 - +	50	+ 0 + - - +	70	- + + 0 0 0
11	+ + 0 - 0 -	31	0 + - - + 0	51	+ + 0 - + -	71	+ - + 0 0 0
12	+ 0 + - 0 -	32	+ - 0 - + 0	52	+ 0 + - + -	72	+ + - 0 0 0
13	0 + + - 0 -	33	- 0 + - + 0	53	0 + + - + -	73	0 0 + 0 0 0
14	0 + + - - 0	34	- 0 + 0 - +	54	0 + + - - +	74	- 0 + 0 0 0
15	+ + 0 0 - -	35	0 + - + 0 -	55	+ + 0 + - -	75	0 - + 0 0 0
16	+ 0 + 0 - -	36	+ - 0 + 0 -	56	+ 0 + + - -	76	+ 0 - 0 0 0
17	0 + + 0 - -	37	- 0 + + 0 -	57	0 + + + - -	77	0 + - 0 0 0
18	0 + - 0 + -	38	- + 0 0 - +	58	+ + + 0 - -	78	0 - - + + +
19	0 + - 0 - +	39	0 - + - + 0	59	+ + + - 0 -	79	- 0 - + + +
1A	0 + - + + -	3A	- + 0 - + 0	5A	+ + + - - 0	7A	- - 0 + + +
1B	0 + - 0 0 +	3B	+ 0 - - + 0	5B	+ + 0 - - 0	7B	- - 0 + + 0
1C	0 - + 0 0 +	3C	+ 0 - 0 - +	5C	+ + 0 - - +	7C	+ + - 0 0 -
1D	0 - + + + -	3D	0 - + + 0 -	5D	+ + 0 0 0 -	7D	0 0 + 0 0 -
1E	0 - + 0 - +	3E	- + 0 + 0 -	5E	- - + + + 0	7E	+ + - - - +
1F	0 - + 0 + -	3F	+ 0 - + 0 -	5F	0 0 - + + 0	7F	0 0 + - - +

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Table 23A–1b—100BASE-T4 8B6T code table

Data octet	6T code group	Data octet	6T code group	Data octet	6T code group	Data octet	6T code group
80	+ - + 0 0 -	A0	0 - 0 + + -	C0	+ - + 0 + -	E0	+ - 0 + + -
81	+ + - 0 - 0	A1	0 0 - + - +	C1	+ + - + - 0	E1	0 + - + - +
82	+ - + 0 - 0	A2	0 - 0 + - +	C2	+ - + + - 0	E2	+ - 0 + - +
83	- + + 0 - 0	A3	- 0 0 + - +	C3	- + + + - 0	E3	- 0 + + - +
84	- + + 0 0 -	A4	- 0 0 + + -	C4	- + + 0 + -	E4	- 0 + + + -
85	+ + - - 0 0	A5	0 0 - - + +	C5	+ + - - 0 +	E5	0 + - - 0 +
86	+ - + - 0 0	A6	0 - 0 - + +	C6	+ - + - 0 +	E6	+ - 0 - + +
87	- + + - 0 0	A7	- 0 0 - + +	C7	- + + - 0 +	E7	- 0 + - + +
88	0 + 0 0 0 -	A8	- + - + + -	C8	0 + 0 0 + -	E8	- + 0 + + -
89	0 0 + 0 - 0	A9	- - + + - +	C9	0 0 + + - 0	E9	0 - + + - +
8A	0 + 0 0 - 0	AA	- + - + - +	CA	0 + 0 + - 0	EA	- + 0 + - +
8B	+ 0 0 0 - 0	AB	+ - - + - +	CB	+ 0 0 + - 0	EB	+ 0 - + - +
8C	+ 0 0 0 0 -	AC	+ - - + + -	CC	+ 0 0 0 + -	EC	+ 0 - + + -
8D	0 0 + - 0 0	AD	- - + - + +	CD	0 0 + - 0 +	ED	0 - + - + +
8E	0 + 0 - 0 0	AE	- + - - + +	CE	0 + 0 - 0 +	EE	- + 0 - + +
8F	+ 0 0 - 0 0	AF	+ - - - + +	CF	+ 0 0 - 0 +	EF	+ 0 - - + +
90	+ - + - - +	B0	0 - 0 0 0 +	D0	+ - + 0 - +	F0	+ - 0 0 0 +
91	+ + - - + -	B1	0 0 - 0 + 0	D1	+ + - - + 0	F1	0 + - 0 + 0
92	+ - + - + -	B2	0 - 0 0 + 0	D2	+ - + - + 0	F2	+ - 0 0 + 0
93	- + + - + -	B3	- 0 0 0 + 0	D3	- + + - + 0	F3	- 0 + 0 + 0
94	- + + - - +	B4	- 0 0 0 0 +	D4	- + + 0 - +	F4	- 0 + 0 0 +
95	+ + - + - -	B5	0 0 - + 0 0	D5	+ + - + 0 -	F5	0 + - + 0 0
96	+ - + + - -	B6	0 - 0 + 0 0	D6	+ - + + 0 -	F6	+ - 0 + 0 0
97	- + + + - -	B7	- 0 0 + 0 0	D7	- + + + 0 -	F7	- 0 + + 0 0
98	0 + 0 - - +	B8	- + - 0 0 +	D8	0 + 0 0 - +	F8	- + 0 0 0 +
99	0 0 + - + -	B9	- - + 0 + 0	D9	0 0 + - + 0	F9	0 - + 0 + 0
9A	0 + 0 - + -	BA	- + - 0 + 0	DA	0 + 0 - + 0	FA	- + 0 0 + 0
9B	+ 0 0 - + -	BB	+ - - 0 + 0	DB	+ 0 0 - + 0	FB	+ 0 - 0 + 0
9C	+ 0 0 - - +	BC	+ - - 0 0 +	DC	+ 0 0 0 - +	FC	+ 0 - 0 0 +
9D	0 0 + + - -	BD	- - + + 0 0	DD	0 0 + + 0 -	FD	0 - + + 0 0
9E	0 + 0 + - -	BE	- + - + 0 0	DE	0 + 0 + 0 -	FE	- + 0 + 0 0
9F	+ 0 0 + - -	BF	+ - - + 0 0	DF	+ 0 0 + 0 -	FF	+ 0 - + 0 0

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Annex 23B

(informative)

Noise budget

Worst-case values for noise effects in the 100BASE-T4 system are as shown in Tables 23B–1 and 23B–2.

Table 23B–1—Carrier presence analysis

Received signal peak amplitude (min.)	792 mVp
NEXT noise	325 mVp

Table 23B–2—Far-end signal analysis

Received signal peak amplitude (min.)	796 mVp
Baseline wander	14 mVp
ISI	80 mVp
Reflections	60 mVp
FEXT noise	87 mVp

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Annex 23C

(informative)

Use of cabling systems with a nominal differential characteristic impedance of 120 Ω

The 100BASE-T4 standard specifies only the use of 100 Ω link segments for conformance. Since ISO/IEC 11801: 1995 also recognizes 120 Ω cabling, this informative annex specifies the conditions for using cabling systems with a nominal characteristic impedance of 120 Ω by 100BASE-T4 conformant stations.

The use of cables with a characteristic impedance outside the range specified in 23.6 will generally increase the mismatching effects in the link components, inducing additional noise in the received signals.

In particular, the use of a homogeneous link segment having a characteristic impedance of 120 Ω ±15 Ω over the frequency band 1 to 16 MHz may add up to 1.4% of additional noise to the signals at the input of the receivers (worst-case short-length link segment).

Therefore, in order to keep the overall noise (MDFEXT + reflections) at the same value as for a 100 Ω link segment when using a 120 Ω link segment, the minimum ELFEXT loss requirement for the cable must be increased by 2 dB (i.e., from 23 dB to 25 dB at 12.5 MHz, see 23.6.3.2). Accordingly, the MDFEXT noise requirement shall be decreased from 87 mV peak to 69 mV peak. In practice, this means that cables rated category 4 or higher, as specified in ISO/IEC 11801: 1995, are required when 120 Ω cables are used with 100BASE-T4 compliant PMDs.

NOTE 1—The use of 100 Ω cords at end points in conjunction with 120 Ω premises cabling may be tolerated provided that all the components of the link are of Category 5, as defined in ISO/IEC 11801: 1995.

NOTE 2—The use of 100 Ω cords at any intermediate cross-connect points on 120 Ω links as well as the use of 120 Ω cords in conjunction with 100 Ω premises cabling is not allowed since it would result in worst-case jitter greater than that allowed in this standard.

CAUTION

Users of this annex are further advised to check with the manufacturer of the particular 100BASE-T4 couplers they intend to use with a 120 Ω link to see whether those couplers can operate correctly on cables with Z_c as high as 120 Ω ± 15 Ω.

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Annex 27A

(normative)

Repeater delay consistency requirements

Proper operation of the network requires that repeaters do not cause the interpacket gap (IPG) to disappear by propagating the end of any carrier event to different output ports with greatly different delay times. Maximum port-to-port delays have been assigned as absolute delays to meet requirements for detection of collision within a slot time and limiting the length of collision fragments to less than minimum frame size. To avoid specification of minimum input-to-output propagation time as absolute values that reduce implementation flexibility, these delays are instead implied by imposing a triangular delay inequality relationship.

Consider three ports {A, B, C}. Using the notation SOP(xy) to mean the start-of-packet delay for an input at port x to resulting output on port y, repeaters shall achieve this relationship for all groups of three ports within a repeater set:

SOP(AC) < SOP(AB) + SOP(BC)

Following a frame transmitted by node A that propagates to nodes B and C, this constraint ensures that node B cannot complete an IPG timer and initiate a transmission that arrives at node C before node C has also advanced its own IPG timer sufficiently that a pending frame can contend for access to the network.

There is a second delay consistency requirement, one that relates to jam propagation by repeaters. Using a notation similar to that above, SOJ(xy) stands for the start-of-jam propagation delay from port x to port y and EOJ(xy) for the end-of-jam delay between same two ports.

To ensure proper detection of collisions and avoid generation of fragments that exceed minimum frame size, maximum values have been imposed on SOJ and EOJ delays through repeaters. No specific minima have been specified as all delays less than the maxima meet the collision detection and fragment length criteria. To prevent the jam pattern from shrinking excessively as it propagates through repeaters, repeaters shall meet this relationship between all pairs of ports:

EOJ(AB) >= SOJ(AB) – 4 bit times

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Annex 28A

(normative)

Selector Field definitions

The Selector Field, S[4:0] in the link codeword, shall be used to identify the type of message being sent by Auto-Negotiation. The following table identifies the types of messages that may be sent. As new messages are developed, this table will be updated accordingly.

The Selector Field uses a 5-bit binary encoding, which allows 32 messages to be defined. All unspecified combinations are reserved. Reserved combinations shall not be transmitted.

Table 28A–1—Selector Field value mappings

S4	S3	S2	S1	S0	Selector description
0	0	0	0	0	Reserved for future Auto-Negotiation development
0	0	0	0	1	IEEE Std 802.3
0	0	0	1	0	IEEE Std 802.9a-1995 (withdrawn)
0	0	0	1	1	IEEE Std 802.5v-2001 (withdrawn)
0	0	1	0	0	IEEE Std 1394
0	0	1	0	1	INCITS
0	0	1	1	X	Reserved for future Auto-Negotiation development[a]
0	1	X	X	X	Reserved for future Auto-Negotiation development
1	X	X	X	X	Reserved for future Auto-Negotiation development

[a]For up-to-date information on the allocation of Auto-Negotiation Selector Fields see http://www.ieee802.org/3/selectors/selectors.html

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Annex 28B

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IEEE 802.3 Selector Base Page definition

This annex provides the Technology Ability Field bit assignments, Priority Resolution table, and Message Page transmission conventions relative to the IEEE 802.3 Selector Field value within the Base Page encoding.

As new IEEE 802.3 LAN technologies are developed, a reserved bit in the Technology Ability field may be assigned to each technology by the standards body.

The new technology will then be inserted into the Priority Resolution hierarchy and made a part of the Auto-Negotiation standard. The relative hierarchy of the existing technologies will not change, thus providing backward compatibility with existing Auto-Negotiation implementations.

It is important to note that the reserved bits are required to be transmitted as logic zeros. This guarantees that devices implemented using the current priority table will be forward compatible with future devices using an updated priority table.

28B.1 Selector field value

The value of the IEEE 802.3 Selector Field is S[4:0] = 00001.

28B.2 Technology Ability Field bit assignments

The Technology bit field consists of bits D5 through D11 (A0–A6, respectively) in the IEEE 802.3 Selector Base Page. Table 28B–1 summarizes the bit assignments.

Note that the order of the bits within the Technology Ability Field has no relationship to the relative priority of the technologies.

Setting Bit A5 or Bit A6 indicates that the DTE has implemented both the optional MAC control sublayer and the PAUSE function as specified in Clause 31 and Annex 31B. This capability is significant only when the link is configured for full duplex operation, regardless of data rate and medium. The encoding of Bits A5 and A6 is specified in Table 28B–2.

Table 28B–1—Technology Ability Field bit assignments

Bit	Technology	Minimum cabling requirement
A0	10BASE-T	Two-pair Category 3
A1	10BASE-T full duplex	Two-pair Category 3
A2	100BASE-TX	Two-pair Category 5
A3	100BASE-TX full duplex	Two-pair Category 5
A4	100BASE-T4	Four-pair Category 3
A5	PAUSE operation for full duplex links	Not applicable
A6	Asymmetric PAUSE operation for full duplex Links	Not applicable

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Table 28B–2—Pause encoding

PAUSE (A5)	ASM_DIR (A6)	Capability
0	0	No PAUSE
0	1	Asymmetric PAUSE toward link partner
1	0	Symmetric PAUSE
1	1	Both Symmetric PAUSE and Asymmetric PAUSE toward local device

The PAUSE bit indicates that the device is capable of providing the symmetric PAUSE functions as defined in Annex 31B. The ASM_DIR bit indicates that asymmetric PAUSE is supported. The value of the PAUSE bit when the ASM_DIR bit is set indicates the direction the PAUSE frames are supported for flow across the link. Asymmetric PAUSE configuration results in independent enabling of the PAUSE receive and PAUSE transmit functions as defined by Annex 31B. See 28B.3 regarding PAUSE configuration resolution.

28B.3 Priority resolution

Since two devices may have multiple abilities in common, a prioritization scheme exists to ensure that the highest common denominator ability is chosen. The following list shall represent the relative priorities of the technologies supported by the IEEE 802.3 Selector Field value, where priorities are listed from highest to lowest.

a) 10GBASE-T full duplex
b) 1000BASE-T full duplex
c) 1000BASE-T
d) 100BASE-T2 full duplex
e) 100BASE-TX full duplex
f) 100BASE-T2
g) 100BASE-T4
h) 100BASE-TX
i) 10BASE-T full duplex
j) 10BASE-T

The rationale for this hierarchy is straightforward. 10BASE-T is the lowest common denominator and therefore has the lowest priority. Full duplex solutions are always higher in priority than their half duplex counterparts. 1000BASE-T has a higher priority than 100 Mb/s technologies. 100BASE-T2 is ahead of 100BASE-TX and 100BASE-T4 because 100BASE-T2 runs across a broader spectrum of copper cabling and can support a wider base of configurations. 100BASE-T4 is ahead of 100BASE-TX because 100BASE-T4 runs across a broader spectrum of copper cabling. The relative order of the technologies specified herein shall not be changed. As each new technology is added, it shall be inserted into its appropriate place in the list, shifting technologies of lesser priority lower in priority. If a vendor-specific technology is implemented, the priority of all IEEE 802.3 standard technologies shall be maintained, with the vendor specific technology inserted at any appropriate priority location.

NOTE—Refer to 28.2.1.2.3 for resolution of Extended Next Pages.

The use of the PAUSE operation for full duplex links (as indicated by bits A5 and A6) is orthogonal to the negotiated data rate, medium, or link technology. The setting of these bits indicates the availability of additional DTE capability when full duplex operation is in use. The PAUSE function shall be enabled according to Table 28B–3 only if the highest common denominator is a full duplex technology. There is no priority resolution associated with the PAUSE operation.

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Table 28B–3—Pause resolution

Local device		Link partner		Local device resolution	Link partner resolution
PAUSE	ASM_DIR	PAUSE	ASM_DIR		
0	0	Don't care	Don't care	Disable PAUSE Transmit and Receive	Disable PAUSE Transmit and Receive
0	1	0	Don't care	Disable PAUSE Transmit and Receive	Disable PAUSE Transmit and Receive
0	1	1	0	Disable PAUSE Transmit and Receive	Disable PAUSE Transmit and Receive
0	1	1	1	Enable PAUSE transmit Disable PAUSE receive	Enable PAUSE receive Disable PAUSE transmit
1	0	0	Don't care	Disable PAUSE Transmit and Receive	Disable PAUSE Transmit and Receive
1	Don't care	1	Don't care	Enable PAUSE Transmit and Receive	Enable PAUSE Transmit and Receive
1	1	0	0	Disable PAUSE Transmit and Receive	Disable PAUSE Transmit and Receive
1	1	0	1	Enable PAUSE receive Disable PAUSE transmit	Enable PAUSE transmit Disable PAUSE receive

28B.4 Message Page transmission convention

Each series of Unformatted Pages shall be preceded by a Message Page containing a message code that defines how the following Unformatted Pages will be used.

Next Page message codes should be allocated globally across Selector Field values so that meaningful communication is possible between technologies using different Selector Field values.

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Annex 28C

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Next Page Message Code field definitions

The Message Code Field of a message page used in Next Page exchange shall be used to identify the meaning of a message. The following table identifies the types of messages that may be sent. As new messages are developed, this table will be updated accordingly.

The Message Code Field uses an 11-bit binary encoding that allows 2048 messages to be defined. All message codes not specified shall be reserved for IEEE use or allocation. Devices that have negotiated Extended Next Page support transmit Extended Next Pages but not other Next Pages.

Extended Next Pages are used to transmit Extended Next Page message codes and the subsequent Extended Next Pages and extended Unformatted Pages. In addition, Extended Next Pages may be used to transmit multiple Message Pages and Unformatted Pages in the following manner. The Message Code Field is mapped to bits M0:10 of the extended Message Page, and the first two Unformatted Code Fields associated with the Message Code Field value are mapped to bits U0:U10 and U16:U26, respectively, of the extended Message Page. Additional Unformatted Code Fields would be mapped to bits U0:U42 of subsequent extended Unformatted Pages. Any unused bits in the Extended Next Pages are transmitted as zero and ignored by the receiver.

If more than two Unformatted Code fields are required by a message code, then additional Unformatted Code Fields are transmitted in the extended Unformatted Pages immediately following the extended Message Page. Up to three Unformatted Code Fields can be transmitted in each extended Unformatted Page, the first in bits U0:10, the second in bits U11:21, and the third in bits U27:37.

When a message code requires the transmission of one or more extended Unformatted Pages, due to the number of Unformatted Code Fields it defines, the Unformatted Code Fields in the extended Message and extended Unformatted Pages shall be in the order specified by the message code.

Table 28C–1—Message code field values

Message code	M 10	M 9	M 8	M 7	M 6	M 5	M 4	M 3	M 2	M 1	M 0	Message code description
0	0	0	0	0	0	0	0	0	0	0	0	Reserved for future Auto-Negotiation use
1	0	0	0	0	0	0	0	0	0	0	1	Null Message
2	0	0	0	0	0	0	0	0	0	1	0	One UP with Technology Ability Field follows
3	0	0	0	0	0	0	0	0	0	1	1	Two UPs with Technology Ability Field follow
4	0	0	0	0	0	0	0	0	1	0	0	One UP with Binary coded Remote fault follows
5	0	0	0	0	0	0	0	0	1	0	1	Organizationally Unique Identifier Tagged Message
6	0	0	0	0	0	0	0	0	1	1	0	PHY Identifier Tag Code

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Table 28C–1—Message code field values *(continued)*

Message code	M 10	M 9	M 8	M 7	M 6	M 5	M 4	M 3	M 2	M 1	M 0	Message code description
7	0	0	0	0	0	0	0	0	1	1	1	100BASE-T2 Technology message code. 100BASE-T2 Ability Page to follow using Unformatted Next Page
8	0	0	0	0	0	0	0	1	0	0	0	1000BASE-T Technology message code. Two 1000BASE-T Ability Pages to follow using Unformatted Next Pages.
9	0	0	0	0	0	0	0	1	0	0	1	10GBASE-T/1000BASE-T Technology message code (Extended Next Page)
10	0	0	0	0	0	0	0	1	0	1	0	EEE Technology Message Code. EEE capability to follow using Unformatted Next Page.
11	0	0	0	0	0	0	0	1	0	1	1	Organizationally Unique Identifier Tagged Message (Extended Next Page)
12.....	0	0	0	0	0	0	0	1	1	0	0	Reserved for future Auto-Negotiation use
.....2047	1	1	1	1	1	1	1	1	1	1	1	Reserved for future Auto-Negotiation use

28C.1 Message code 0—Auto-Negotiation reserved code 1

This code is reserved for future Auto-Negotiation function enhancements. Devices shall not transmit this code.

28C.2 Message code 1—Null Message code

The Null Message code shall be transmitted during Next Page exchange when the Local Device has no further messages to transmit and the Link Partner is still transmitting valid Next Pages. See 28.2.3.4 for more details.

28C.3 Message code 2—Technology Ability extension code 1

This message code is reserved for future expansion of the Technology Ability Field and indicates that a defined user code with a specific Technology Ability Field encoding follows.

28C.4 Message code 3—Technology Ability extension code 2

This message code is reserved for future expansion of the Technology Ability Field and indicates that two defined user codes with specific Technology Ability Field encodings follow.

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28C.5 Message code 4—Remote fault number code

This message code shall be followed by a single user code whose encoding specifies the type of fault that has occurred. The following user codes are defined:

0: RF Test
This code can be used to test Remote Fault operation.
1: Link Loss
2: Jabber
3: Parallel Detection Fault
This code may be sent to identify when bit 6.4 is set.

28C.6 Message code 5—Organizationally Unique Identifier (OUI) tag code

The OUI Tagged Message shall consist of a single message code of 0000 0000 0101 followed by four user codes defined as follows. The first user code shall contain the most significant 11 bits of the OUI or CID (bits 23:13) with the most significant bit in bit 10 of the user code. The second user code shall contain the next most significant 11 bits of the OUI or CID (bits 12:2) with the most significant bit in bit 10 of the user code. The third user code shall contain the remaining least significant 2 bits of the OUI or CID (bits 1:0) with the most significant bit in bit 10 of the user code. Bits 8:0 of the third user code contain a user-defined user code value that is specific to the OUI or CID transmitted. The fourth and final user code shall contain a user-defined user code value that is specific to the OUI or CID transmitted.

For example, assume that a manufacturer's IEEE-assigned OUI/CID value is AC-DE-48 and the manufacturer-selected user-defined user code associated with the OUI/CID is $1100\,1110\,0001\,1111\,1100_2$. The message code values generated from these two numbers is encoded into four message codes, as specified in Figure 28C–1. For clarity, the position of the global broadcast *g* is illustrated.

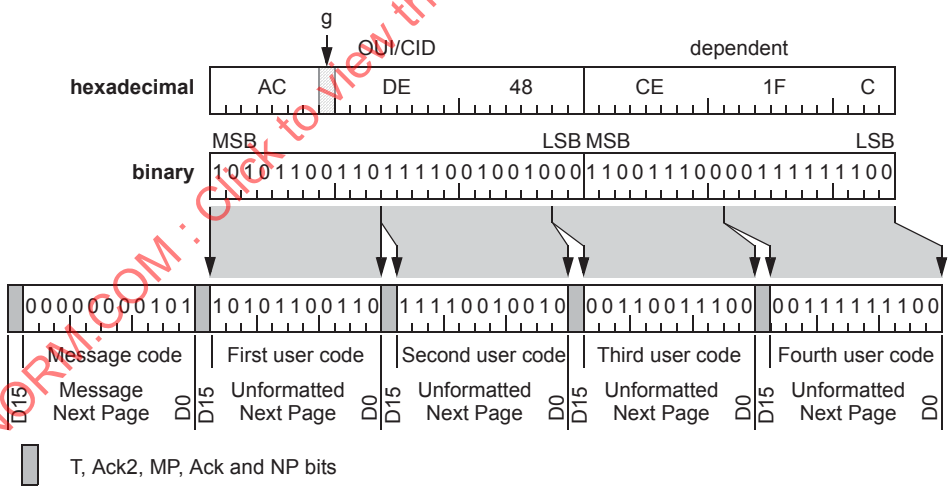

Figure 28C–1—Message code 5 sequence

NOTE—Figure 28C–1 shows the order Next Pages are transmitted, with the first transmitted Next Page shown in the leftmost position. While Figure 28–11 and Figure 28–12 use the convention that the most significant bit (i.e., the last bit to be transmitted) is the rightmost bit, Figure 28C–1 uses the opposite convention, i.e., the most significant bit of each page is shown in the leftmost position. This is a pictorial difference only; there is no difference in the actual order of bits transmitted.

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Devices that negotiate the use of Extended Next Page messages may use this message encapsulated within the Extended Next Page message as described in Annex 28C, however it is recommended that devices use message code 11 for Extended Next Page OUI tagged messages.

28C.7 Message code 6—PHY identifier tag code

The PHY ID tag code message shall consist of a single message code of 0000 0000 0110 followed by four user codes defined as follows. The first user code shall contain the most significant 11 bits of the PHY ID (2.15:5) with the most significant bit in bit 10 of the user code. The second user code shall contain bits 2.4:0 to 3.15:10 of the PHY ID with the most significant bit in bit 10 of the user code. The third user code shall contain bits 3.9:0 of the PHY ID with the most significant bit in bit 10 of the user code. Bit 0 in the third user code shall contain a user-defined user code value that is specific to the PHY ID transmitted. The fourth and final user code shall contain a user-defined user code value that is specific to the PHY ID transmitted.

28C.8 Message code 2047—Auto-Negotiation reserved code 2

This code is reserved for future Auto-Negotiation function enhancements. Devices shall not transmit this code.

28C.9 Message code 7—100BASE-T2 technology message code

Clause 32 (100BASE-T2) uses Next Page message code 7 to indicate that T2 implementations will follow the transmission of this page [the initial, Message (formatted) Next Page] with two Unformatted Next Pages which contain information defined in 32.5.4.2.

28C.10 Message code 8—1000BASE-T technology message code

Clause 40 (1000BASE-T) uses Next Page message code 8 to indicate that 1000BASE-T implementations will follow the transmission of this page [the initial, Message (formatted) Next Page] with two Unformatted Next Pages that contain information defined in 40.5.1.2.

28C.11 Message code 9—10GBASE-T and 1000BASE-T technology message code

Clause 55 (10GBASE-T) uses Extended Next Page message code 9 to indicate that 10GBASE-T and 1000BASE-T abilities are contained within this Extended Next Page. The Next Page that contains this information is defined in 55.6.1. This page shall not be sent if Extended Next Page mode is disabled.

28C.12 Message code 10—EEE technology message code

Multiple clauses use Next Page message code 10 to indicate that EEE technology messages will follow the transmission of this page [the initial, Message (formatted) Next Page] with one Unformatted Next Page. The contents of the unformatted code field bits (U10:U0) shall be as defined in 45.2.7.13.

EEE capability negotiation is defined in 78.3.

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28C.13 Message code 11—Organizationally Unique Identifier Tagged Message (Extended Next Page)

Devices that negotiate the use of Extended Next Page messages may use the Extended Next Page OUI Tagged Message. This shall consist of a single message code of 000 0000 1011 and bits U23-U0 of the unformatted code field shall contain the OUI or CID (with most significant bit of the OUI or CID in U23, the second most significant bit in U22, etc.). Bits U31-U24 contain user-defined data. If the Next Page flag is set, the message page shall be followed by an unformatted Extended Next Page containing user-defined data.

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Annex 28D

(normative)

Description of extensions to Clause 28 and associated annexes

28D.1 Introduction

This annex is to be used to document extensions and modifications to Clause 28 required by IEEE 802.3 clauses and other standards that use Auto-Negotiation and that were approved after July 1995. It provides a single location to define such extensions and modifications without changing the basic contents of Clause 28.

Subclause 28D.2 lists those clauses and standards that require extensions to Clause 28 and provides pointers to the subclauses where those extensions are listed.

28D.2 Extensions to Clause 28

28D.2.1 Extensions required for Clause 31 (full duplex)

Clause 31 (full duplex) requires the use of Auto-Negotiation. Extensions to Clause 28 and associated annexes required for the correct operation of full duplex are shown in 28D.3.

28D.2.2 Extensions required for Clause 32 (100BASE-T2)

Clause 32 (100BASE-T2) requires the use of Auto-Negotiation. Extensions to Clause 28 required for correct operation of 100BASE-T2 are shown in 28D.4.

28D.3 Extensions for Clause 31

Full duplex requires the use of bit A5 in the Technology Ability Field of the IEEE 802.3 Selector Base Page. (This bit is also defined as MII bit 4.10.) This bit was previously defined as “reserved for future technology.”

Bit	Technology	Minimum cabling requirement
A5	PAUSE operation for full duplex links	Not applicable

Bit A5 (PAUSE operation for full duplex links) signifies that the DTE has implemented both the optional MAC Control sublayer and the PAUSE function as specified in Clause 31 and Annex 31B. This capability is significant only when the link is configured for full duplex operation, regardless of data rate and medium.

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28D.4 Extensions for Clause 32 (100BASE-T2)

Clause 32 (100BASE-T2) makes special use of Auto-Negotiation and requires additional MII registers. This use is summarized below. Details are provided in 32.5.

Auto-Negotiation is mandatory for 100BASE-T2 (32.1.3.4).

100BASE-T2 introduces the concept of MASTER and SLAVE to define DTEs and to facilitate the timing of transmit and receive operations. Auto-Negotiation is used to provide information used to configure MASTER/SLAVE status (32.5.4.3).

100BASE-T2 uses unique Next Page transmit and receive registers (MII Registers 8, 9, and 10) in conjunctions with Auto-Negotiation. These registers are in addition to Registers 0–7 as defined in 28.2.4 (32.5.2).

100BASE-T2 use of Auto-Negotiation generates information which is stored in configuration and status bits defined for the MASTER-SLAVE Control register (MII Register 9) and the MASTER-SLAVE Status register (MII Register 10).

100BASE-T2 requires an ordered exchange of Next Page messages (32.5.1).

100BASE-T2 parameters are configured based on information provided by the ordered exchange of Next Page messages.

100BASE-T2 adds new message codes to be transmitted during Auto-Negotiation (32.5.4.2).

100BASE-T2 adds 100BASE-T2 full duplex and half duplex capabilities to the priority resolution table (28B.3) and MII Status Register (22.2.4.2).

T2 is defined as a valid value for “x” in 28.3.1 (e.g., link_status_T2). T2 represents that the 100BASE-T2 PMA is the signal source.

28D.5 Extensions required for Clause 40 (1000BASE-T)

Clause 40 (1000BASE-T) makes special use of Auto-Negotiation and requires additional MII registers. This use is summarized below. Details are provided in 40.5.

a) Auto-Negotiation is mandatory for 1000BASE-T (see 40.5.1).
b) 1000BASE-T requires an ordered exchange of Next Page messages (see 40.5.1.2), or optionally an exchange of an Extended Next Page message
c) 1000BASE-T parameters are configured based on information provided by the exchange of Next Page messages.
d) 1000BASE-T uses MASTER and SLAVE to define PHY operations and to facilitate the timing of transmit and receive operations. Auto-Negotiation is used to provide information used to configure MASTER-SLAVE status (see 40.5.2).
e) 1000BASE-T transmits and receives Next Pages for exchange of information related to MASTER-SLAVE operation. The information is specified in MII registers 9 and 10 (see 32.5.2 and 40.5.1.1), which are required in addition to registers 0-8 as defined in 28.2.4.
f) 1000BASE-T adds new message codes to be transmitted during Auto-Negotiation (see 40.5.1.3).
g) 1000BASE-T adds 1000BASE-T full duplex and half duplex capabilities to the priority resolution table (see 28B.3) and MII Extended Status Register (see 22.2.2.4).
h) 1000BASE-T is defined as a valid value for “x” in 28.3.1 (e.g., link_status_1GigT.) 1GigT represents that the 1000BASE-T PMA is the signal source.

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i) 1000BASE-T supports Asymmetric Pause as defined in Annex 28B.

28D.6 Extensions required for Clause 55 (10GBASE-T)

Clause 55 (10GBASE-T) makes special use of Auto-Negotiation and requires additional MDIO registers. This use is summarized below. Details are provided in 55.6.

a) Auto-Negotiation is mandatory for 10GBASE-T.
b) Extended Next Page support is mandatory for 10GBASE-T.
c) 10GBASE-T requires an exchange of an Extended Next Page message.
d) 10GBASE-T parameters are configured based on information provided by the exchange of an Extended Next Page message.
e) 10GBASE-T uses MASTER and SLAVE to define PHY operations and to facilitate the timing of transmit and receive operations. Auto-Negotiation is used to provide information used to configure MASTER-SLAVE status.
f) 10GBASE-T transmits and receives an Extended Next Page for exchange of information related to MASTER-SLAVE operation. The information is specified in 45.2.7.
g) 10GBASE-T adds new message codes to be transmitted during Auto-Negotiation.
h) 10GBASE-T adds 10GBASE-T full duplex capabilities to the priority resolution table (see 28B.3).
i) 10GBASE-T is defined as a valid value for "x" in 28.3.1 (e.g., link_status_10GigT.) 10GigT represents that the 10GBASE-T PMA is the signal source.
j) 10GBASE-T supports Asymmetric Pause as defined in Annex 28B.

28D.7 Extensions required for Energy-Efficient Ethernet (Clause 78)

Energy-Efficient Ethernet (Clause 78) makes use of Auto-Negotiation and requires additional MDIO registers. Auto-negotiation is mandatory for all EEE PHYs that support LPI. Details are provided in 78.3.

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Annex 29A

(informative)

DTE and repeater delay components

29A.1 DTE delay

Round-trip DTE delay = MAC transmit start to MDI output
+ MDI input to MDI output (worst case, nondeferred)
+ MDI input to collision detect

NOTE 1—Refer to Clause 23, Clause 24, Clause 25, and Clause 26.

NOTE 2—Worst-case values are used for the one T4 and one TX/FX value shown in Table 29–3. (TX/FX values for MAC transmit start and MDI input to collision detect; T4 value for MDI input to MDI output.)

29A.2 Repeater delay

Repeater delay= SOP (start-of-packet propagation delay)
+ SOJ (start-of-jam propagation delay)

NOTE—Refer to Clause 27.

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Annex 29B

(informative)

Recommended topology documentation

It is strongly recommended that detailed records documenting the topology components of 100BASE-T networks be prepared and maintained to facilitate subsequent modification. Proper 100BASE-T topology design requires an accurate knowledge of link segment and hub parameters to ensure proper operation of single and multisegment, single collision domain networks. Link segment documentation is site-specific and requires careful documentation. It is recommended that the information shown in Table 29B–1 be collected for each link segment and archived for future reference. Hub performance parameters may be obtained from manufacturer documentation.

Table 29B–1—Recommended link segment documentation

	Horizontal wiring (wiring closet, from punch-down block to end station wall plate)	MII cable(s)	Wiring closet patch cord	End station connecting cable
Length				
Type (e.g., Category 3)				
Cable manufacturer				
Cable code/id (from manufacturer)				
Cable delay (in bit times per meter)				

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Annex 30A

(normative)

GDMO specification for IEEE 802.3 managed object classes

NOTE—The GDMO specification was moved to IEEE Std 802.3.1-2011.

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Annex 30B

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GDMO and ASN.1 definitions for management

NOTE—The GDMO specification was moved to IEEE Std 802.3.1-2011 Clause C.1 Common attributes template.

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Annex 30C

(normative)

SNMP MIB definitions for Link Aggregation

NOTE—The SNMP for Link Aggregation specification was moved to IEEE Std 802.1AX-2008.

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Annex 31A

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MAC Control opcode assignments

Table 31A–1 shows the currently defined opcode values and interpretations:

Table 31A–1—MAC Control opcodes

Opcode (Hexadecimal)	MAC Control function	Specified in	Value/Comment	Timestamp[a]
00-00	Reserved			
00-01	PAUSE	Annex 31B	Requests that the recipient stop transmitting non-control frames for a period of time indicated by the parameters of this function.	No
00-02	GATE	Clause 64, Clause 77	Request that the recipient allow transmission of frames at a time, and for a period of time indicated by the parameters of this function.	Yes
00-03	REPORT	Clause 64, Clause 77	Notify the recipient of pending transmission requests as indicated by the parameters of this function.	Yes
00-04	REGISTER_REQ	Clause 64, Clause 77	Request that the station be recognized by the protocol as participating in a gated transmission procedure as indicated by the parameters of this function.	Yes
00-05	REGISTER	Clause 64, Clause 77	Notify the recipient that the station is recognized by the protocol as participating in a gated transmission procedure as indicated by the parameters of this function.	Yes
00-06	REGISTER_ACK	Clause 64, Clause 77	Notify the recipient that the station acknowledges participation in a gated transmission procedure.	Yes
00-07 through 01-00	Reserved			
01-01	PFC	Annex 31D and IEEE Std 802.1Q	Requests that the recipient stop transmissions in the priorities indicated in the parameters of the function for a period of time also indicated in the parmeters.	No
01-02 through FF-FD	Reserved			
FF–FE	EXTENSION	Annex 31C	This frame is used for Organization–Specific Extension. Upon reception of this message, the MAC Control generates MA_CONTROL.Indication informing the MAC Control Client to perform the relevant action.	No
FF-FF	Reserved			

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[a]The timestamp field is generated by MAC Control and is not exposed through the client interface.

Opcodes are transmitted high-order octet first. Within each octet, bits are transmitted least-significant bit first. Reserved opcodes shall not be used by MAC Control sublayer entities.

Table 31A–2 through Table 31A–9 show the elements and semantics of the indication_operand_list for MA_CONTROL.indication primitives for each currently defined opcode value in Table 31A–1:

Table 31A–2—PAUSE MAC Control indications

PAUSE (opcode 0x0001)		
indication_operand_list element	**Value**	**Interpretation**
pause_status	paused	Indicates that the PAUSE function is inhibiting transmission of data frames by the MAC client.
	not_paused	Indicates that the PAUSE function is not inhibiting transmission of data frames by the MAC client.

Table 31A–3—GATE MAC Control indications

GATE (opcode 0x0002)		
indication_operand_list element	**Value**	**Interpretation**
start	32 bit	Time when transmission should be initiated.
length	16 bit	Interval of time during which transmission is allowed.
status	arrive	Indicates that a grant has been received for future activation.
	active	Indicates that the GATE function is allowing transmission of frames.
	deactive	Indicates that the GATE function is inhibiting transmission of frames.
force_report	true	The OLT expects the ONU to transmit a REPORT message during the transmission opportunity identified by start and length fields.
	false	The OLT does not request the ONU to transmit a REPORT message during the transmission opportunity identified by start and length fields.
discovery	true	This grant is reserved for use during discovery.
	false	This grant is not reserved for use by the discovery process, and is available for use by all traffic.
discoveryInformation[a]	16 bits	See Table 77–3 for the internal structure of the discoveryInformation field.

[a]Only present in 10G–EPON GATE MAC Control indication (Clause 77).

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Table 31A–4—REPORT MAC Control indications

REPORT (opcode 0x0003)		
indication_operand_list element	**Value**	**Interpretation**
RTT	32 bit	Indicates the calculated round trip time for the station, as calculated following the REPORT message reception.
n	Integer	Indicates the number of queue status reports present
report_list	valid[8]	Indicates whether the corresponding status element is present when set to true.
	status[8]	Indicates amount of data waiting in the corresponding queue including the associated transmission overhead.

Table 31A–5—REGISTER_REQ MAC Control indications

REGISTER_REQ (opcode 0x0004)		
indication_operand_list element	**Value**	**Interpretation**
status	incoming	Indicates that a station is requesting recognition.
	retry	Indicates that the station should reattempt registration.
flags	register	Indicates that the station is requesting to register.
	deregister	Indicates that the station is requesting to deregister.
pending_grants	Integer	Indicates the maximal number of future GATES that can be stored by the GATE function.
RTT	32 bit	Indicates the calculated round trip time for the station, as calculated following the REGISTER_REQ message reception.
laserOnTime[a]	8 bits	Indicates the Laser On Time characteristic for the given ONU transmitter, expressed in the units of time_quanta.
laserOffTime[a]	8 bits	Indicates the Laser Off Time characteristic for the given ONU transmitter, expressed in the units of time_quanta.
discoveryInformation[a]	16 bits	See Table 77–7 for the internal structure of the discoveryInformation field.

[a]Only present in 10G–EPON REGISTER_REQ MAC Control indication (Clause 77).

Table 31A–6—REGISTER MAC Control indications

REGISTER (opcode 0x0005)		
indication_operand_list element	**Value**	**Interpretation**
SA	48 bit	MAC address of OLT to which registration is being performed.
ID	16 bit	LLID assigned by the OLT for use by the ONU.

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Table 31A–6—REGISTER MAC Control indications *(continued)*

REGISTER (opcode 0x0005)		
indication_operand_list element	**Value**	**Interpretation**
status	accepted	Indicates that the requested registration is successful.
	denied	Indicates that the requested registration attempt is denied by the higher-layer-entity.
	deregistered	Indicates that the ONU has been deregistered, i.e., the associated LLID has been deallocated.
	reregistered	Indicates that the ONU is explicitly asked to re-register.
laserOnTime[a]	8 bits	Indicates the Laser On Time characteristic for the given ONU transmitter, expressed in the units of time_quanta.
laserOffTime[a]	8 bits	Indicates the Laser Off Time characteristic for the given ONU transmitter, expressed in the units of time_quanta.

[a]Only present in 10G–EPON REGISTER MAC Control indication (Clause 77).

Table 31A–7—REGISTER_ACK MAC Control indications

REGISTER_ACK (opcode 0x0006)		
indication_operand_list element	**Value**	**Interpretation**
SA	48 bit	MAC address of ONU to which registration is being performed.
ID	16 bit	Indicates the LLID allocated to the ONU.
status	accepted	Indicates the station has been recognized as participating in gated transmission.
	denied	Indicates the station has been excluded from participating in gated transmission.
	reset	Indicates the station has been requested to resubmit a registration request.
	deregistered	Indicates that the station will no longer be participating in gated transmission.
RTT	32 bit	Indicates the calculated round trip time for the station, as calculated following the REGISTER_ACK message reception.

Table 31A–8—EXTENSION MAC Control indications

EXTENSION (opcode 0xFFFE)		
indication_operand_list element	**Value**	**Interpretation**
OUI	24 bits	Organizationally-Unique Identifier (OUI) or Company ID (CID) that determines the format and semantics of the Value field and its subfields, if any are defined.
Value	Variable	Organization-specific value, distinguished by the OUI or CID.

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Table 31A–9—PFC MAC Control indications

PFC (opcode 0x0101)		
indication_operand_list element	**Value**	**Interpretation**
priority_enable_vector	2 octets	The most significant octet is reserved (i.e., set to zero on transmission and ignored on receipt). Each bit of the least significant octet indicates if the corresponding field in the time_vector parameter is valid. The bits of the least significant octet are named e[0] (the least significant bit) to e[7] (the most significant bit). Bit e[n] refers to Priority n. For each e[n] bit set to one, the corresponding time[n] value is valid. For each e[n] bit set to zero, the corresponding time[n] value is invalid.
time_vector	a list of eight 2-octet unsigned integers	A list of eight 2-octet fields named time[0] to time[7]. The eight time[n] values are always present regardless of the value of the corresponding e[n] bit. Each time[n] field is a 2-octet, unsigned integer containing the length of time for which the receiving station is requested to inhibit transmission of data frames associated with Priority n. The field is transmitted most significant octet first, and least significant octet second. The time[n] fields are transmitted sequentially, with time[0] transmitted first and time[7] transmitted last. Each time[n] value is measured in units of pause_quanta, equal to the time required to transmit 512 bits of a frame at the data rate of the MAC. Each time[n] field can assume a value in the range of 0 to 65 535 pause_quanta.

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Annex 31B

(normative)

MAC Control PAUSE operation

31B.1 PAUSE description

The PAUSE operation is used to inhibit transmission of data frames for a specified period of time. A MAC Control client wishing to inhibit transmission of data frames from another station on the network generates a MA_CONTROL.request primitive specifying:

a) The globally assigned 48-bit multicast address 01-80-C2-00-00-01,
b) The PAUSE opcode,
c) A request_operand indicating the length of time for which it wishes to inhibit data frame transmission. (See 31B.2.)

The PAUSE operation cannot be used to inhibit transmission of MAC Control frames.

PAUSE frames shall only be sent by DTEs configured to the full duplex mode of operation.

The globally assigned 48-bit multicast address 01-80-C2-00-00-01 has been reserved for use in MAC Control PAUSE frames for inhibiting transmission of data frames from a DTE in a full duplex mode IEEE 802.3 LAN. IEEE 802.1D-conformant bridges will not forward frames sent to this multicast destination address, regardless of the state of the bridge's ports, or whether or not the bridge implements the MAC Control sublayer. To allow generic full duplex flow control, stations implementing the PAUSE operation shall instruct the MAC (e.g., through layer management) to enable reception of frames with destination address equal to this multicast address.

NOTE—By definition, an IEEE 802.3 LAN operating in full duplex mode comprises exactly two stations, thus there is no ambiguity regarding the destination DTE's identity. The use of a well-known multicast address relieves the MAC Control sublayer and its client from having to know, and maintain knowledge of, the individual 48-bit address of the other DTE in a full duplex environment.

When MAC Control PFC operation (see Annex 31D and IEEE Std 802.1Q) has been enabled, MAC Control PAUSE operation shall be disabled.

31B.2 Parameter semantics

The PAUSE opcode takes the following request_operand:

pause_time
: A 2-octet, unsigned integer containing the length of time for which the receiving station is requested to inhibit data frame transmission. The field is transmitted most-significant octet first, and least-significant octet second. The pause_time is measured in units of pause_quanta, equal to 512 bit times of the particular implementation (see 4.4). The range of possible pause_time is 0 to 65535 pause_quanta.

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31B.3 Detailed specification of PAUSE operation

The state machines in 31B.3 follow the conventions in 21.5. (See 25.1.1 for an example statement. That also covers the timer conventions from 14 which apply here.)

31B.3.1 Transmit operation

Upon receipt of a MA_CONTROL.request primitive containing the PAUSE opcode from a MAC client, the MAC Control sublayer calls the MAC sublayer MAC:MA_DATA.request service primitive with the following parameters:

a) The destination_address is set equal to the destination_address parameter of the MA_CONTROL.request primitive. This parameter is currently restricted to the value specified in 31B.1.
b) The source_address is set equal to the 48-bit individual address of the station.
c) The length/type field (i.e., the first two octets) within the mac_service_data_unit parameter is set to the IEEE 802.3 MAC Control Ethertype value assigned in 31.4.1.3.
d) The remainder of the mac_service_data_unit is set equal to the concatenation of the PAUSE opcode encoding (see Annex 31A), the pause_time request operand specified in the MA_CONTROL.request primitive, and a field containing zeros of the length specified in 31.4.1.6.
e) The frame_check_sequence is omitted.

Upon receipt of a data transmission request from the MAC client through the MCF:MA_DATA.request primitive, if the transmission of data frames has not been inhibited due to reception of a valid MAC Control frame specifying the PAUSE operation and a non-zero pause_time, the MAC Control sublayer calls the MAC sublayer MAC:MA_DATA.request service primitive with its parameters identical to the MCF:MA_DATA.indication primitive.

31B.3.2 Transmit state diagram for PAUSE operation

It is not required that an implementation be able to transmit PAUSE frames. MAC Control sublayer entities that transmit PAUSE frames shall implement the Transmit state diagram specified in this subclause.

31B.3.2.1 Constants

pause_command
: The 2-octet encoding of the PAUSE command, as specified in Annex 31A.

reserved_multicast_address
: The 48-bit address specified in 31B.1 (a).

802.3_MAC_Control
: The 16 bit Ethertype field assignment for 802.3 MAC Control specified in 31.4.1.3.

phys_Address
: A 48-bit value, equal to the unicast address of the station implementing the MAC Control sublayer.

31B.3.2.2 Variables

transmitEnabled
: A Boolean set by network management to indicate that the station is permitted to transmit on the network.

Values: true; Transmitter is enabled by management
false; Transmitter is disabled by management

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transmission_in_progress
: A Boolean used to indicate to the Receive state diagram that a MAC:MA_DATA.request service primitive call is pending.
Values: true; transmission is in progress
false; transmission is not in progress

n_quanta_tx
: An integer indicating the number of pause_quanta that the transmitter of a PAUSE frame is requesting that the receiver pause.

pause_timer_Done
: A Boolean set by the MAC Control PAUSE Operation Receive state diagram to indicate the expiration of a pause_timer initiated by reception of a MAC Control frame with a PAUSE opcode.
Values: true; The pause_timer has expired.
false; The pause_timer has not expired.

pause_mac_service_data_unit
: The concatenation of IEEE 802.3_MAC_Control, pause_command, n_quanta_tx, zeros.

31B.3.2.3 Functions

None

31B.3.2.4 Timers

pause_timer
: The timer governing the inhibition of transmission of data frames (see 31.5.1) from a MAC Client by the PAUSE function.

31B.3.2.5 Messages

MA_CONTROL.request
: The service primitive used by a client to request a MAC Control sublayer function with the specified request_operands.

MCF:MA_DATA.request
: The service primitive used by a client to request MAC data transmission with the specified parameters.

MAC:MA_DATA.request
: The service primitive issued by the MAC Control sublayer to transmit a MAC frame with the specified parameters. The action invoked is not considered to end until the transmission of the frame by the MAC has concluded and the ability of the MAC control layer to determine this is implementation dependent.

31B.3.2.6 Transmit state diagram for PAUSE operation

Figure 31B–1 depicts the Transmit state diagram for a MAC Control sublayer entity implementing the PAUSE operation.

31B.3.3 Receive operation

The opcode-independent MAC Control sublayer Receive state diagram accepts and parses valid frames received from the MAC sublayer. MAC Control sublayer entities that implement the PAUSE operation shall implement the Receive state diagram specified in this subclause. The functions specified in this subclause are performed upon receipt of a valid Control frame containing the PAUSE opcode, and define the function called by the INITIATE MAC CONTROL FUNCTION state of Figure 31–4. (See 31.5.3.)

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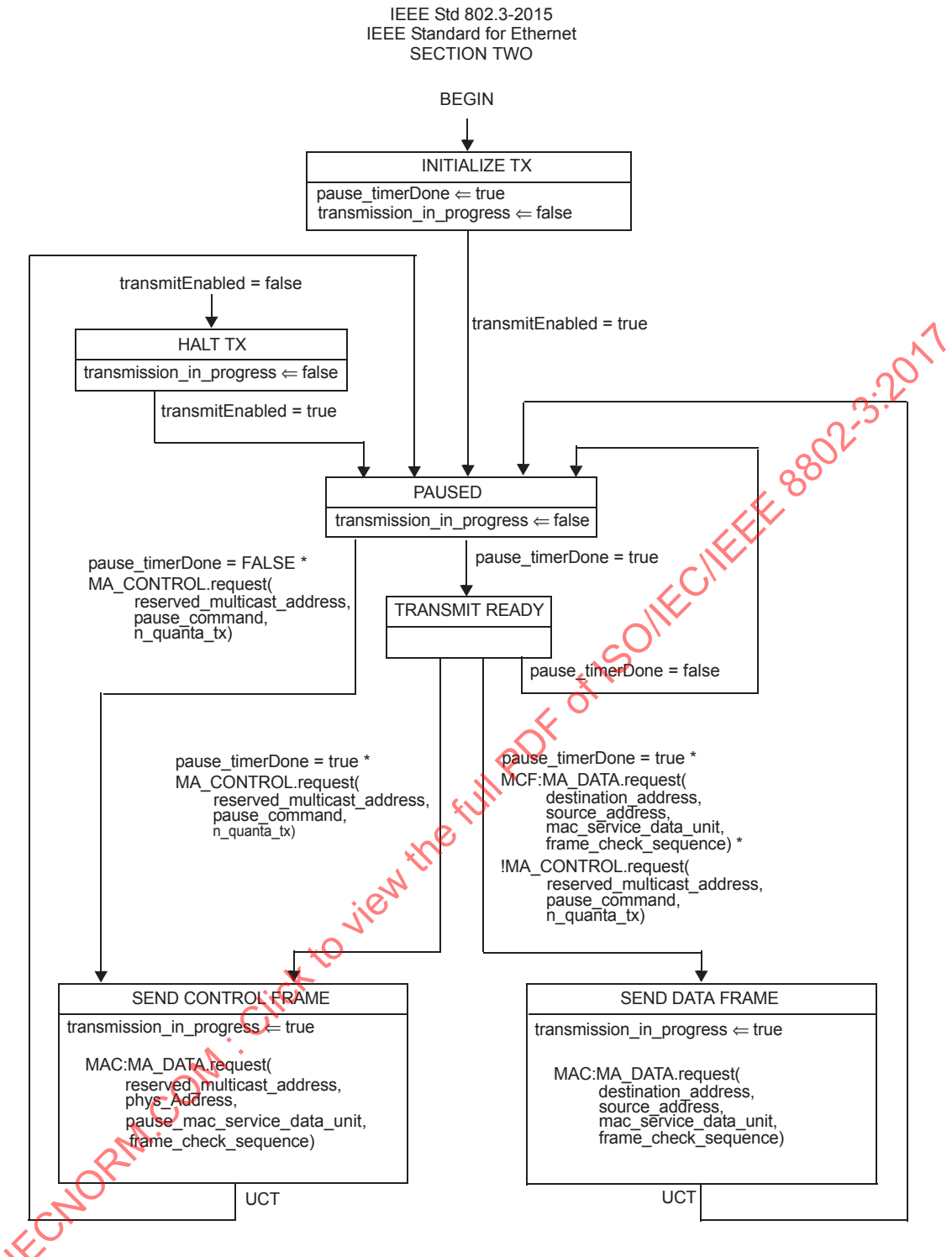

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Figure 31B–1—PAUSE Operation Transmit state diagram

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Upon receipt of a valid MAC Control frame with the opcode indicating PAUSE and the destination address indicating either: (1) the reserved multicast address specified in 31B.1, or (2) the unique physical address associated with this station, the MAC Control sublayer starts a timer for the length of time specified by the pause_time request_operand in the Control frame (see 31B.2). The value of the variable pause_timer_Done is set to false upon the setting of the pause_timer to a non-zero value by the MAC Control PAUSE Operation Receive state diagram. The value of the variable pause_timer_Done is set to true when the timer value reaches zero (i.e., the timer expires). If the received PAUSE operation indicates a pause_timer value of zero, the value of pause_timer_Done is set to true immediately.

The receipt of a valid MAC Control frame with the opcode indicating PAUSE and the destination address indicating the reserved multicast address specified in 31B.1 or the unique physical address associated with this station will cause the pause_timer to be set according to the pause_time request_operand in the newly received frame, regardless of the current setting of the pause_timer, i.e., new PAUSE operations override earlier PAUSE operations.

31B.3.4 Receive state diagram for PAUSE operation

31B.3.4.1 Constants

pause_quantum
: The unit of measurement for pause time specified in 31B.2.

pause_command
: The 2-octet encoding of the PAUSE command, as specified in Annex 31A.

reserved_multicast_address
: The 48-bit address specified in 31B.1 (a).

phys_Address
: A 48-bit value, equal to the unicast address of the station implementing the MAC Control sublayer.

31B.3.4.2 Variables

n_quanta_rx
: An integer used to extract the number of pause_quanta to set the pause_timer from the dataParam of the received MAC frame.

opcode
: The opcode parsed from the received MAC frame.

DA
: The destination address from the MAC:MA_DATA.indication service primitive.

data
: The data payload parsed from the received MAC frame.

transmission_in_progress
: A Boolean used by the Transmit state diagram to indicate that a MAC:MA_DATA.request service primitive call is pending.
Values: true; transmission is in progress
false; transmission is not in progress

31B.3.4.3 Timers

pause_timer
: The timer governing the inhibition of transmission of data frames.

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31B.3.4.4 Receive state diagram (INITIATE MAC CONTROL FUNCTION) for PAUSE operation

Figure 31B–2 depicts the INITIATE MAC CONTROL FUNCTION for the PAUSE operation. (See 31.5.3.)

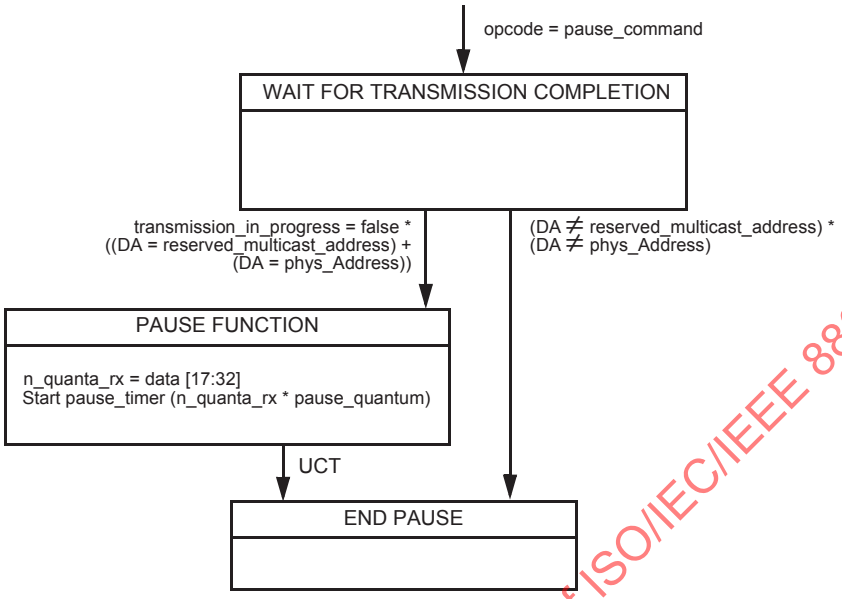

Figure 31B–2—PAUSE Operation Receive state diagram

31B.3.5 Status indication operation

MAC Control sublayer entities that implement the PAUSE operation shall implement the Indication state diagram specified in this subclause.

The PAUSE function sets the pause status variable to one of two values: paused or not_paused, and indicates this to its client through the MA_CONTROL.indication primitive.

31B.3.6 Indication state diagram for pause operation

31B.3.6.1 Constants

pause_command
: The 2-octet encoding of the PAUSE command, as specified in Annex 31A.

31B.3.6.2 Variables

pause_status
: Used to indicate the state of the MAC Control sublayer for the PAUSE operation. It takes one of two values: paused or not_paused.

pause_timer_Done
: A Boolean set by the MAC Control PAUSE Operation Receive state diagram to indicate the expiration of a pause_timer initiated by reception of a MAC Control frame with a PAUSE opcode.

Values: true; The pause_timer has expired.
false; The pause_timer has not expired.

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31B.3.6.3 Messages

MA_CONTROL.indication

The service primitive used to indicate the state of the MAC Control sublayer to its client.

31B.3.6.4 Indication state diagram for PAUSE operation

Figure 31B–3 depicts the Indication State Diagram for a MAC Control sublayer implementing the PAUSE operation.

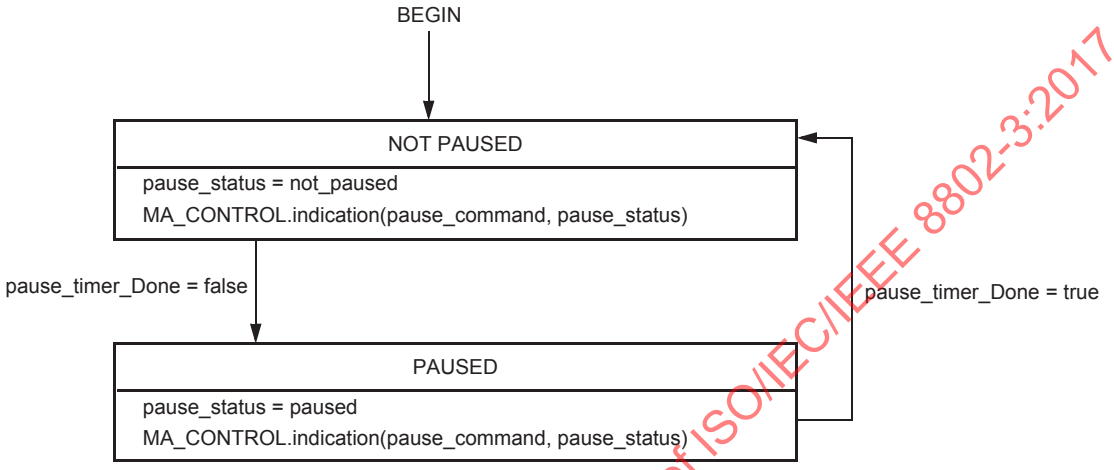

Figure 31B–3—PAUSE Operation Indication state diagram

31B.3.7 Timing considerations for PAUSE operation

In a full duplex mode DTE, it is possible to receive PAUSE frames asynchronously with respect to the transmission of MAC frames. For effective flow control, it is necessary to place an upper bound on the length of time that a DTE can transmit data frames after receiving a valid PAUSE frame with a non-zero pause_time request_operand.

Reception of a PAUSE frame shall not affect the transmission of a MAC frame that has been submitted by the MAC Control sublayer to the underlying MAC (i.e., the MAC:MA_DATA.request service primitive is synchronous, and is never interrupted).

At operating speeds of 100 Mb/s or less, a station that implements an exposed MII, shall not begin to transmit a (new) frame (assertion of TX_EN at the MII, see 22.2.2.3) more than one pause_quantum after the reception of a valid PAUSE frame (deassertion of RX_DV at the MII, see 22.2.2.7) that contains a nonzero value of pause_time. Stations that do not implement an exposed MII, shall measure this time at the MDI, with the timing specification increased to one pause_quantum + 64 BT.

At an operating speed of 1000 Mb/s, a station shall not begin to transmit a (new) frame more than two pause_quanta after the reception of a valid PAUSE frame that contains a non-zero value of pause_time, as measured at the MDI.

At operating speeds of 10 Gb/s, a station with a 10GBASE-T PHY shall not begin to transmit a (new) frame more than 74 pause_quanta after the reception of a valid PAUSE frame that contains a non-zero value of pause_time, as measured at the MDI. A station using any other 10 Gb/s PHY shall not begin to transmit a (new) frame more than 60 pause_quanta after the reception of a valid PAUSE frame that contains a non-zero value of pause_time, as measured at the MDI.

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At operating speeds of 40 Gb/s, a station shall not begin to transmit a (new) frame more than 118 pause_quanta after the reception of a valid PAUSE frame that contains a non-zero value of pause_time, as measured at the MDI.

At operating speeds of 100 Gb/s, a station shall not begin to transmit a (new) frame more than 394 pause_quanta after the reception of a valid PAUSE frame that contains a non-zero value of pause_time, as measured at the MDI.

In addition to DTE and MAC Control delays, system designers should take into account the delay of the link segment when designing devices that implement the PAUSE operation.

The PAUSE response time may be verified by demonstrating that no more than max_overrun bytes of frame data are sent by the station after reception of a valid PAUSE frame that contains a non-zero value of pause_time. The value of max_overun is defined for the following operating speeds, where frame_length is the maximum frame length transmitted by the station during the test:

10 Gb/s (using 10GBASE-T) - max_overrun = 4736 + frame_length.

10 Gb/s (not using 10GBASE-T) - max_overrun = 3840 + frame_length.

40 Gb/s - max_overrun = 7552 + frame_length.

100 Gb/s - max_overrun = 25216 + frame_length.

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31B.4 Protocol implementation conformance statement (PICS) proforma for MAC Control PAUSE operation[22]

31B.4.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Annex 31B, MAC Control PAUSE operation, shall complete the following PICS proforma in addition to the PICS of Clause 31.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

31B.4.2 Identification

31B.4.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations, other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

31B.4.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Annex 31B, MAC Control PAUSE operation
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; The answer Yes means that the implementation does not conform to IEEE Std 802.3-2015)	

Date of Statement	

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31B.4.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*PST	Support for transmit of PAUSE frames	31B.3.2	N/A	O	Yes [ ] No [ ]
*MIIa	At operating speeds of 100 Mb/s or less, MII connection exists and is accessible for test.	31B.3.7	N/A	O	Yes [ ] No [ ]
*MIIb	At operating speeds of 100 Mb/s or less, MII connection does not exist or is not accessible for test.	31B.3.7	N/A	O	Yes [ ] No [ ]
*MIIc	At operating speeds of 1000 Mb/s	31B.3.7	N/A	O	Yes [ ] No [ ]
*MIId	At operating speeds of 10 Gb/s with PHY types other than 10GBASE-T.	31B.3.7	N/A	O	Yes [ ] No [ ]
*MIIe	At operating speeds of 10 Gb/s with PHY types of 10GBASE-T.	31B.3.7	N/A	O	Yes [ ] No [ ]
*MIIf	At operating speeds of 40 Gb/s.	31B.3.7	N/A	O	Yes [ ] No [ ]
*MIIg	At operating speeds of 100 Gb/s.	31B.3.7	N/A	O	Yes [ ] No [ ]

31B.4.4 PAUSE command requirements

Item	Feature	Subclause	Value/Comment	Status	Support
PCR1	Duplex mode of DTE	31B.1	Full duplex	M	Yes [ ]
PCR2	Reception of frames with destination address equal to the multicast address 01-80-C2-00-00-01	31B.1	Enabled	M	Yes [ ]
PCR3	PAUSE operation on PFC enable	31B.1	Disabled	PFC: M	Yes [ ]

31B.4.5 PAUSE command state diagram requirements

Item	Feature	Subclause	Value/Comment	Status	Support
PSD1	Transmit state diagram for PAUSE operation	31B.3.2	Meets requirements of Figure 31B–1	PST: M	N/A [ ] M:Yes [ ]
PSD2	Receive state diagram for PAUSE operation	31B.3.4	Meets requirements of Figure 31B–2	M	Yes [ ]
PSD3	Indication state diagram for PAUSE operation	31B.3.6	Meets requirements of Figure 31B–3	M	Yes [ ]

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31B.4.6 PAUSE command MAC timing considerations

Item	Feature	Subclause	Value/Comment	Status	Support
TIM1	Effect of PAUSE frame on a frame already submitted to underlying MAC	31B.3.7	Has no effect	M	Yes [ ]
	Delay from receiving valid PAUSE command, with non-zero value for pause_time, to cessation of transmission	31B.3.7	Measured as described		
TIM2	Measurement point for station with MII		Delay at MII ≤ one pause_quantum	MIIa: M	N/A [ ] M: Yes [ ]
TIM3	Measurement point for station without MII at 100 Mb/s or less		Delay at MDI ≤ one pause_quantum + 64 BT	MIIb: M	N/A [ ] M: Yes [ ]
TIM4	Measurement point for station at 1000 Mb/s		Delay at MDI ≤ two pause_quanta	MIIc: M	N/A [ ] M: Yes [ ]
TIM5	Measurement point for station at 10 Gb/s with PHY types other than 10GBASE-T		Delay at MDI ≤ 60 pause_quanta	MIId: M	N/A [ ] M: Yes [ ]
TIM6	Measurement point for station at 10Gb/s with PHY type of 10GBASE-T		Delay at MDI ≤ 74 pause_quanta	MIIe: M	N/A [ ] M: Yes [ ]
TIM7	Measurement point for station at 40 Gb/s		Delay at MDI ≤ 118 pause_quanta	MIIf: M	N/A [ ] M: Yes [ ]
TIM8	Measurement point for station at 100 Gb/s		Delay at MDI ≤ 394 pause_quanta	MIIg: M	N/A [ ] M: Yes [ ]

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Annex 31C

(normative)

MAC Control organization specific extension operation

31C.1 Organization specific extension description

The extension operation is used to provide a standardized means for other organizations, to define their own MAC Control protocols outside the scope of this standard. The requirements defined in Clause 31 apply to these protocols.

31C.2 Transmission of Extension MAC Control frame

Upon receipt of a MA_CONTROL.request primitive containing the EXTENSION opcode from a MAC client, the MAC control sublayer calls the MAC sublayer MAC:MA_DATA.request service primitive with the following parameters:

a) The destination_address is set equal to the destination_address parameter of the MA_CONTROL.request primitive. This parameter is currently restricted to either the value 01–80–C2–00–00–01 or to the 48 bit individual address of the destination station.
b) The source_address is set equal to the 48 bit individual address of the station.
c) The length/type field (i.e., the first two octets) within the mac_service_data_unit parameter is set to the IEEE 802.3 MAC Control Ethertype value assigned in 31.4.1.3.
d) The remainder of the mac_service_data_unit is set to the concatenation of the Extension Opcode, Organizationally Unique Identifier (OUI) or Company ID (CID)[23] assigned to the organization by the IEEE, and the organization-specific data.
e) The frame_check_sequence is omitted.

MAC Control sublayer entities that transmit or receive EXTENSION frames shall pass them through without additional processing.

31C.3 Receive operation

The opcode–independent MAC Control sublayer Receive state diagram accepts and parses valid frames received from the MAC sublayer. MAC Control sublayer entities that implement the EXTENSION operation shall implement the Receive state diagram specified in this subclause. The functions specified in this subclause are performed upon receipt of a valid Control frame containing the EXTENSION opcode and define the function called by the INITIATE MAC CONTROL FUNCTION state of Figure 31–4 (see 31.5.3).

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[23]Details defining the format of OUIs and CIDs can be found in IEEE Std 802-2014. Interested applicants should contact the IEEE Standards Department, Institute of Electrical and Electronics Engineers, http://standards.ieee.org/develop/regauth/, 445 Hoes Lane, Piscataway, NJ 08854, USA.

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31C.3.1 Receive state diagram (INITIATE MAC CONTROL FUNCTION) for EXTENSION operation

Figure 31C–2 depicts the INITIATE MAC CONTROL FUNCTION for the EXTENSION operation (see 31.5.3). Upon reception of EXTENSION frames, the frame is sent to the MAC CONTROL client.

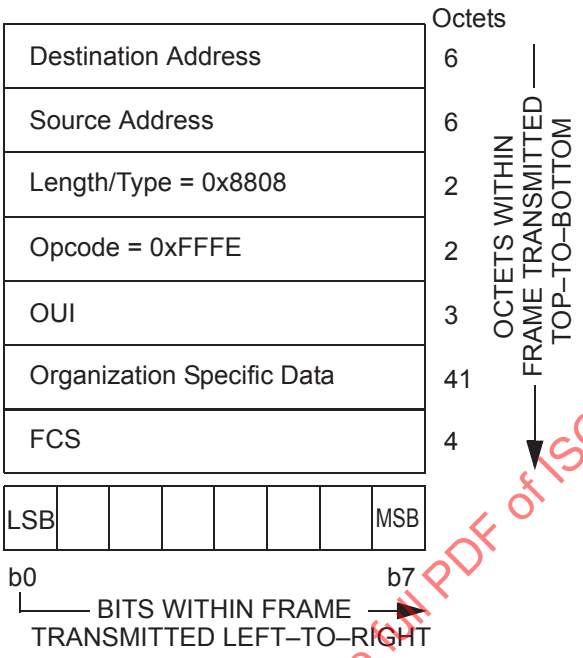

Figure 31C–1—MAC Control EXTENSION Frame

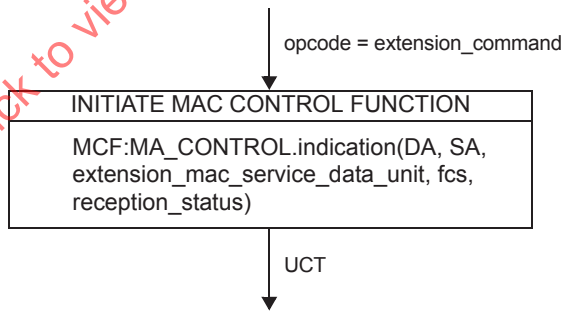

Figure 31C–2—EXTENSION receive function

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31C.4 Protocol implementation conformance statement (PICS) proforma for MAC Control organization specific extension operation[24]

31C.4.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Annex 31A, MAC Control organization specific extension operation, shall complete the following PICS proforma in addition to the PICS of Clause 31.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

31C.4.2 Identification

31C.4.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations, other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

31C.4.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Annex 31A, MAC Control organization specific extension operation
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; The answer Yes means that the implementation does not conform to IEEE Std 802.3-2015)	

Date of Statement	

31C.4.3 EXTENSION command state diagram requirements

Item	Feature	Subclause	Value/Comment	Status	Support
ESD1	Receive state diagram for EXTENSION operation	31C.3	Meets requirements of Figure 31C–2	M	Yes [ ]

[24]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this annex so that it can be used for its intended purpose and may further publish the completed PICS.

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Annex 31D

(normative)

MAC Control PFC operation

31D.1 PFC description

The Priority-based Flow Control (PFC) operation is used to inhibit transmission of data frames on one or more priorities for a specified period of time. The behavior of a MAC Control client supporting PFC operation is specified in IEEE Std 802.1Q. A MAC Control client wishing to inhibit transmission of data frames from the link partner generates a MA_CONTROL.request primitive specifying:

a) The globally assigned 48-bit multicast address 01-80-C2-00-00-01,
b) The PFC opcode,
c) A request_operand list with two operands: priority_enable_vector and time_vector. (See 31D.2)

Unlike the MAC Control PAUSE operation, the inhibition of frames for the PFC operation occurs in the MAC Control client. Upon receiving a PFC frame, the only action in MAC Control is to generate a MA_CONTROL.indication primitive with the indication_operand list specified in Table 31A–9.

The PFC operation does not inhibit transmission of MAC Control frames.

PFC operation shall not be enabled on DTEs configured to the half-duplex mode of operation. PFC is intended for use over full-duplex point-to-point links. Use on shared media such as EPON is out of the scope of this standard.

The globally assigned 48-bit multicast address 01-80-C2-00-00-01 has been reserved for use in MAC Control frames. Bridges conformant to IEEE Std 802.1D or IEEE Std 802.1Q will not forward frames sent to this multicast destination address, regardless of the state of the bridge's ports, and whether or not the bridge implements the MAC Control sublayer. To allow PFC full duplex flow control, stations implementing the PFC operation shall instruct the MAC (e.g., through layer management) to enable reception of frames with destination address equal to this multicast address.

NOTE—By definition, an IEEE 802.3 LAN operating in full duplex mode comprises exactly two stations, thus there is no ambiguity regarding the destination DTE's identity. The use of a well-known multicast address relieves the MAC Control sublayer and its client from having to know, and maintain knowledge of, the individual 48-bit address of the other DTE in a full duplex environment.

31D.2 Parameter semantics

The PFC opcode takes the following request_operand_list:

priority_enable_vector:
A 2-octet vector. The most significant octet is reserved (i.e., set to zero on transmission and ignored on receipt). Each bit of the least significant octet indicates if the corresponding field in the time_vector parameter is valid. The bits of the least significant octet are named e[0] (the least significant bit) to e[7] (the most significant bit). Bit e[n] refers to Priority n. For each e[n] bit set to one, the corresponding time[n] value is valid. For each e[n] bit set to zero, the corresponding time[n] value is invalid.

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time_vector:

A list of eight 2-octet fields named time[0] to time[7]. The eight time[n] values are always present regardless of the value of the corresponding e[n] bit. Each time[n] field is a 2-octet, unsigned integer containing the length of time for which the receiving station is requested to inhibit transmission of data frames associated with Priority n. The field is transmitted most significant octet first, and least significant octet second. The time[n] fields are transmitted sequentially, with time[0] transmitted first and time[7] transmitted last. Each time[n] value is measured in units of pause_quanta, equal to the time required to transmit 512 bits of a frame at the data rate of the MAC. Each time[n] field can assume a value in the range of 0 to 65 535 pause_quanta.

31D.3 PFC transmit

The state machines in 31D.3 follow the conventions in 21.5. (See 25.1.1 for an example statement. That also covers the timer conventions from 14 which apply here.)

Upon receipt of a MA_CONTROL.request primitive containing the PFC opcode from a MAC client, the MAC Control sublayer calls the MAC sublayer MAC:MA_DATA.request service primitive with the following parameters:

a) The destination_address is set equal to the destination_address parameter of the MA_CONTROL.request primitive. This parameter is currently restricted to the value specified in 31D.1.
b) The source_address is set equal to the 48-bit individual address of the station.
c) The length/type field (i.e., the first two octets) within the mac_service_data_unit parameter is set to the IEEE 802.3 MAC Control Ethertype value assigned in 31.4.1.3.
d) The remainder of the mac_service_data_unit is set equal to the concatenation of the PFC opcode encoding (see Annex 31A), the priority_enable_vector and the time_vector specified in the MA_CONTROL.request primitive, and a field containing zeros of the length specified in 31.4.1.6.
e) The frame_check_sequence is omitted.

Figure 31D–1 depicts the MAC Control PFC Frame transmitted in response to an MA_Control.request primitive with the PFC opcode.

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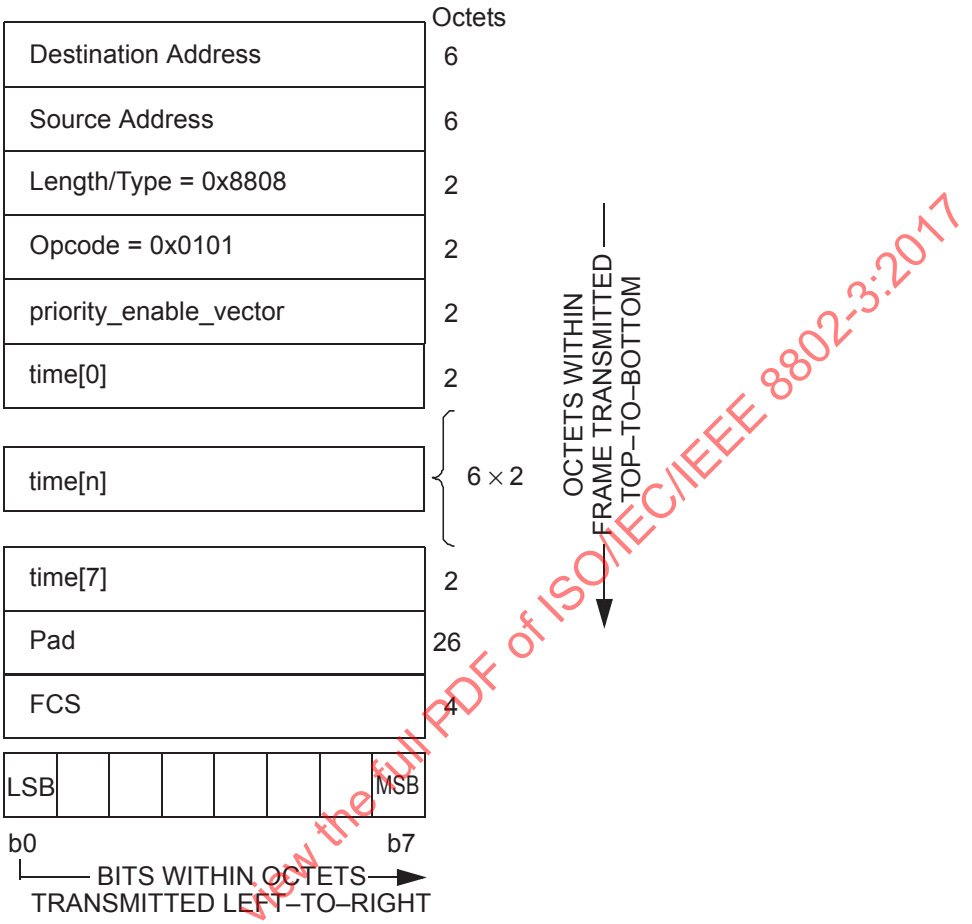

Figure 31D–1—MAC Control EXTENSION Frame

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31D.4 Transmit state diagram for PFC operation

MAC Control sublayer entities that transmit PFC frames shall implement the Transmit state diagram specified in this subclause.

31D.4.1 Constants

pfc_command
: The 2-octet encoding of the PFC opcode, as specified in Annex 31A.

phys_Address
: A 48-bit value, equal to the unicast address of the station implementing the MAC Control sublayer.

reserved_multicast_address
: The 48-bit address specified in 31D.1 (a).

802.3_MAC_Control
: The 16 bit Ethertype field assignment for 802.3 MAC Control specified in 31.4.1.3.

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31D.4.2 Variables

transmitEnabled
: A Boolean set by network management to indicate that the station is permitted to transmit on the network.
Values: true; Transmitter is enabled by management
false; Transmitter is disabled by management

pfc_operand_list
: The priority_enable_vector and time_vector from the MA_CONTROL.request.

pfc_mac_service_data_unit
: The concatenation of IEEE 802.3_MAC_Control, pfc_command, priority_enable_vector, time_vector, zeros.

31D.4.3 Messages

MA_CONTROL.request
: The service primitive used by a client to request a MAC Control sublayer function with the specified request_operands.

MCF:MA_DATA.request
: The service primitive used by a client to request MAC data transmission with the specified parameters.

MAC:MA_DATA.request
: The service primitive issued by the MAC Control sublayer to transmit a MAC frame with the specified parameters. The action invoked is not considered to end until the transmission of the frame by the MAC has concluded and the ability of the MAC control layer to determine this is implementation dependent.

31D.4.4 Transmit state diagram for PFC operation

Figure 31B–1 depicts the Transmit state diagram for a MAC Control sublayer entity implementing the PFC operation.

31D.5 PFC receive

The opcode-independent MAC Control sublayer Receive state diagram accepts and parses valid frames received from the MAC sublayer. The functions specified in this subclause are performed upon receipt of a valid Control frame containing the PFC opcode, and define the function called by the INITIATE MAC CONTROL FUNCTION state of Figure 31–4. (See 31.5.3.) Upon receipt of a valid MAC Control frame with the opcode indicating PFC and the destination address indicating the reserved multicast address specified in 31D.1, the MAC Control sublayer generates the MA_CONTROL.indication to the MAC Control Client.

31D.6 Receive state diagram for PFC operation

MAC Control sublayer entities that transmit PFC frames shall implement the Receive state diagram specified in this subclause.

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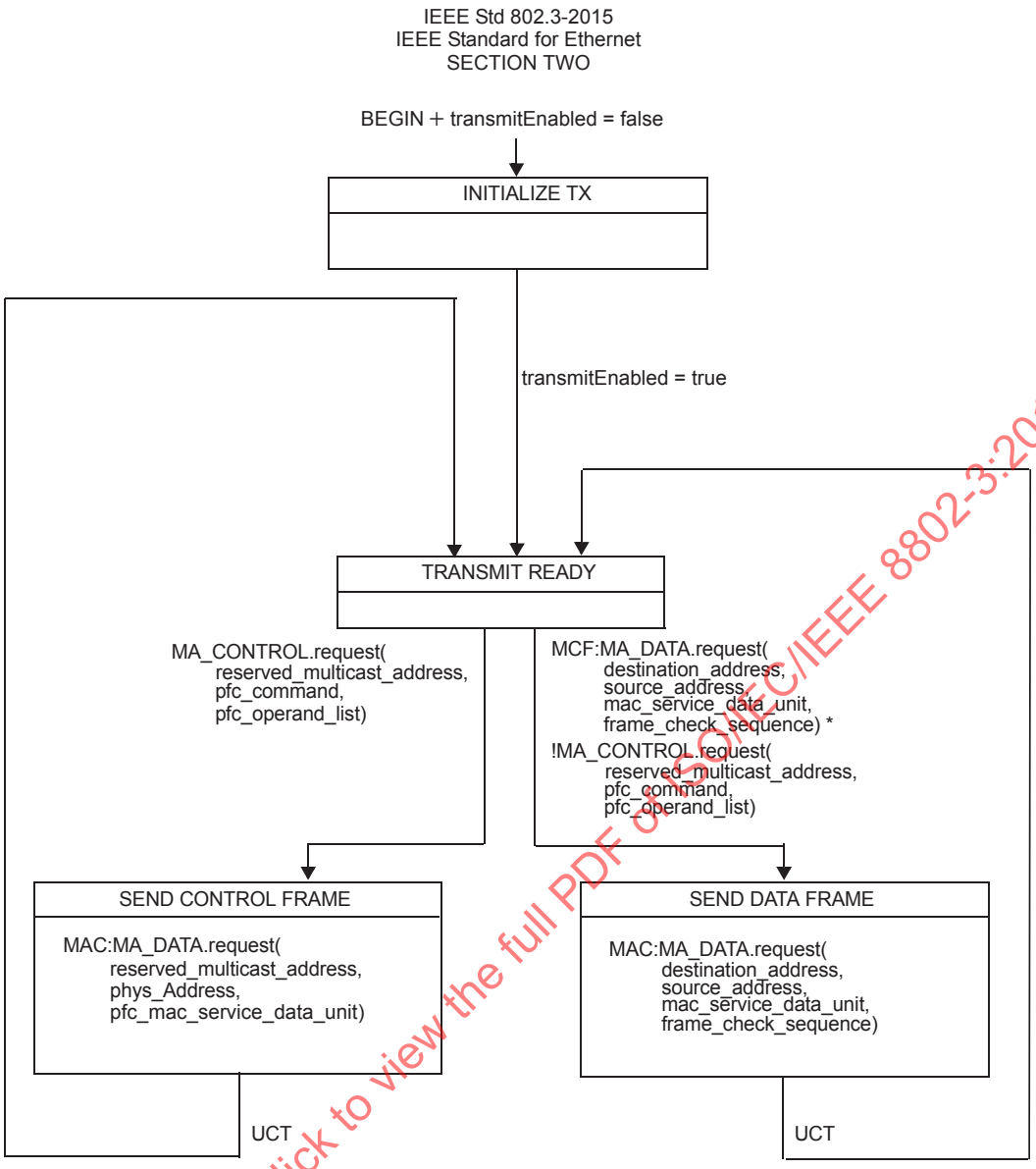

Figure 31D–2—PFC Operation Transmit state diagram

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31D.6.1 Constants

pfc_command
: The 2-octet encoding of the PFC opcode, as specified in Annex 31A.

reserved_multicast_address
: The 48-bit address specified in 31D.1 (a).

31D.6.2 Variables

opcode
: The opcode parsed from the received MAC frame.

DA
: The destination address from the MAC:MA_DATA.indication service primitive.

pfc_operand_list
: The priority_enable_vector and time_vector parsed from the received frame.

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31D.6.3 Receive state diagram (INITIATE MAC CONTROL FUNCTION) for PFC operation

Figure 31B–2 depicts the INITIATE MAC CONTROL FUNCTION for the PFC operation. (See 31.5.3.)

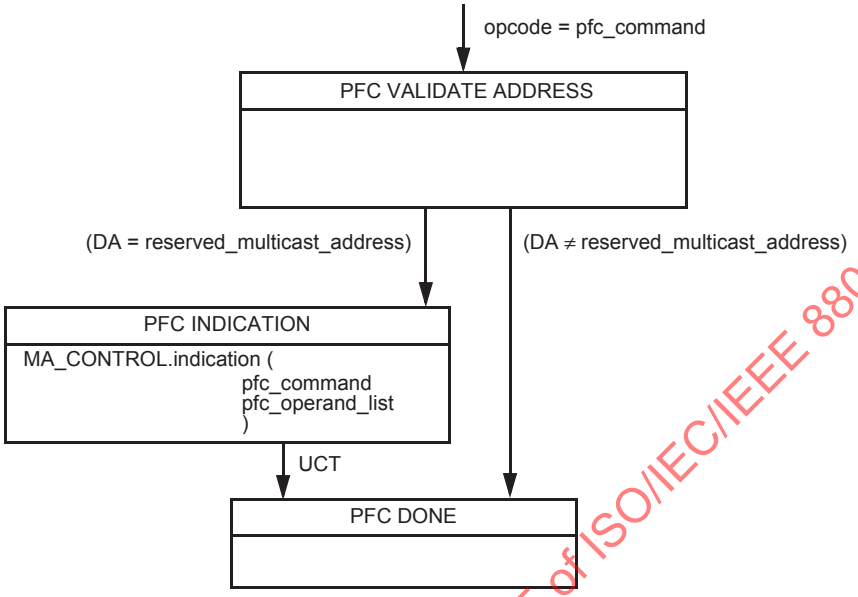

Figure 31D–3—PFC Operation Receive state diagram

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31D.7 Protocol implementation conformance statement (PICS) proforma for MAC Control PFC operation[25]

31D.7.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Annex 31D, MAC Control PFC operation, shall complete the following PICS proforma in addition to the PICS of Clause 31.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

31D.7.2 Identification

31D.7.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations, other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

31D.7.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Annex 31D, MAC Control PFC operation
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; The answer Yes means that the implementation does not conform to IEEE Std 802.3-2015)	

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31D.7.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
PFC	Support for transmit and reception of PFC frames	31D.3 and 31D.5	N/A	M	Yes [ ]

31D.7.4 PFC command requirements

Item	Feature	Subclause	Value/Comment	Status	Support
PFC1	Duplex mode of DTE	31D.1	Full duplex	M	Yes [ ]
PFC2	Reception of frames with destination address equal to the multicast address 01-80-C2-00-00-01	31D.1	Enabled	M	Yes [ ]

31D.7.5 PFC command state diagram requirements

Item	Feature	Subclause	Value/Comment	Status	Support
PSDT	Transmit state diagram for PFC operation	31D.4	Meets requirements of Figure 31D–2	M	Yes [ ]
PSDR	Receive state diagram for PFC operation	31D.6	Meets requirements of Figure 31D–3	M	Yes [ ]

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Annex 32A

(informative)

Use of cabling systems with nominal differential characteristic impedance of 120 Ω or 150 Ω

The 100BASE-T2 standard specifies only the use of 100 Ω link segments for conformance. Since ISO/IEC 11801: 1995 also recognizes 120 Ω and 150 Ω cabling, this informative annex specifies the conditions for using cabling systems with nominal characteristic impedances of 120 Ω and 150 Ω by 100BASE-T2 conformant stations.

The use of cabling with a characteristic impedance outside the range specified in 32.7.2.2 will generally increase the mismatching effects in the link components if directly coupled to the PHY without a impedance transforming balun and results in the following consequences:

a) Increased echo due primarily to poorer hybrid performance
b) Increased cabling attenuation roughness due to increased reflections
c) Increased transmitter launch amplitude
d) Possible non-linearities in transmitter

The effect of increased echo and reflection is more than compensated by use of Category 4 or higher 120 Ω cabling or 150 Ω cabling consistent with ISO/IEC 11801 specifications. The increased transmitter launch level will not be an additional noise or EMC problem on these quality cabling. Manufacturers intending to support a direct connection of 120 Ω or 150 Ω cabling to the 100BASE-T2 PHY must ensure that the transmitters can tolerate the impedance without additional non-linearity.

If baluns are used instead of a direct connection, care must be taken to ensure that the corner frequencies of the baluns do not substantially interfere with the 100BASE-T2 signals. In practice, a lower corner frequency less than 100 kHz and an upper corner frequency greater than 30 MHz should be adequate for use with Category 4 or higher 120 Ω cabling or 150 Ω cabling consistent with ISO/IEC 11801 specifications.

CAUTION

Users of the present annex are further advised to check with the manufacturer of the particular 100BASE-T2 devices they intend to use with a 120 Ω or 150 Ω link whether those devices can operate correctly on cabling with Zc as high as 120 Ω ± 15 Ω and 150 Ω ± 15 Ω.

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Annex 33A

(informative)

PSE-PD stability

33A.1 Recommended PSE design guidelines and test setup

In order to prevent potential oscillations between the PSE and PD, the sum of the PSE port output impedance (Zo_port), the cable impedance (Zc), the PD input port circuitry impedance (Zpd_cir) and the PD EMI output filter impedance (Z_emi) should be lower than the PD power supply input impedance (Zin_ps_pd). This subclause focuses on the PSE part.

Port output impedance consists of two parts:

a) PSE power supply output impedance (Zo_ps), which is a function of the load (P_{Port}), and
b) Series elements (Z_ser) that connect the PSE power supply output to the port.

Therefore, the total Port output impedance during normal powering mode is Zo_port=Zo_ps+Z_ser.

In order to maintain PSE-PD stability, the following guidelines apply:

c) Zo_ps max = 0.3 Ω at frequencies up to 100 kHz at $P_{Port} = P_{Type}$ as defined in Table 33–11.
Zo_ps can be extracted from Z_{port} by measuring V_{Port} / I_{Port} (with an external power dynamic analyzer system) as a function of frequency and subtracting from Z_{port} the value of Zser (f = DC) which is limited by the value of Zser at DC (low frequency).
d) If Zo_ps < Zo_ser and V_{Port} is kept to V_{Port} min and V_{Port} max as defined in Table 33–11 during dynamic load changes from 10 Hz to 100 kHz, then the value of Zo_ps is not limited.

Compliance to the above requirements should be made by measuring the port output impedance from 10 Hz to 100 kHz with a load of P_{Type} as defined in Table 33–11 at short cable length, or by presenting simulation results.

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See Figure 1 for the PSE-PD system impedance allocation.

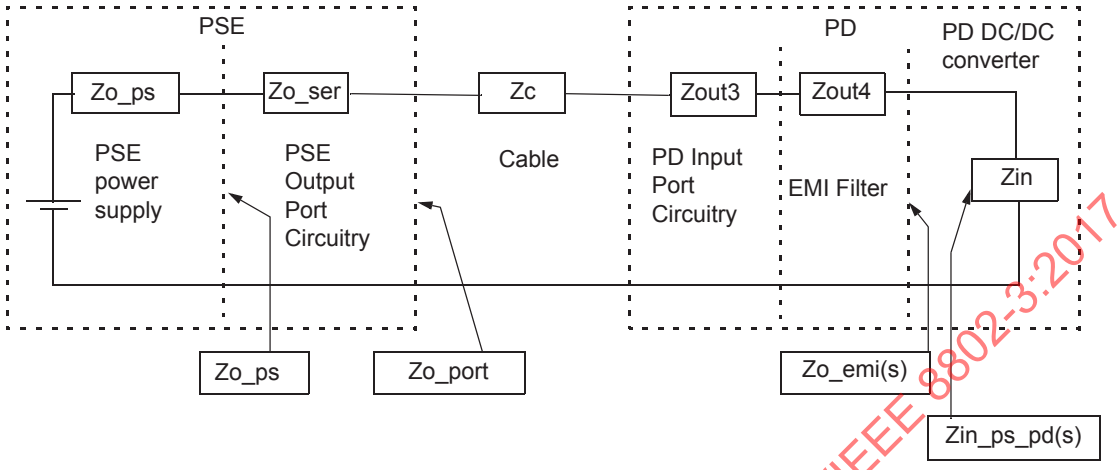

Figure 33A–1—PSE-PD system impedance allocation

See Figure 33A–2 for the test setup and Figure 33A–3 for the test requirements.

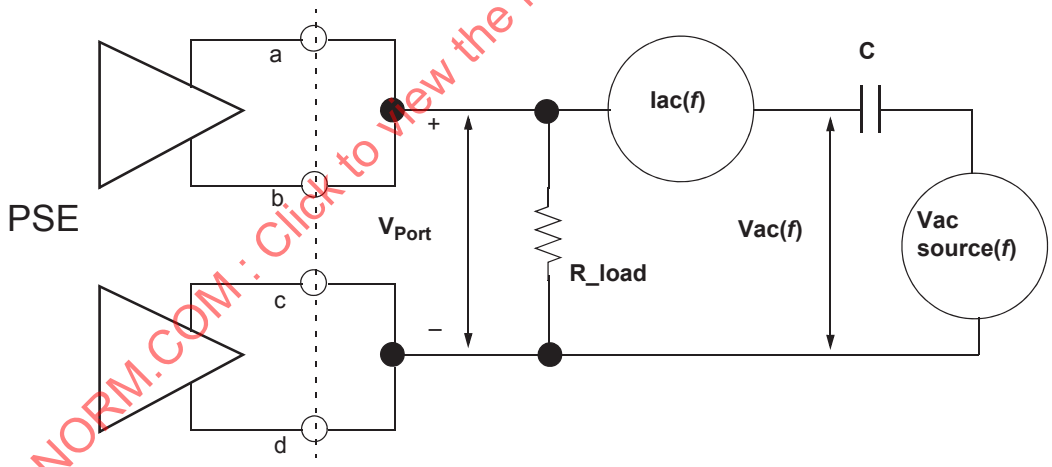

Figure 33A–2—Test setup for measuring Zo_port

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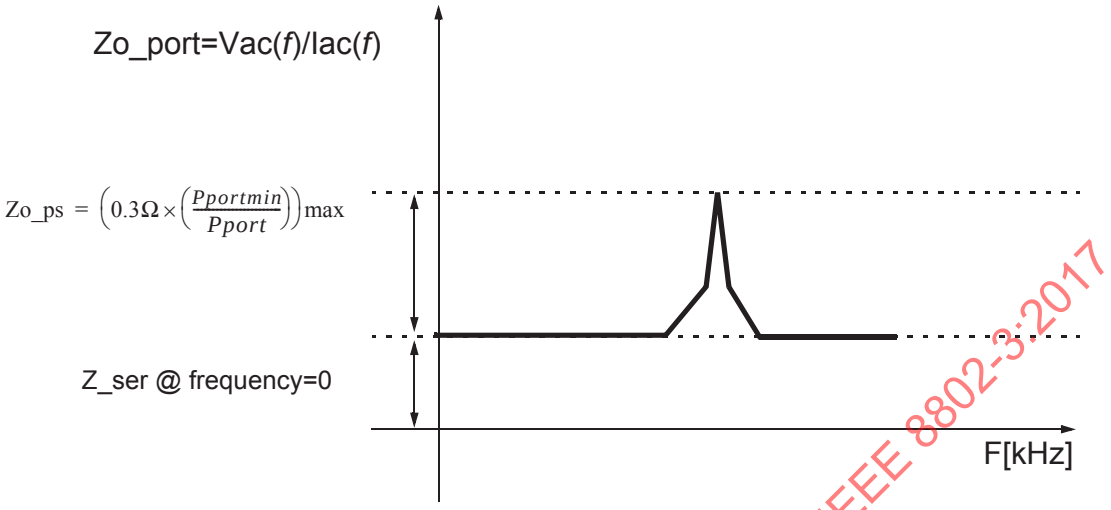

Figure 33A–3—Test requirements for measuring Zo_port

33A.2 Recommended PD design guidelines

PD port input impedance consists of the following two parts:

a) PD port input circuits including the EMI filter (Zin_ser), and
b) PD power supply input impedance (Zin_ps_pd), which is fed by the output of the EMI filter (Zo_emi).

In order to maintain stability with the PSE, the PD power supply input impedance (Zin_ps_pd) should be higher than the output impedance of the total network including the PD EMI output filter impedance fed by the cable (MDI) output impedance, which is fed by the PSE port output impedance.

The worst-case scenario is when the cable (MDI) length is zero (in terms of lower damping factor).

The access to the PD input power supply is not possible through the PD port for evaluating the various impedances and derivation of the above parameters. Because of this, measuring the PD input impedance is a complicated task and the following guidelines should be followed by the PD vendor:

c) The PD power supply input impedance (Zin_ps_pd) at max load of $P_{port} = P_{Port}$ max as defined in Table 33–18 should be higher than 30 Ω at any frequency up to the PD power supply crossover frequency. If the PD power supply is consuming less than $P_{port} = P_{Port}$ max as defined in Table 33–18, then Zin_ps_pd min = $30 \times P_{Port}$ max / P_{port}.
d) The PD power supply EMI filter output impedance should be Zo_emi = 2.7 Ω max. If the PD power supply is consuming less than $P_{port} = P_{Port}$ max, then Zo_emi = $2.7 \times P_{Port}$ max / P_{port}.

See Figure 33A–1 for the PSE-PD system impedance allocation.

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IEEE Standard for Ethernet

SECTION THREE

This section includes Clause 34 through Clause 43 and Annex 36A through Annex 43C.

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34. Introduction to 1000 Mb/s baseband network

34.1 Overview

Gigabit Ethernet couples an extended version of Ethernet to a family of 1000 Mb/s Physical Layers. The relationships among Gigabit Ethernet, the extended Ethernet, and the ISO/IEC Open System Interconnection (OSI) reference model are shown in Figure 34–1.

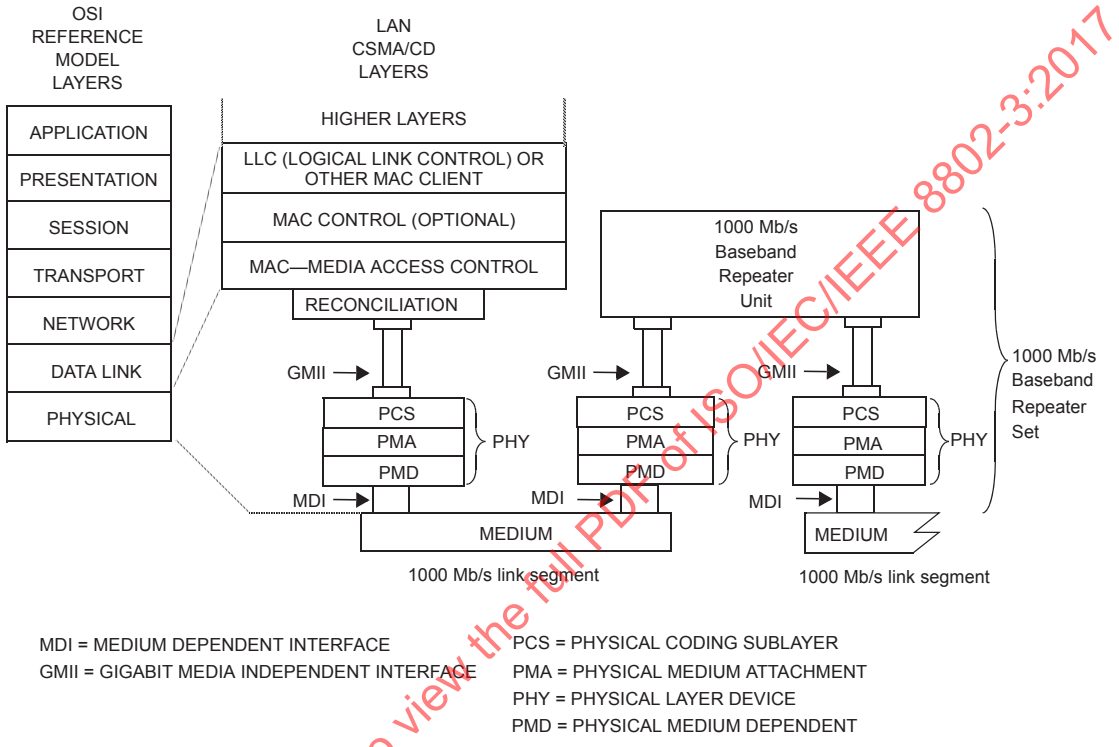

Figure 34–1—Architectural positioning of Gigabit Ethernet (1000 Mb/s operation)

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The Gigabit Ethernet MAC layer interface connects through a Gigabit Media Independent Interface layer to Physical Layer entities (PHY sublayers). The set of PHY sublayer specifications include operation over multiple media (e.g., copper cables, fiber optic cables and backplanes).

Gigabit Ethernet extends the Ethernet MAC beyond 100 Mb/s to 1000 Mb/s. The bit rate is faster, and the bit times are shorter—both in proportion to the change in bandwidth. In full duplex mode, the minimum packet transmission time has been reduced by a factor of ten. Achievable topologies for 1000 Mb/s full duplex operation are comparable to those found in 100BASE-T full duplex mode. In half duplex mode, the minimum packet transmission time has been reduced, but not by a factor of ten. Cable delay budgets are similar to those in 100BASE-T. The resulting achievable topologies for the half duplex 1000 Mb/s CSMA/CD MAC are similar to those found in half duplex 100BASE-T.

34.1.1 Reconciliation Sublayer (RS) and Gigabit Media Independent Interface (GMII)

The Gigabit Media Independent Interface (Clause 35) provides an interconnection between the Media Access Control (MAC) sublayer and Physical Layer entities (PHY) and between PHY Layer and Station

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Management (STA) entities. This GMII supports 1000 Mb/s operation through its eight bit wide (octet wide) transmit and receive paths. The Reconciliation sublayer provides a mapping between the signals provided at the GMII and the MAC/PLS service definition.

34.1.2 Physical Layer signaling systems

This standard specifies a family of Physical Layer implementations. The generic term 1000 Mb/s MAC refers to any use of the 1000 Mb/s IEEE 802.3 MAC (the Gigabit Ethernet MAC) coupled with any Physical Layer implementation.

Various clauses of this standard comprise a family of Physical Layer implementations for operation at 1000 Mb/s. Each PHY type includes specifications for encoding and decoding of information, and how those encoded data are transmitted on the supported transmission medium or media. These PHY types may share some PHY sublayer components and signaling methods, or may use signaling methods specific to the supported media and applications.

34.1.3 Repeater

A repeater set (Clause 41) is an integral part of any half duplex Gigabit Ethernet network with more than two DTEs in a collision domain. A repeater set extends the physical system topology by coupling two or more segments. Only one repeater is permitted within a single collision domain. Some Gigabit Ethernet PHY types only support full duplex operation. Topologies composed of full duplex only devices do not allow repeaters.

34.1.4 Auto-Negotiation, type 1000BASE-X

Auto-Negotiation (Clause 37) provides a 1000BASE-X device with the capability to detect the abilities (modes of operation) supported by the device at the other end of a link segment, determine common abilities, and configure for joint operation. Auto-Negotiation is performed upon link startup through the use of a special sequence of reserved link codewords. Clause 37 adopts the basic architecture and algorithms from Clause 28, but not the use of fast link pulses. Auto-Negotiation for 1000BASE-KX is defined in Clause 73.

34.1.5 Auto-Negotiation, type 1000BASE-T

Auto-Negotiation (Clause 28) is used by 1000BASE-T devices to detect the abilities (modes of operation) supported by the device at the other end of a link segment, determine common abilities, and configure for joint operation. Auto-Negotiation is performed upon link startup through the use of a special sequence of fast link pulses.

34.1.6 Management

Managed objects, attributes, and actions are defined for all Gigabit Ethernet components (Clause 30).

34.2 State diagrams

State diagrams take precedence over text.

The conventions of 1.2 are adopted, along with the extensions listed in 21.5.

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34.3 Protocol implementation conformance statement (PICS) proforma

The supplier of a protocol implementation that is claimed to conform to any part of IEEE 802.3, Clause 35 through Clause 41, shall complete a protocol implementation conformance statement (PICS) proforma.

A completed PICS proforma is the PICS for the implementation in question. The PICS is a statement of which capabilities and options of the protocol have been implemented. A PICS is included at the end of each clause as appropriate. Each of the Gigabit Ethernet PICS conforms to the same notation and conventions used in 100BASE-T (see 21.6).

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35. Reconciliation Sublayer (RS) and Gigabit Media Independent Interface (GMII)

35.1 Overview

This clause defines the logical and electrical characteristics for the Reconciliation Sublayer (RS) and Gigabit Media Independent Interface (GMII) between CSMA/CD media access controllers and various PHYs. Figure 35–1 shows the relationship of the Reconciliation sublayer and GMII to the ISO/IEC OSI reference model.

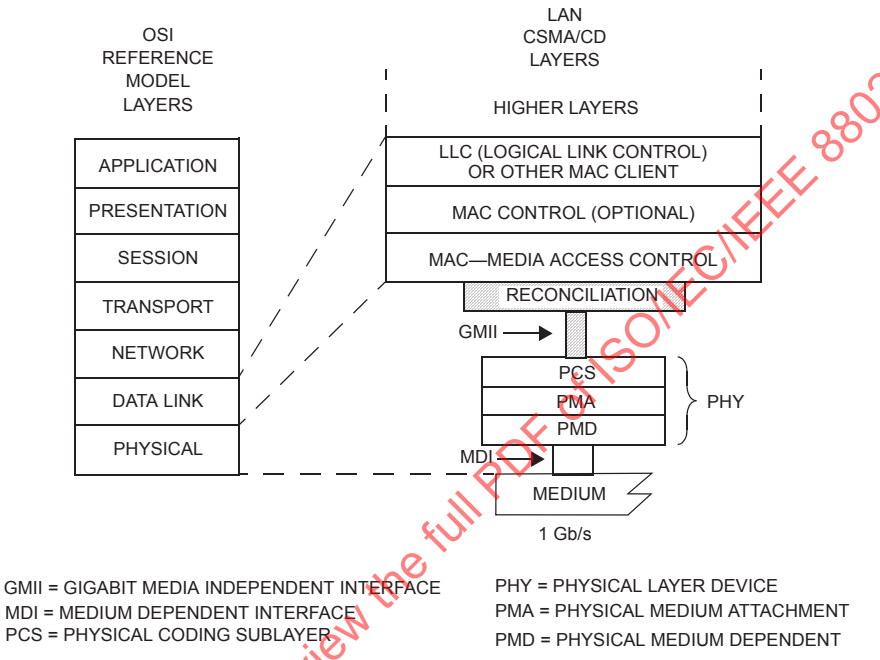

Figure 35–1—GMII relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

The purpose of this interface is to provide a simple, inexpensive, and easy-to-implement interconnection between Media Access Control (MAC) sublayer and PHYs, and between PHYs and Station Management (STA) entities.

This interface has the following characteristics:

a) It is capable of supporting 1000 Mb/s operation.
b) Data and delimiters are synchronous to clock references.
c) It provides independent eight-bit-wide transmit and receive data paths.
d) It provides a simple management interface.
e) It uses signal levels, compatible with common CMOS digital ASIC processes and some bipolar processes.
f) It provides for full duplex operation.

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35.1.1 Summary of major concepts

a) The GMII is based on the MII defined in Clause 22.
b) Each direction of data transfer is serviced by Data (an eight-bit bundle), Delimiter, Error, and Clock signals.
c) Two media status signals are provided. One indicates the presence of carrier, and the other indicates the occurrence of a collision.
d) The GMII uses the MII management interface composed of two signals that provide access to management parameters and services as specified in Clause 22.
e) MII signal names have been retained and the functions of most signals are the same, but additional valid combinations of signals have been defined for 1000 Mb/s operation.
f) The Reconciliation sublayer maps the signal set provided at the GMII to the PLS service primitives provided to the MAC.
g) GMII signals are defined such that an implementation may multiplex most GMII signals with the similar PMA service interface defined in Clause 36.
h) The GMII may also support Low Power Idle (LPI) signaling as defined for Energy-Efficient Ethernet in Clause 78 for certain PHY types.

35.1.2 Application

This clause applies to the interface between the MAC and PHYs, and between PHYs and Station Management entities. The implementation of the interface is primarily intended as a chip-to-chip (integrated circuit to integrated circuit) interface implemented with traces on a printed circuit board. A motherboard-to-daughterboard interface between two or more printed circuit boards is not precluded. The use of parts of the GMII (e.g., data paths, but not the Clause 22 management interface or associated management registers), and the use of the GMII as an interface between logic modules on the same chip is not precluded.

This interface is used to provide media independence so that an identical media access controller may be used with any of the copper and optical PHY types.

35.1.3 Rate of operation

The GMII supports only 1000 Mb/s operation and is defined within this clause. Operation at 10 Mb/s and 100 Mb/s is supported by the MII defined in Clause 22.

PHYs that provide a GMII shall support 1000 Mb/s operation, and may support additional rates using other interfaces (e.g., MII). PHYs must report the rates at which they are capable of operating via the management interface. Reconciliation sublayers that provide a GMII shall support 1000 Mb/s and may support additional rates using other interfaces.

35.1.4 Allocation of functions

The allocation of functions at the GMII balances the need for media independence with the need for a simple and cost-effective interface.

While the Attachment Unit Interface (AUI) was defined to exist between the Physical Signaling (PLS) and Physical Medium Attachment (PMA) sublayers for 10 Mb/s DTEs, the GMII (like the Clause 22 MII) maximizes media independence by cleanly separating the Data Link and Physical Layers of the ISO/IEC seven-layer reference model. This allocation also recognizes that implementations can benefit from a close coupling between the PLS or PCS sublayer and the PMA sublayer.

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35.2 Functional specifications

The GMII is designed to make the differences among the various media transparent to the MAC sublayer. The selection of logical control signals and the functional procedures are all designed to this end.

35.2.1 Mapping of GMII signals to PLS service primitives and Station Management

The Reconciliation sublayer maps the signals provided at the GMII to the PLS service primitives defined in Clause 6. The PLS service primitives provided by the Reconciliation sublayer, and described here, behave in exactly the same manner as defined in Clause 6. The mapping is changed for EEE capability (see 78.3), as described in 35.4.

An LPI_IDLE.request primitive with value ASSERT shall not be generated unless the attached link is operational (i.e., link_status = OK, according to the underlying PCS/PMA). The PHY shall not cause an LP_IDLE.request primitive with value ASSERT to be generated for at least one second following a link_status change to OK (see 78.1.2.1.2).

EEE capability requires the use of the MAC defined in Annex 4A for simplified full duplex operation (with carrier sense deferral). This provides full duplex operation but uses the carrier sense signal to defer transmission when the PHY is in its low power state.

Figure 35–2 depicts a schematic view of the Reconciliation sublayer inputs and outputs, and demonstrates that the GMII management interface is controlled by the Station Management entity (STA).

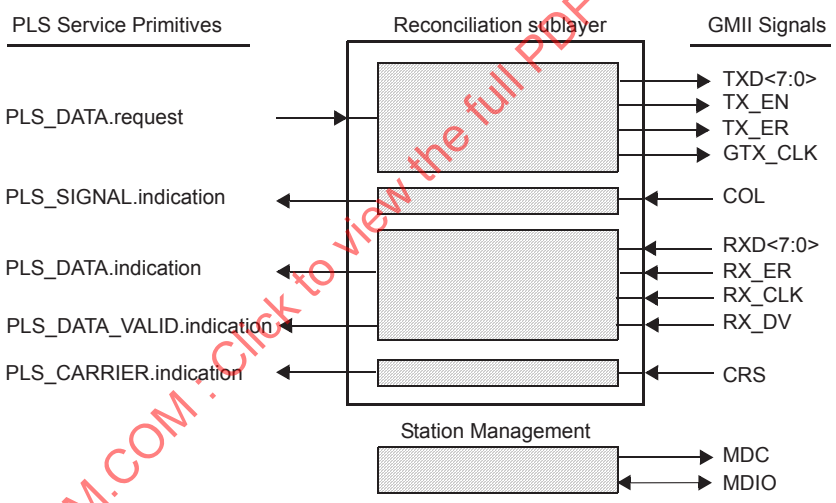

Figure 35–2—Reconciliation Sublayer (RS) inputs and outputs and STA connections to GMII

35.2.1.1 Mapping of PLS_DATA.request

35.2.1.1.1 Function

Map the primitive PLS_DATA.request to the GMII signals TXD<7:0>, TX_EN, TX_ER and GTX_CLK.

35.2.1.1.2 Semantics of the service primitive

PLS_DATA.request (OUTPUT_UNIT)

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The OUTPUT_UNIT parameter can take one of five values: ONE, ZERO, TRANSMIT_COMPLETE, EXTEND or EXTEND_ERROR. It represents or is equivalent to a single data bit. These values are conveyed by the signals TX_EN, TX_ER, TXD<7>, TXD<6>, TXD<5>, TXD<4>, TXD<3>, TXD<2>, TXD<1> and TXD<0>.

Each of the eight TXD signals conveys either a ONE or ZERO of data while TX_EN is asserted. Eight data bit equivalents of EXTEND or EXTEND_ERROR are conveyed by a specific encoding of the TXD<7:0> signals when TX_EN is not asserted, and TX_ER is asserted, see Table 35–1. Synchronization between the Reconciliation sublayer and the PHY is achieved by way of the GTX_CLK signal. The value TRANSMIT_COMPLETE is conveyed by the deassertion of either TX_EN or TX_ER at the end of a MAC's transmission.

35.2.1.1.3 When generated

The GTX_CLK signal is generated by the Reconciliation sublayer. The TXD<7:0>, TX_EN and TX_ER signals are generated by the Reconciliation sublayer after every group of eight PLS_DATA.request transactions from the MAC sublayer to request the transmission of eight data bits on the physical medium, to extend the carrier event the equivalent of eight bits, or to stop transmission.

35.2.1.2 Mapping of PLS_DATA.indication

35.2.1.2.1 Function

Map the primitive PLS_DATA.indication to the GMII signals RXD<7:0>, RX_DV, RX_ER, and RX_CLK.

35.2.1.2.2 Semantics of the service primitive

PLS_DATA.indication (INPUT_UNIT)

The INPUT_UNIT parameter can take one of three values: ONE, ZERO or EXTEND. It represents or is equivalent to a single data bit. These values are derived from the signals RX_DV, RX_ER, RXD<7>, RXD<6>, RXD<5>, RXD<4>, RXD<3>, RXD<2>, RXD<1>, and RXD<0>. The value of the data transferred to the MAC is controlled by GMII error indications, see 35.2.1.5.

Each of the eight RXD signals conveys either a ONE or ZERO of data while RX_DV is asserted. Eight data bit equivalents of EXTEND are conveyed by a specific encoding of the RXD<7:0> signals when RX_DV is not asserted, and RX_ER is asserted; see Table 35–2. Synchronization between the Reconciliation sublayer and the PHY is achieved by way of the RX_CLK signal.

35.2.1.2.3 When generated

This primitive is generated to all MAC sublayer entities in the network after a PLS_DATA.request is issued. Each octet transferred on RXD<7:0> will result in the generation of eight PLS_DATA.indication transactions.

35.2.1.3 Mapping of PLS_CARRIER.indication

35.2.1.3.1 Function

Map the primitive PLS_CARRIER.indication to the GMII signal CRS.

35.2.1.3.2 Semantics of the service primitive

PLS_CARRIER.indication (CARRIER_STATUS)

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The CARRIER_STATUS parameter can take one of two values: CARRIER_ON or CARRIER_OFF. CARRIER_STATUS assumes the value CARRIER_ON when the GMII signal CRS is asserted and assumes the value CARRIER_OFF when CRS is deasserted.

35.2.1.3.3 When generated

The PLS_CARRIER.indication service primitive is generated by the Reconciliation sublayer whenever the CARRIER_STATUS parameter changes from CARRIER_ON to CARRIER_OFF or vice versa.

35.2.1.4 Mapping of PLS_SIGNAL.indication

35.2.1.4.1 Function

Map the primitive PLS_SIGNAL.indication to the GMII signal COL.

35.2.1.4.2 Semantics of the service primitive

PLS_SIGNAL.indication (SIGNAL_STATUS)

The SIGNAL_STATUS parameter can take one of two values: SIGNAL_ERROR or NO_SIGNAL_ERROR. SIGNAL_STATUS assumes the value SIGNAL_ERROR when the GMII signal COL is asserted, and assumes the value NO_SIGNAL_ERROR when COL is deasserted.

35.2.1.4.3 When generated

The PLS_SIGNAL.indication service primitive is generated whenever SIGNAL_STATUS makes a transition from SIGNAL_ERROR to NO_SIGNAL_ERROR or vice versa.

35.2.1.5 Response to error indications from GMII

If, during frame reception, both RX_DV and RX_ER are asserted, the Reconciliation sublayer shall ensure that the MAC will detect a FrameCheckError in that frame.

Carrier is extended when RX_DV is not asserted and RX_ER is asserted with a proper encoding of RXD<7:0>. When a Carrier Extend Error is received during the extension, the Reconciliation sublayer shall send PLS_DATA.indication values of ONE or ZERO and ensure that the MAC will detect a FrameCheckError in the sequence.

These requirements may be met by incorporating a function in the Reconciliation sublayer that produces a received frame data sequence delivered to the MAC sublayer that is guaranteed to not yield a valid CRC result, as specified by the algorithm in 3.2.9. This data sequence may be produced by substituting data delivered to the MAC.

Other techniques may be employed to respond to Data Reception Error or Carrier Extend Error provided that the result is that the MAC sublayer behaves as though a FrameCheckError occurred in the received frame.

35.2.1.6 Conditions for generation of TX_ER

If, during the process of transmitting a frame, it is necessary to request that the PHY deliberately corrupt the contents of the frame in such a manner that a receiver will detect the corruption with the highest degree of probability, then Transmit Error Propagation shall be asserted by the appropriate encoding of TX_ER, and TX_EN. Similarly, if during the process of transmitting carrier extension to a frame, it is necessary to request that the PHY deliberately corrupt the contents of the carrier extension in such a manner that a receiver will detect

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the corruption with the highest degree of probability, then Carrier Extend Error shall be signalled by the appropriate encoding of TXD<7:0>.

This capability has additional use within a repeater. For example, a repeater that detects an RX_ER during frame reception on an input port may propagate that error indication to its output ports by asserting TX_ER during the process of transmitting that frame.

35.2.1.7 Mapping of PLS_DATA_VALID.indication

35.2.1.7.1 Function

Map the primitive PLS_DATA_VALID.indication to the GMII signals RX_DV, RX_ER and RXD<7:0>.

35.2.1.7.2 Semantics of the service primitive

PLS_DATA_VALID.indication (DATA_VALID_STATUS)

The DATA_VALID_STATUS parameter can take one of two values: DATA_VALID or DATA_NOT_VALID. DATA_VALID_STATUS assumes the value DATA_VALID when the GMII signal RX_DV is asserted, or when RX_DV is not asserted, RX_ER is asserted and the values of RXD<7:0> indicate Carrier Extend or Carrier Extend Error. DATA_VALID_STATUS assumes the value DATA_NOT_VALID at all other times.

35.2.1.7.3 When generated

The PLS_DATA_VALID.indication service primitive is generated by the Reconciliation sublayer whenever DATA_VALID_STATUS parameter changes from DATA_VALID to DATA_NOT_VALID or vice versa.

35.2.2 GMII signal functional specifications

35.2.2.1 GTX_CLK (1000 Mb/s transmit clock)

GTX_CLK is a continuous clock used for operation at 1000 Mb/s. GTX_CLK provides the timing reference for the transfer of the TX_EN, TX_ER, and TXD signals from the Reconciliation sublayer to the PHY. The values of TX_EN, TX_ER, and TXD are sampled by the PHY on the rising edge of GTX_CLK. GTX_CLK is sourced by the Reconciliation sublayer.

The GTX_CLK frequency is nominally 125 MHz, one-eighth of the transmit data rate.

NOTE—For EEE capability, GTX_CLK may be halted according to 35.2.2.6.

35.2.2.2 RX_CLK (receive clock)

RX_CLK is a continuous clock that provides the timing reference for the transfer of the RX_DV, RX_ER and RXD signals from the PHY to the Reconciliation sublayer. RX_DV, RX_ER and RXD are sampled by the Reconciliation sublayer on the rising edge of RX_CLK. RX_CLK is sourced by the PHY.

The frequency of RX_CLK may be derived from the received data or it may be that of a nominal clock (e.g., GTX_CLK). When the received data rate at the PHY is within tolerance, the RX_CLK frequency shall be 125MHz ±0.01%, one-eighth of the MAC receive data rate.

There is no need to transition between the recovered clock reference and a nominal clock reference on a frame-by-frame basis. If loss of received signal from the medium causes a PHY to lose the recovered RX_CLK reference, the PHY shall source the RX_CLK from a nominal clock reference. Transitions from nominal clock to recovered clock or from recovered clock to nominal clock shall not decrease the period, or time between

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adjacent edges, of RX_CLK below the limits specified in Table 35–8, and shall not increase the time between adjacent edges of RX_CLK more than twice the nominal clock period.

Transitions from local clock to recovered clock or from recovered clock to local clock shall be made only while RX_DV and RX_ER are deasserted. During the interval between the assertion of CRS and the assertion of RX_DV at the beginning of a frame, the PHY may extend a cycle of RX_CLK by holding it in either the high or low condition until the PHY has successfully locked onto the recovered clock. Following the deassertion of RX_DV at the end of a frame, or the deassertion of RX_ER at the end of carrier extension, the PHY may extend a cycle of RX_CLK by holding it in either the high or low condition for an interval that shall not exceed twice the nominal clock period.

NOTE 1—This standard neither requires nor assumes a guaranteed phase relationship between the RX_CLK and GTX_CLK signals. See additional information in 35.5.

NOTE 2—For EEE capability, RX_CLK may be halted during periods of low utilization according to 35.2.2.10.

35.2.2.3 TX_EN (transmit enable)

TX_EN in combination with TX_ER indicates the Reconciliation sublayer is presenting data on the GMII for transmission. It shall be asserted by the Reconciliation sublayer synchronously with the first octet of the preamble and shall remain asserted while all octets to be transmitted are presented to the GMII. TX_EN shall be negated prior to the first rising edge of GTX_CLK following the final data octet of a frame. TX_EN is driven by the Reconciliation sublayer and shall transition synchronously with respect to the GTX_CLK.

Figure 35–3 depicts TX_EN behavior during a frame transmission with no collisions and without carrier extension or errors.

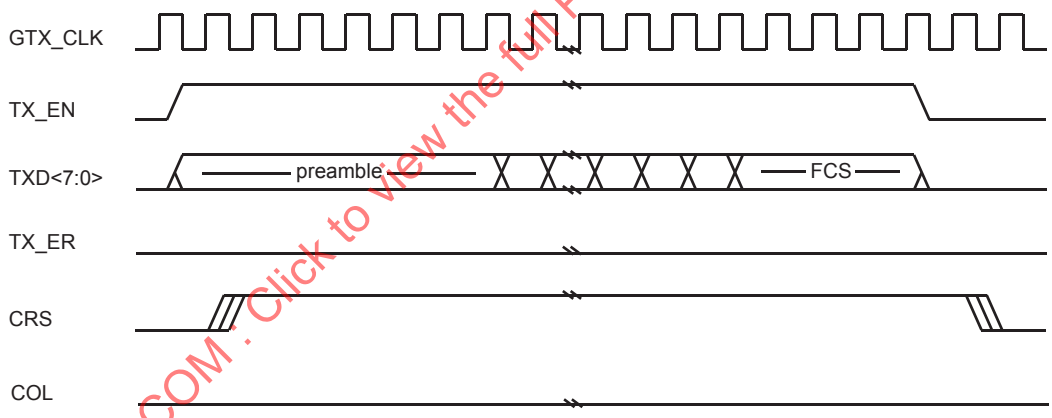

Figure 35–3—Basic frame transmission

35.2.2.4 TXD (transmit data)

TXD is a bundle of eight data signals (TXD<7:0>) that are driven by the Reconciliation sublayer. TXD<7:0> shall transition synchronously with respect to the GTX_CLK. For each GTX_CLK period in which TX_EN is asserted and TX_ER is deasserted, data are presented on TXD<7:0> to the PHY for transmission. TXD<0> is the least significant bit. While TX_EN and TX_ER are both deasserted, TXD<7:0> shall have no effect upon the PHY.

While TX_EN is deasserted and TX_ER is asserted, TXD<7:0> are used to request the PHY to generate LPI, Carrier Extend, or Carrier Extend Error code-groups. The use of TXD<7:0> during the transmission of a frame

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with carrier extension is described in 35.2.2.5. Carrier extension shall only be signalled immediately following the data portion of a frame. The use of TXD<7:0> to signal LPI transitions is described in 35.2.2.6.

For EEE capability, the RS shall use the combination of TX_EN deasserted, TX_ER asserted, and TXD<7:0> equal to 0x01 as shown in Table 35–1 as a request to enter, or remain in the LPI state. Transition into and out of the LPI state is shown in Figure 35–8.

Table 35–1 specifies the permissible encodings of TXD<7:0>, TX_EN, and TX_ER.

Table 35–1—Permissible encodings of TXD<7:0>, TX_EN, and TX_ER

TX_EN	TX_ER	TXD<7:0>	Description	PLS_DATA.request parameter
0	0	00 through FF	Normal inter-frame	TRANSMIT_COMPLETE
0	1	00	Reserved	—
0	1	01	Assert LPI	—
0	1	02 through 0E	Reserved	—
0	1	0F	Carrier Extend	EXTEND (eight bits)
0	1	10 through 1E	Reserved	—
0	1	1F	Carrier Extend Error	EXTEND_ERROR (eight bits)
0	1	20 through FF	Reserved	—
1	0	00 through FF	Normal data transmission	ZERO, ONE (eight bits)
1	1	00 through FF	Transmit error propagation	No applicable parameter
NOTE—Values in TXD<7:0> column are in hexadecimal.				

35.2.2.5 TX_ER (transmit coding error)

TX_ER is driven by the Reconciliation Sublayer and shall transition synchronously with respect to the GTX_CLK. When TX_ER is asserted for one or more TX_CLK periods while TX_EN is also asserted, the PHY shall emit one or more code-groups that are not part of the valid data or delimiter set somewhere in the frame being transmitted. The relative position of the error within the frame need not be preserved. Figure 35–4 shows the behavior of TX_ER during the transmission of a frame propagating an error.

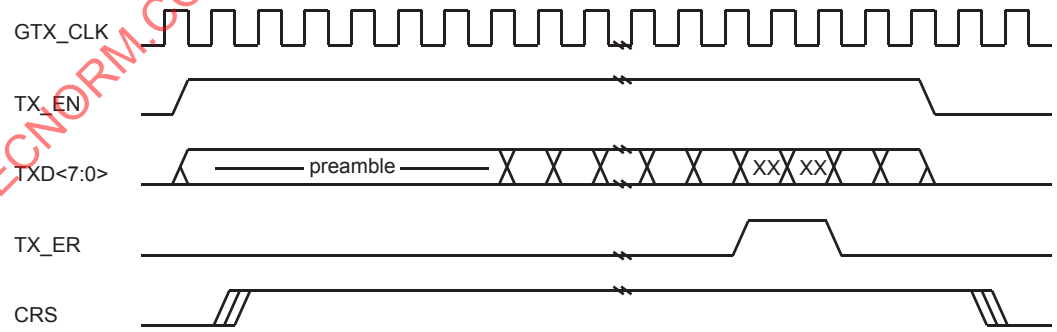

Figure 35–4—Propagating an error within a frame

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Assertion of appropriate TXD values when TX_EN is deasserted and TX_ER is asserted will cause the PHY to generate either Carrier Extend or Carrier Extend Error code-groups. The transition from TX_EN asserted and TX_ER deasserted to TX_EN deasserted and TX_ER asserted with TXD specifying Carrier Extend shall result in the PHY transmitting an end-of-packet delimiter as the initial code-groups of the carrier extension. Figure 35–5 and Figure 35–6 show the behavior of TX_ER during the transmission of carrier extension. The propagation of an error in carrier extension is requested by holding TX_EN deasserted and TX_ER asserted along with the appropriate value of TXD<7:0>.

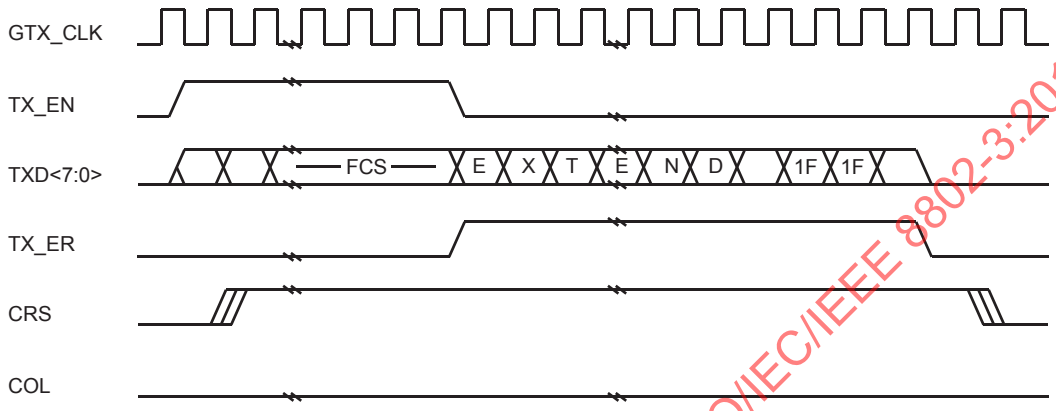

Figure 35–5—Propagating an error within carrier extension

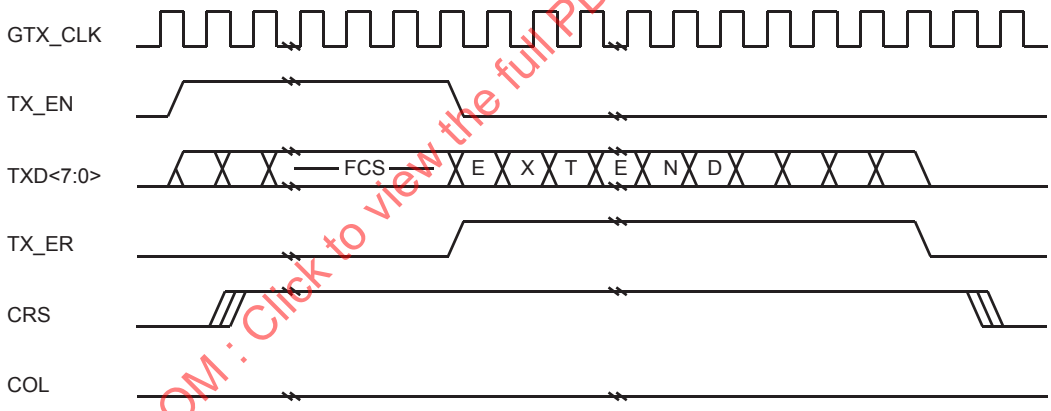

Figure 35–6—Transmission with carrier extension

Burst transmission of frames also uses carrier extension between frames of the burst. Figure 35–7 shows the behavior of TX_ER and TX_EN during burst transmission.

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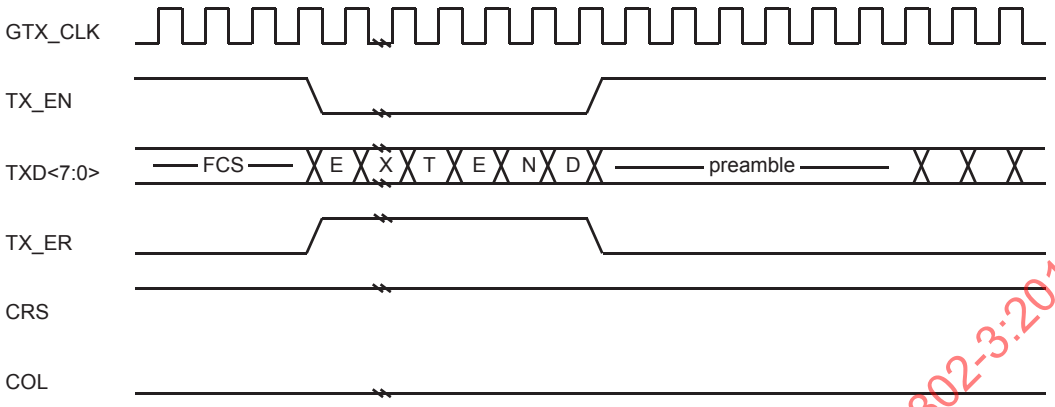

Figure 35–7—Burst transmission

35.2.2.6 Transmit direction LPI transition

EEE capability and the LPI client are described in 78.1. The LPI client requests the PHY to transition to its low power state by asserting TX_ER and setting TXD<7:0> to 0x01. The LPI client maintains the same state for these signals for the entire time that the PHY is to remain in the low power state.

The LPI client may halt GTX_CLK at any time more than 9 clock cycles after the start of the LPI state as shown in Figure 35–8 if and only if the Clock stop capable bit is asserted (45.2.3.1.4).

The LPI client requests the PHY to transition out of its low power state by deasserting TX_ER and TXD. The LPI client should not assert TX_EN for valid transmit data until after the wake-up time specified for the PHY.

Figure 35–8 shows the behavior of TX_EN, TX_ER and TXD<7:0> during the transition into and out of the LPI state.

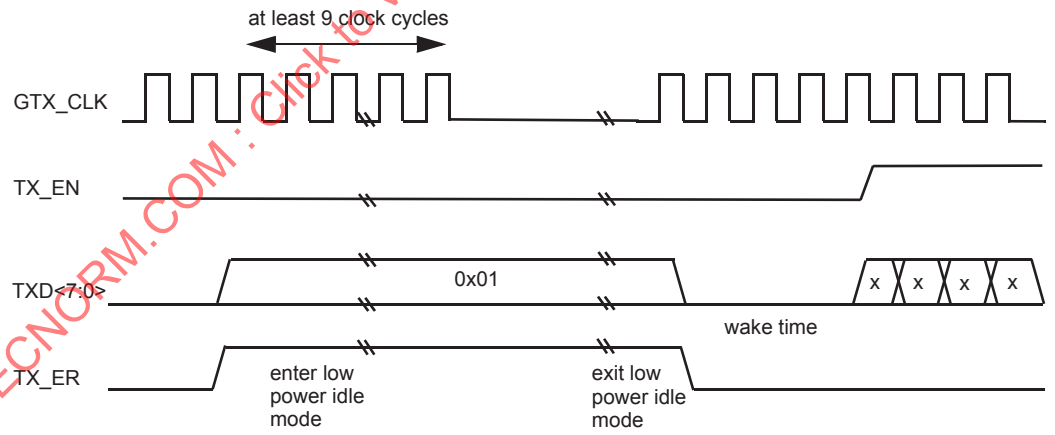

Figure 35–8—LPI transition

Table 35–1 summarizes the permissible encodings of TXD<7:0>, TX_EN, and TX_ER.

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35.2.2.7 RX_DV (receive data valid)

RX_DV is driven by the PHY to indicate that the PHY is presenting recovered and decoded data on the RXD<7:0> bundle. RX_DV shall transition synchronously with respect to the RX_CLK. RX_DV shall be asserted continuously from the first recovered octet of the frame through the final recovered octet and shall be negated prior to the first rising edge of RX_CLK that follows the final octet. In order for a received frame to be correctly interpreted by the Reconciliation sublayer and the MAC sublayer, RX_DV must encompass the frame, starting no later than the Start Frame Delimiter (SFD) and excluding any End-of-Frame delimiter.

Figure 35–9 shows the behavior of RX_DV during frame reception with no errors or carrier extension.

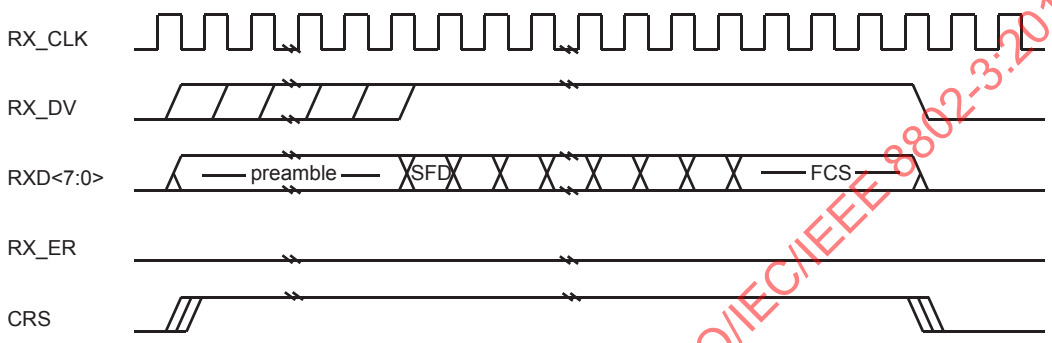

Figure 35–9—Basic frame reception

35.2.2.8 RXD (receive data)

RXD is a bundle of eight data signals (RXD<7:0>) that are driven by the PHY. RXD<7:0> shall transition synchronously with respect to RX_CLK. For each RX_CLK period in which RX_DV is asserted, RXD<7:0> transfer eight bits of recovered data from the PHY to the Reconciliation sublayer. RXD<0> is the least significant bit. Figure 35–9 shows the behavior of RXD<7:0> during frame reception.

While RX_DV is deasserted, the PHY may provide a False Carrier indication by asserting the RX_ER signal while driving the specific value listed in Table 35–2 onto RXD<7:0>. See 36.2.5.2.3 for a description of the conditions under which a PHY will provide a False Carrier indication. LPI transitions are described in 35.2.2.10.

While RX_DV is deasserted, the PHY may indicate that it is receiving LPI by asserting the RX_ER signal while driving the value 0x01 onto RXD<7:0>.

In order for a frame to be correctly interpreted by the MAC sublayer, a completely formed SFD must be passed across the GMII.

In a DTE operating in half duplex mode, a PHY is not required to loop data transmitted on TXD<7:0> back to RXD<7:0> unless the loopback mode of operation is selected as defined in 22.2.4.1.2. In a DTE operating in full duplex mode, data transmitted on TXD <7:0> shall not be looped back to RXD <7:0> unless the loopback mode of operation is selected.

While RX_DV is deasserted and RX_ER is asserted, a specific RXD<7:0> value is used to transfer recovered Carrier Extend from the PHY to the Reconciliation sublayer. A Carrier Extend Error is indicated by another specific value of RXD<7:0>. Figure 35–10 shows the behavior of RX_DV during frame reception with carrier extension. Carrier extension shall only be signalled immediately following frame reception.

Burst transmission of frames also uses carrier extension between frames of the burst. Figure 35–11 shows the behavior of RX_ER and RX_DV during burst reception.

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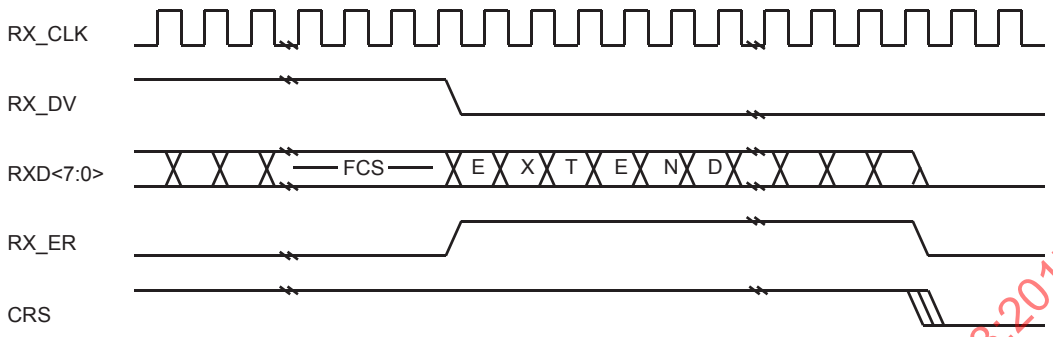

Figure 35–10—Frame reception with carrier extension

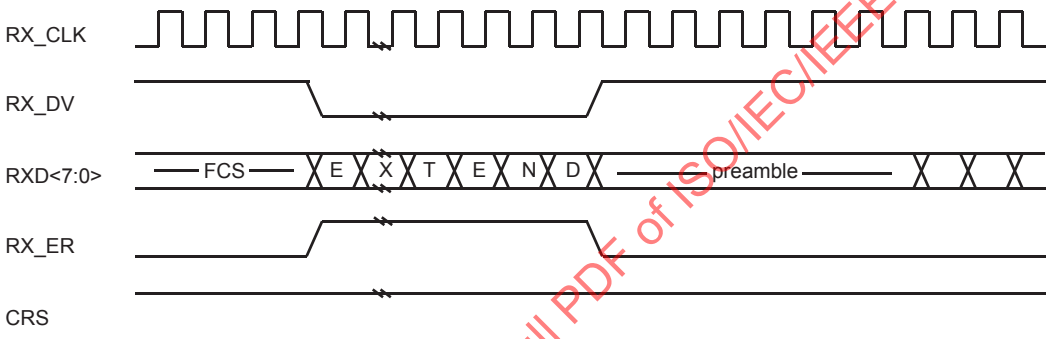

Figure 35–11—Burst reception

Table 35–2 specifies the permissible encoding of RXD<7:0>, RX_ER, and RX_DV, along with the specific indication that shall be interpreted by the RS.

Table 35–2—Permissible encoding of RXD<7:0>, RX_ER, and RX_DV

RX_DV	RX_ER	RXD<7:0>	Description	PLS_DATA.indication parameter
0	0	00 through FF	Normal inter-frame	No applicable parameter
0	1	00	Normal inter-frame	No applicable parameter

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Table 35–2—Permissible encoding of RXD<7:0>, RX_ER, and RX_DV *(continued)*

RX_DV	RX_ER	RXD<7:0>	Description	PLS_DATA.indication parameter
0	1	01	Assert LPI	No applicable parameter
0	1	02 through 0D	Reserved	—
0	1	0E	False Carrier indication	No applicable parameter
0	1	0F	Carrier Extend	EXTEND (eight bits)
0	1	10 through 1E	Reserved	—
0	1	1F	Carrier Extend Error	ZERO, ONE (eight bits)
0	1	20 through FF	Reserved	—
1	0	00 through FF	Normal data reception	ZERO, ONE (eight bits)
1	1	00 through FF	Data reception error	ZERO, ONE (eight bits)
NOTE—Values in RXD<7:0> column are in hexadecimal.				

35.2.2.9 RX_ER (receive error)

RX_ER is driven by the PHY and shall transition synchronously with respect to RX_CLK. When RX_DV is asserted, RX_ER shall be asserted for one or more RX_CLK periods to indicate to the Reconciliation sublayer that an error (e.g., a coding error, or another error that the PHY is capable of detecting that may otherwise be undetectable at the MAC sublayer) was detected somewhere in the frame presently being transferred from the PHY to the Reconciliation sublayer.

The effect of RX_ER on the Reconciliation sublayer is defined in 35.2.1.5. Figure 35–12 shows the behavior of RX_ER during the reception of a frame with errors. Two independent error cases are illustrated. When RX_DV is asserted, assertion of RX_ER indicates an error within the data octets of a frame. An error within carrier extension is indicated by driving the appropriate value on RXD<7:0> while keeping RX_ER asserted.

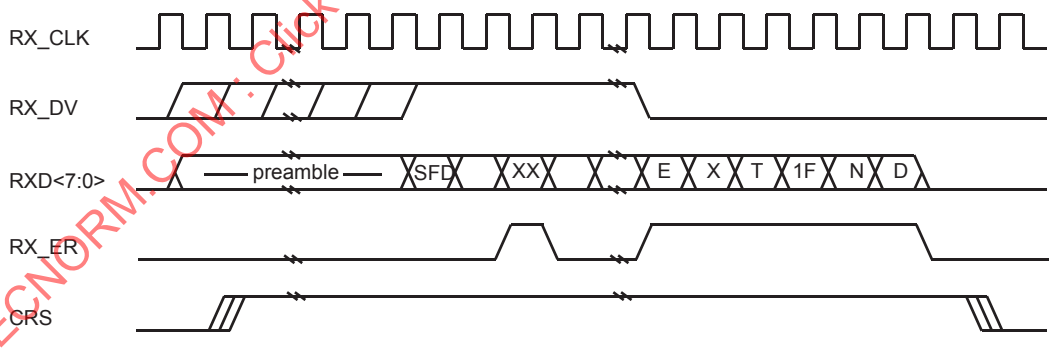

Figure 35–12—Two examples of reception with error

Assertion of RX_ER when RX_DV is deasserted with specific RXD values indicates the decode of carrier extension by the PHY. The transition from RX_DV asserted and RX_ER deasserted to RX_DV deasserted and RX_ER asserted with RXD specifying Carrier Extend shall result in the Reconciliation sublayer indicating EXTEND INPUT_UNITs to the MAC. Figure 35–10 shows the behavior of RX_DV and RX_ER during frame reception with carrier extension.

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While RX_DV is deasserted, the PHY may provide a False Carrier indication by asserting the RX_ER signal for at least one cycle of the RX_CLK while driving the appropriate value onto RXD<7:0>, as defined in Table 35–2. See 36.2.5.2.3 for a description of the conditions under which a PHY will provide a False Carrier indication. Figure 35–13 shows the behavior of RX_ER, RX_DV and RXD<7:0> during a False Carrier indication.

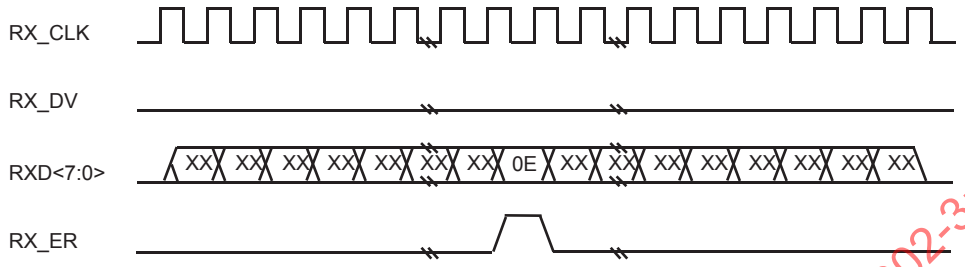

Figure 35–13—False Carrier indication

35.2.2.10 Receive direction LPI transition

EEE capability and the LPI client are described in 78.1. When the PHY receives signals from the link partner indicating LPI, it signals this to the LPI client by asserting RX_ER and setting RXD<7:0> to 0x01 while keeping RX_DV deasserted. The PHY maintains these signals in this state while it remains in the low power state. When the PHY receives signals from the link partner indicating its transition out of the low power state, it signals this to the LPI client by deasserting RX_ER and returning to normal interframe encoding.

While the PHY device is indicating LPI, the PHY device may halt the RX_CLK as shown in Figure 35–14 if and only if the Clock stop enable bit is asserted (see 45.2.3.1.4). The PHY may restart RX_CLK at any time while it is asserting LPI, but shall restart RX_CLK so that at least one positive transition occurs before it deasserts LPI.

Figure 35–14 shows the behavior of RX_ER, RX_DV, and RXD<7:0> during LPI transitions.

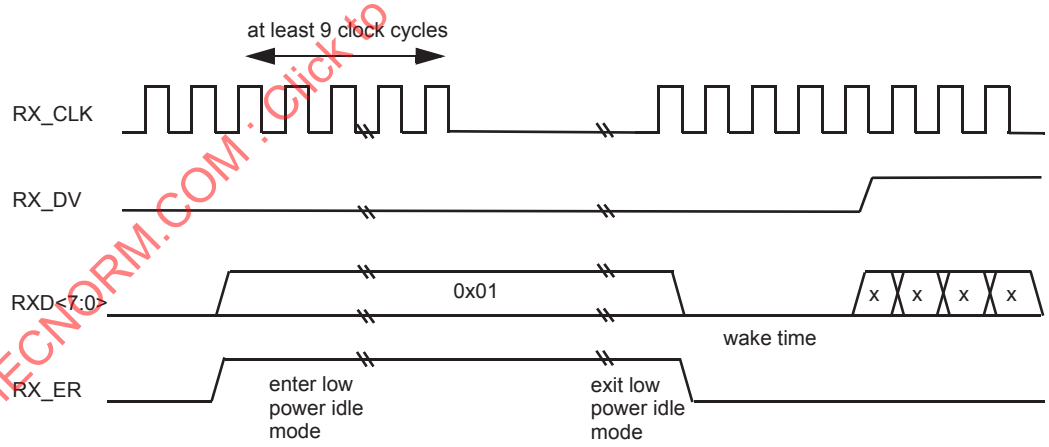

Figure 35–14—LPI transitions (receive)

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35.2.2.11 CRS (carrier sense)

CRS is driven by the PHY. Except when used in a repeater, a PHY in half duplex mode shall assert CRS when either the transmit or receive medium is non-idle and shall deassert CRS when both the transmit and receive media are idle. The PHY shall ensure that CRS remains asserted throughout the duration of a collision condition.

When used in a repeater, a PHY shall assert CRS when the receive medium is non-idle and shall deassert CRS when the receive medium is idle.

CRS is not required to transition synchronously with respect to either the GTX_CLK or the RX_CLK.

The behavior of CRS is unspecified when the PHY is in full duplex mode.

Figure 35–3 and Figure 35–5 show the behavior of CRS during a frame transmission without a collision, while Figure 35–15 and Figure 35–16 show the behavior of CRS during a frame transmission with a collision.

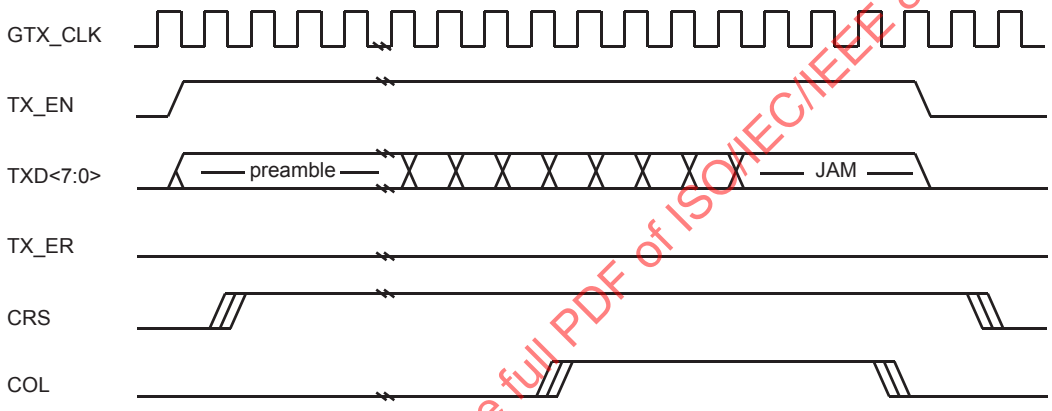

Figure 35–15—Transmission with collision

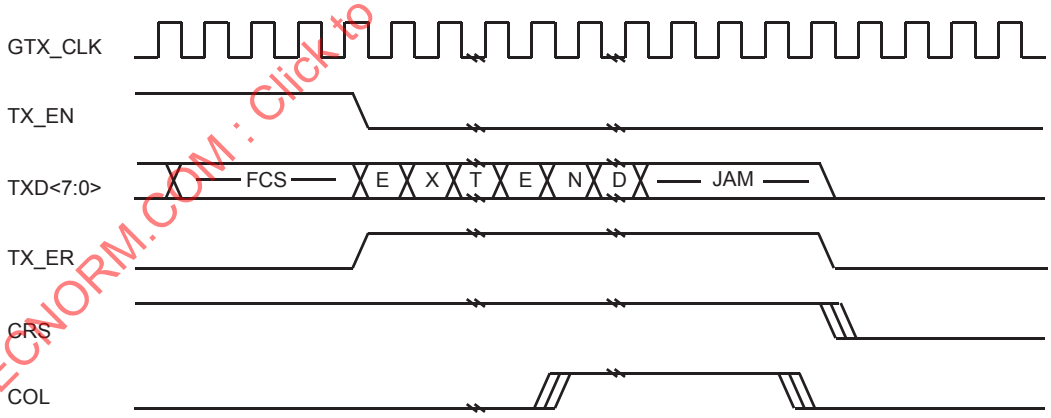

Figure 35–16—Transmission with collision in carrier extension

35.2.2.12 COL (collision detected)

COL is driven by the PHY and shall be asserted upon detection of a collision on the medium, and shall remain asserted while the collision condition persists.

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COL is not required to transition synchronously with respect to either the GTX_CLK or the RX_CLK.

The behavior of the COL signal is unspecified when the PHY is in full duplex mode.

Figure 35–15 and Figure 35–16 show the behavior of COL during a frame transmission with a collision.

35.2.2.13 MDC (management data clock)

MDC is specified in 22.2.2.13.

35.2.2.14 MDIO (management data input/output)

MDIO is specified in 22.2.2.14.

35.2.3 GMII data stream

Packets transmitted through the GMII shall be transferred within the data stream shown in Figure 35–17.

<inter-frame><preamble><sfd><data><efd><extend>

Figure 35–17—GMII data stream

For the GMII, transmission and reception of each octet of data shall be as shown in Figure 35–18.

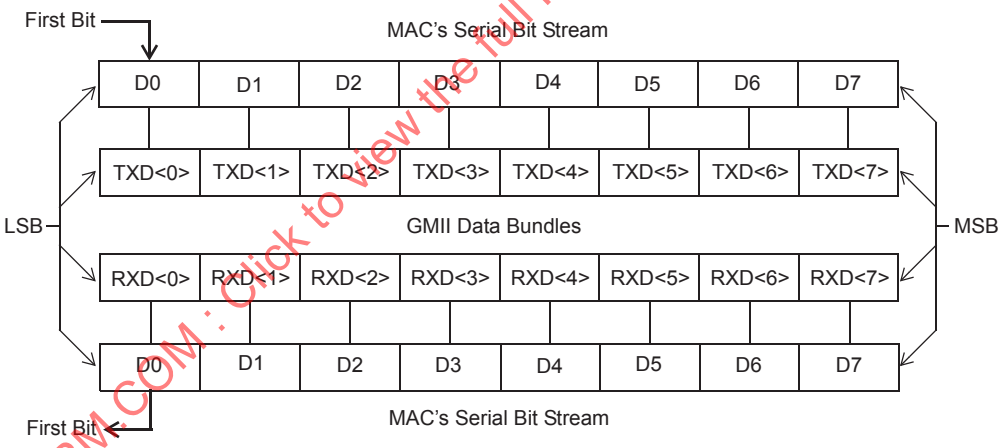

Figure 35–18—Relationship of data bundles to MAC serial bit stream

35.2.3.1 Inter-frame <inter-frame>

The inter-frame <inter-frame> period on a GMII transmit or receive path is an interval during which no data activity occurs on the path. Between bursts or single frame transmissions, the absence of data activity on the receive path is indicated by the deassertion of both RX_DV and RX_ER or the deassertion of the RX_DV signal with an RXD<7:0> value of 00 hexadecimal. On the transmit path the absence of data activity is indicated by the deassertion of both TX_EN and TX_ER.

Between frames within a burst, the inter-frame period is signalled as Carrier Extend on the GMII. As shown in Figure 35–7, this is done by asserting TX_ER with the appropriate encoding of TXD<7:0> simultaneous with

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the deassertion of TX_EN on the transmit path; and, as shown in Figure 35–11, by asserting RX_ER with the appropriate encoding of RXD<7:0> simultaneous with the deassertion of RX_DV on the receive path.

Within a burst, the MAC interFrameSpacing parameter defined in Clause 4, is measured from the deassertion of the TX_EN signal to the assertion of the TX_EN signal, and between bursts measured from the deassertion of the CRS signal to the assertion of the CRS signal.

35.2.3.2 Preamble <preamble> and start of frame delimiter <sfd>

35.2.3.2.1 Transmit case

The preamble <preamble> begins a frame transmission. The bit value of the preamble field at the GMII is unchanged from that specified in 4.2.5 and when generated by a MAC shall consist of 7 octets with the following bit values:

10101010 10101010 10101010 10101010 10101010 10101010 10101010

The SFD (Start Frame Delimiter) <sfd> indicates the start of a frame and immediately follows the preamble. The bit value of the SFD at the GMII is unchanged from that specified in 4.2.6, and is the following bit sequence:

10101011

The preamble and SFD are shown above with their bits ordered for serial transmission from left to right. As shown, the leftmost bit of each octet is the LSB of the octet and the rightmost bit of each octet is the MSB of the octet.

The preamble and SFD shall be transmitted through the GMII as octets starting from the assertion of TX_EN.

35.2.3.2.2 Receive case

The conditions for assertion of RX_DV are defined in 35.2.2.7. The operation of 1000 Mb/s PHYs can result in shrinkage of the preamble between transmission at the source GMII and reception at the destination GMII. Table 35–3 depicts the case where no preamble bytes are conveyed across the GMII. This case may not be possible with a specific PHY, but illustrates the minimum preamble with which MAC shall be able to operate. Table 35–4 depicts the case where the entire preamble is conveyed across the GMII.

Table 35–3—Start of receive with no preamble preceding SFD

Signal	Bit values of octets received through GMII[a]			
RXD0	X	X	1[b]	D0[c]
RXD1	X	X	0	D1
RXD2	X	X	1	D2
RXD3	X	X	0	D3
RXD4	X	X	1	D4
RXD5	X	X	0	D5
RXD6	X	X	1	D6
RXD7	X	X	1	D7
RX_DV	0	0	1	1

[a]Leftmost octet is the first received.
[b]Start Frame Delimiter octet.
[c]D0 through D7 is the first octet of the PDU (first octet of the Destination Address).

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Table 35–4—Start of receive with entire preamble preceding SFD

Signal	Bit values of octets received through GMII[a]									
RXD0	X	1	1	1	1	1	1	1	1[b]	D0[c]
RXD1	X	0	0	0	0	0	0	0	0	D1
RXD2	X	1	1	1	1	1	1	1	1	D2
RXD3	X	0	0	0	0	0	0	0	0	D3
RXD4	X	1	1	1	1	1	1	1	1	D4
RXD5	X	0	0	0	0	0	0	0	0	D5
RXD6	X	1	1	1	1	1	1	1	1	D6
RXD7	X	0	0	0	0	0	0	0	1	D7
RX_DV	0	1	1	1	1	1	1	1	1	1

[a]Leftmost octet is the first received.
[b]Start Frame Delimiter octet.
[c]D0 through D7 is the first octet of the PDU (first octet of the Destination Address).

35.2.3.3 Data <data>

The data <data> in a well-formed frame shall consist of a set of data octets.

35.2.3.4 End-of-Frame delimiter <efd>

Deassertion of the TX_EN signal constitutes an End-of-Frame delimiter <efd> for data conveyed on TXD<7:0>, and deassertion of RX_DV constitutes an End-of-Frame delimiter for data conveyed on RXD<7:0>.

35.2.3.5 Carrier extension <extend>

The Reconciliation sublayer signals carrier extension <extend> on the transmit path by the assertion of the TX_ER signal with the appropriate value of TXD<7:0> simultaneous with the deassertion of the TX_EN signal. Carrier extension is signaled on the receive path by the assertion of the RX_ER signal with the appropriate encoding on RXD<7:0> simultaneous with the deassertion of RX_DV. Carrier extension may not be present on all frames.

35.2.3.6 Definition of Start of Packet and End of Packet Delimiters

For the purposes of Clause 30 layer management, the Start of Packet delimiter is defined as the rising edge of RX_DV; and the End of Packet delimiter is defined as the falling edge of RX_DV. (See 30.2.2.2.2.)

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35.2.4 MAC delay constraints (with GMII)

A Gigabit Ethernet MAC with a GMII shall comply with the delay constraints in Table 35–5.

Table 35–5—MAC delay constraints (with GMII)

Sublayer measurement points	Event	Min (bits)	Max (bits)	Input timing reference	Output timing reference
MAC ⇔ GMII	MAC transmit start to TX_EN = 1 sampled		48		GTX_CLK rising
	CRS assert to MAC detect[a]	0	48		
	CRS deassert to MAC detect[a]	0	48		
	CRS assert to TX_EN = 1 sampled (worst-case nondeferred transmit)		112		GTX_CLK rising
	COL assert to MAC detect	0	48		
	COL deassert to MAC detect	0	48		
	COL assert to TXD = Jam sampled (worst-case collision response)		112		GTX_CLK rising; first octet of Jam

[a]For any given implementation: Max deassert – Min. assert ≤ 16 bits.

35.2.5 Management functions

The GMII shall use the MII management register set specified in 22.2.4. The detailed description of some management registers is dependent on the PHY type and is specified in either 22.2.4 or 37.2.5.

35.3 Signal mapping

The GMII is specified such that implementers may share pins for implementation of the GMII, the MII specified in Clause 22 and the TBI specified in Clause 36. A recommended mapping of the signals for the GMII, MII, and TBI is shown in Table 35–6. Implementers using this recommended mapping are to comply with the GMII electrical characteristics in 35.5, MII electrical characteristics in 22.3, and the TBI electrical characteristics in 36.3 as appropriate for the implemented interfaces.

In an implementation supporting the MII and GMII, some signal pins are not used in both interfaces. For example, the TXD and RXD data bundles are four bits wide for the MII and eight bits wide for the GMII. Also, the GTX_CLK is only used when operating as a GMII while TX_CLK is used when operating as an MII.

Similarly, an implementation supporting both the GMII and TBI interfaces will map TBI signals onto the GMII control signal pins of TX_ER, TX_EN, RX_ER, and RX_DV. The COL and CRS signals of the GMII have no corollary in the TBI.

It is recommended that unused signal pins be driven to a valid logic state.

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Table 35–6—Signal mapping

GMII	MII	TBI
TX_ER	TX_ER	TX<9>
TX_EN	TX_EN	TX<8>
TXD<7>		TX<7>
TXD<6>		TX<6>
TXD<5>		TX<5>
TXD<4>		TX<4>
TXD<3>	TXD<3>	TX<3>
TXD<2>	TXD<2>	TX<2>
TXD<1>	TXD<1>	TX<1>
TXD<0>	TXD<0>	TX<0>
COL	COL	

GMII	MII	TBI
RX_ER	RX_ER	RX<9>
RX_DV	RX_DV	RX<8>
RXD<7>		RX<7>
RXD<6>		RX<6>
RXD<5>		RX<5>
RXD<4>		RX<4>
RXD<3>	RXD<3>	RX<3>
RXD<2>	RXD<2>	RX<2>
RXD<1>	RXD<1>	RX<1>
RXD<0>	RXD<0>	RX<0>
CRS	CRS	

35.4 LPI Assertion and Detection

Certain PHYs support Energy-Efficient Ethernet (see Clause 78). PHYs with EEE capability support LPI assertion and detection. LPI operation and the LPI client are described in 78.1. LPI signaling allows the LPI client to signal to the PHY and to the link partner that a break in the data stream is expected and components may use this information to enter power-saving modes that require additional time to resume normal operation. Similarly, it allows the LPI client to understand that the link partner has sent such an indication.

The LPI assertion and detection mechanism fits conceptually between the PLS Service Primitives and the GMII signals as shown in Figure 35–19.

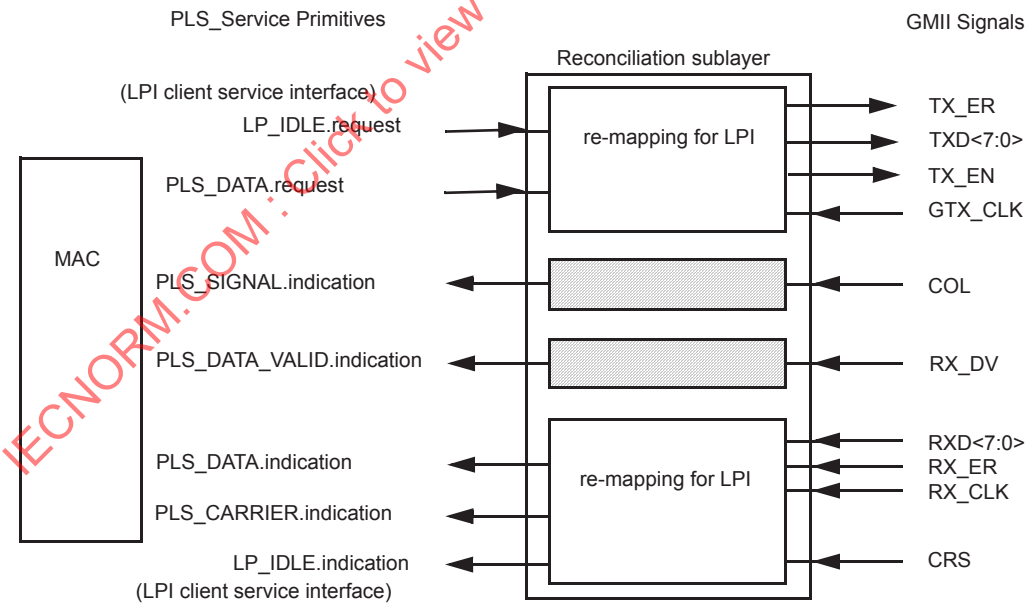

Figure 35–19—LPI assertion and detection mechanism

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The definition of TX_EN, TX_ER and TXD<7:0> is derived from the state of PLS_DATA.request (35.2.1.1), except when it is overridden by an assertion of LP_IDLE.request.

Similarly, RX_ER and RXD<7:0> are mapped to PLS_DATA.indication except when LP_IDLE is detected

CRS is mapped to PLS_CARRIER.indication except when LP_IDLE.request is asserted or the wake timer has yet to expire.

The timing of PLS_CARRIER.indication when used for the LPI function is controlled by the LPI transmit state diagram.

35.4.1 LPI messages

LP_IDLE.indication(LPI_INDICATION)

A primitive that indicates to the LPI client that the PHY has detected the assertion or deassertion of LPI from the link partner.

Values:DEASSERT: The link partner is operating with normal interframe behavior (default).
ASSERT: The link partner has asserted LPI.

LP_IDLE.request(LPI_REQUEST)

The LPI_REQUEST parameter can take one of two values: ASSERT or DEASSERT. ASSERT initiates the signaling of LPI to the link partner. DEASSERT stops the signaling of LPI to the link partner. The effect of receipt of this primitive is undefined if link_status is not OK (see 28.2.6.1.1) or if LPI_REQUEST=ASSERT within 1 s of the change of link_status to OK.

35.4.2 Transmit LPI state diagram

The operation of LPI in the PHY requires that the MAC does not send valid data for a time after LPI has been deasserted as governed by resolved Transmit T_{w_sys} defined in 78.4.2.3.

This wake-up time is enforced by the transmit LPI state diagram and the rules mapping CARRIER_SENSE.indication defined in 35.2.1. The implementation shall conform to the behavior described by the transmit LPI state diagram shown in Figure 35–20.

35.4.2.1 Conventions

The notation used in the state diagram follows the conventions of 34.2.

35.4.2.2 Variables and counters

The transmit LPI state diagram uses the following variables and counters:

power_on

Condition that is true until such time as the power supply for the device that contains the RS has reached the operating region.

Values:FALSE: The device is completely powered (default).
TRUE: The device has not been completely powered.

rs_reset

Used by management to control the resetting of the RS.

Values:FALSE: Do not reset the RS (default).
TRUE: Reset the RS.

tw_timer

A timer that counts the time since the deassertion of LPI. The terminal count of the timer is the value of the resolved $T_{w_sys_tx}$ as defined in 78.2 and 78.4. The minimum value of $T_{w_sys_tx}$ shall be 16.5 µs for 1000BASE-T and 13.26 µs for 1000BASE-KX. Signal tw_timer_done is asserted on reaching its terminal count.

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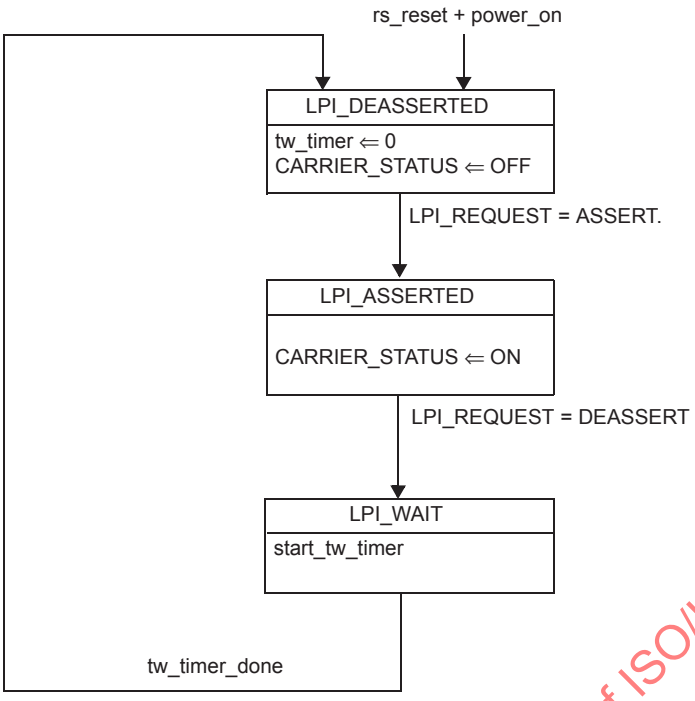

Figure 35–20—Transmit LPI state diagram

35.4.2.3 State diagram

35.4.3 Considerations for transmit system behavior

The transmit system should expect that egress data flow will be halted for at least resolved $T_{w_sys_tx}$ (see 78.2) time, in microseconds, after it requests the deassertion of LPI. Buffering and queue management should be designed to accommodate this.

35.4.3.1 Considerations for receive system behavior

The mapping function of the Reconciliation Sublayer shall continue to signal IDLE on PLS_DATA.indicate while it is detecting LP_IDLE on the GMII. The receive system should be aware that data frames may arrive at the GMII following the deassertion of LPI_INDICATION with a delay corresponding to the link partner's resolved $T_{w_sys_rx}$ (as specified in 78.5) time, in microseconds.

35.5 Electrical characteristics

The electrical characteristics of the GMII are specified such that the GMII can be applied within a variety of 1000 Mb/s equipment types. The electrical specifications are optimized for an integrated circuit to integrated circuit application environment. This includes applications where a number of PHY integrated circuits may be connected to a single integrated circuit as may be found in a repeater. Though specified for use on a single circuit board, applications to a motherboard-to-daughterboard interconnection are not precluded.

The electrical characteristics specified in this clause apply to all GMII signals except MDIO and MDC. The electrical characteristics for MDIO and MDC are specified in 22.3.4.

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35.5.1 DC characteristics

All GMII drivers and receivers shall comply with the dc parametric attributes specified in Table 35–7.

The potential applied to the input of a GMII receiver may exceed the potential of the receiver's power supply (i.e., a GMII driver powered from a 3.6 V supply driving V_{OH} into a GMII receiver powered from a 2.5 V supply). Tolerance for dissimilar GMII driver and receiver supply potentials is implicit in these specifications.

Table 35–7—DC specifications

Symbol	Parameter	Conditions		Min	Max	Units
V_{OH}	Output High Voltage	I_{OH} = -1.0 mA	V_{CC} = Min	2.10	3.60	V
V_{OL}	Output Low Voltage	I_{OL} = 1.0 mA	V_{CC} = Min	GND	0.50	V
V_{IH}	Input High Voltage			1.70	—	V
V_{IL}	Input Low Voltage			—	0.90	V
I_{IH}	Input High Current	V_{CC} = Max	V_{IN} = 2.1 V	—	40	µA
I_{IL}	Input Low Current	V_{CC} = Max	V_{IN} = 0.5 V	–600	—	µA

35.5.2 AC characteristics

The GMII ac electrical characteristics are specified in a manner that allows the implementer flexibility in selecting the GMII topologies its devices support and the techniques used to achieve the specified characteristics.

All GMII devices are required to support point-to-point links. The electrical length of the circuit board traces used to implement these links can be long enough to exhibit transmission line effects and require some form of termination. The implementer is allowed the flexibility to select the driver output characteristics and the termination technique and components to be used with its drivers for point-to-point links.

Implementers may elect to support other GMII topologies in addition to the point-to-point topology and may specify different termination techniques and components for each supported topology.

Since the output characteristics and output voltage waveforms of GMII drivers depend on the termination technique and the location of the termination components, the ac output characteristics of GMII drivers are not explicitly specified. Rather, the ac characteristics of the signal delivered to a GMII receiver are specified. These characteristics are independent of the topology and termination technique and apply uniformly to all GMII applications.

35.5.2.1 Signal Timing measurements

All GMII ac timing measurements are made at the GMII receiver input and are specified relative to the $V_{IL_AC(max)}$ and $V_{IH_AC(min)}$ thresholds.

The GTX_CLK and RX_CLK parameters t_{PERIOD}, t_{HIGH}, and t_{LOW} are defined in Figure 35–21. The GTX_CLK and RX_CLK parameters t_R and t_F and other transient performance specifications are defined in Figure 35–22. These parameters and the GTX_CLK and RX_CLK rising and falling slew rates are measured using the GMII point-to-point test circuit shown in Figure 35–24.

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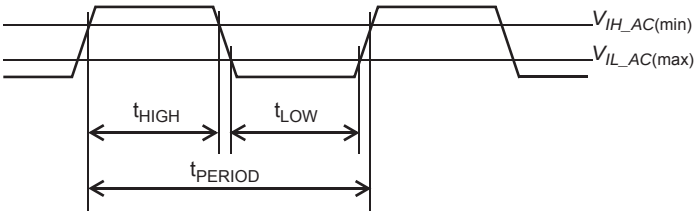
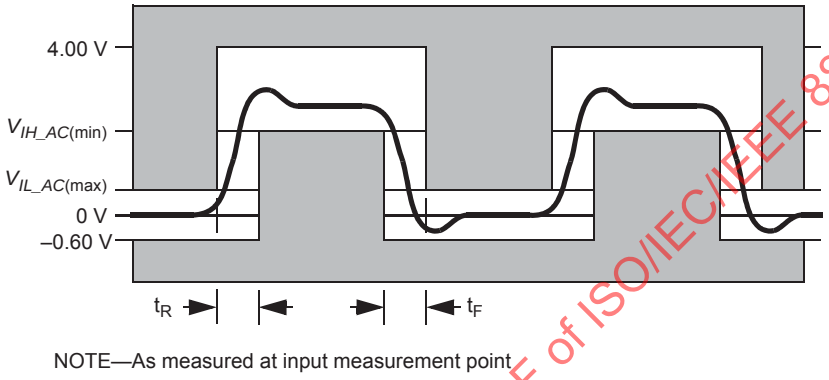


Figure 35–21—GTX_CLK and RX_CLK timing parameters at receiver input



NOTE—As measured at input measurement point

Figure 35–22—GMII receiver input potential template

The t_{SETUP} and t_{HOLD} parameters are defined in Figure 35–23. These parameters are measured using the GMII setup and hold time test circuit shown in Figure 35–25.

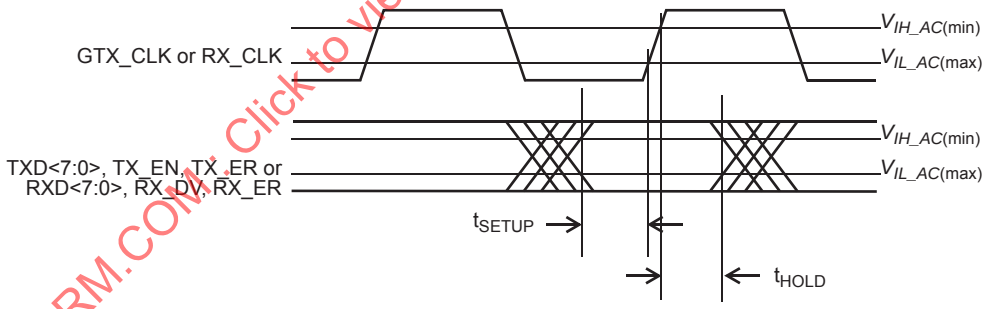


Figure 35–23—GMII signal timing at receiver input

35.5.2.2 GMII test circuit topology

The GMII point-to-point test circuit is defined in Figure 35–24. All parameter measurements made with this circuit are made at the Input Measurement Point defined in Figure 35–24. The 5 pF capacitor is included to approximate the input load of a GMII receiver. The termination networks used to implement the GMII point-to-point test circuit shall be those specified by the implementer of the GMII driver for 50 Ω ± 15% impedance transmission line point-to-point links. One or both of the termination networks specified by the implementer of the GMII driver may be straight-through connections if the networks are not needed to comply with the GMII ac and transient performance specifications.

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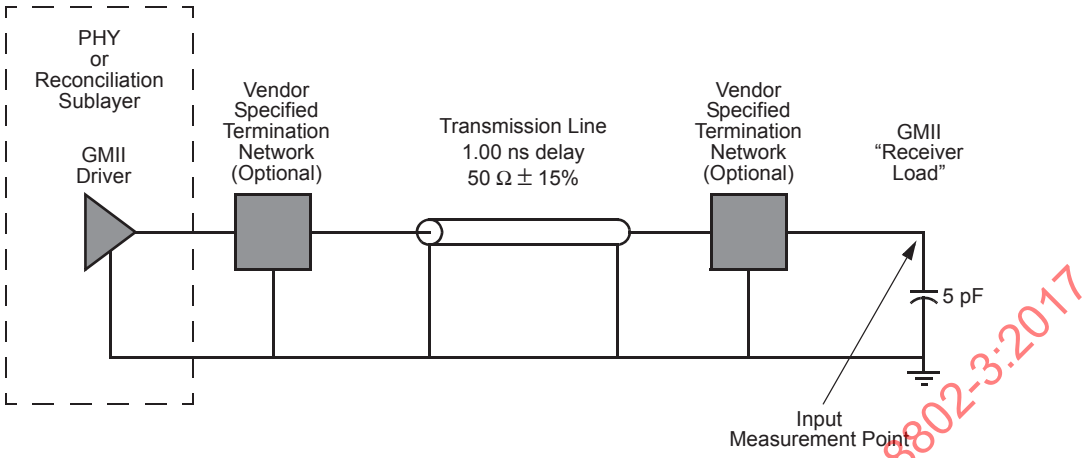

Figure 35–24—GMII point-to-point test circuit

The GMII point-to-point test circuit specifies a 1 ns transmission line. In a GMII implementation, the circuit board traces between the PHY and Reconciliation sublayer are not restricted to a delay of 1 ns.

The GMII setup and hold time test circuit is defined in Figure 35–25. The circuit is comprised of the source of the synchronous GMII signal under test and its clock (the Reconciliation Layer or the PHY) and two GMII point-to-point test circuits. One of the test circuits includes the GMII driver for the signal under test, the other test circuit includes the GMII driver for the clock that provides timing for the signal under test. The signal under test is measured at the "Signal Measurement Point" relative to its clock, which is measured at the Clock Measurement Point as defined in Figure 35–25.

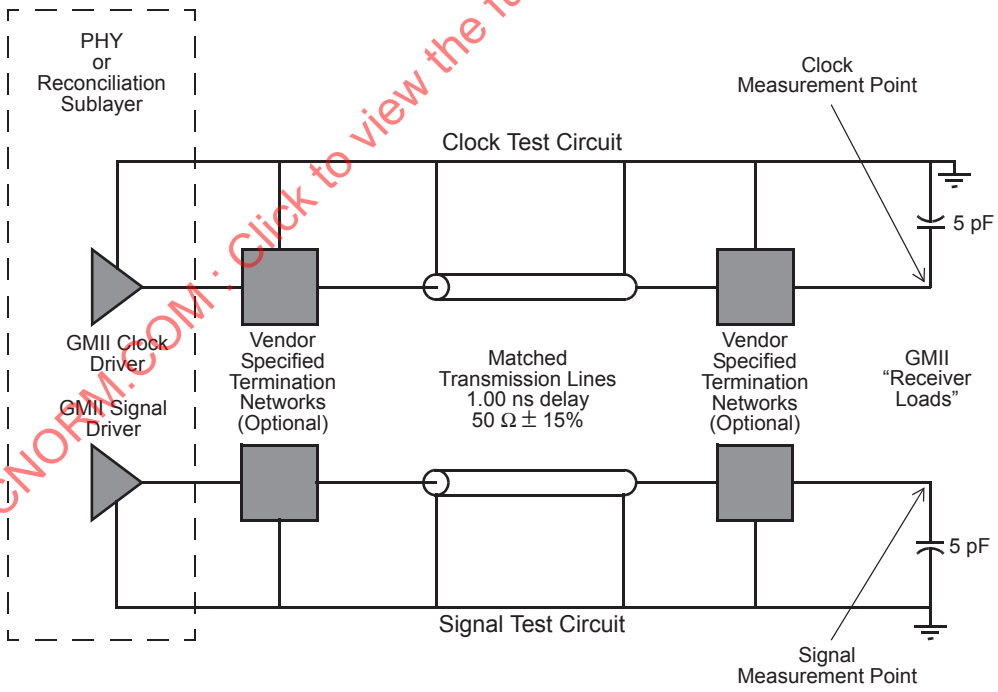

Figure 35–25—GMII setup and hold time test circuit

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35.5.2.3 GMII ac specifications

A GMII driver, when used in combination with the termination networks specified by the implementer of the driver for a specific GMII topology, shall produce a potential at the input pin of any GMII receiver in that topology that complies with the input potential template shown in Figure 35–22. This requirement applies for all GMII signals and any GMII topology.

To ensure that all GMII devices support point-to-point links, a GMII driver, when driving the GMII point-to-point test circuit shown in Figure 35–24, shall produce a potential at the Input Measurement Point of the GMII point-to-point test circuit that complies with the input potential template shown in Figure 35–22.

All GMII signal sources, including the GMII drivers, GMII receivers and GMII signals shall comply with the ac specifications in Table 35–8.

Table 35–8—AC specifications

Symbol	Parameter	Conditions	Min	Max	Units
V_{IL_AC}	Input Low Voltage ac	—	—	0.70	V
V_{IH_AC}	Input High Voltage ac	—	1.90	—	V
f_{FREQ}	GTX_CLK Frequency	—	125 – 100 ppm	125 + 100 ppm	MHz
t_{PERIOD}	GTX_CLK Period		7.50	8.50	ns
t_{PERIOD}	RX_CLK Period	—	7.50	—	ns
t_{HIGH}	GTX_CLK, RX_CLK Time High	—	2.50	—	ns
t_{LOW}	GTX_CLK, RX_CLK Time Low	—	2.50	—	ns
t_R	GTX_CLK, RX_CLK Rise Time	V_{IL_AC}(max) to V_{IH_AC}(min)	—	1.00	ns
t_F	GTX_CLK, RX_CLK Fall Time	V_{IH_AC}(min) to V_{IL_AC}(max)	—	1.00	ns
—	Magnitude of GTX_CLK, RX_CLK Slew Rate (rising)[a]	V_{IL_AC}(max) to V_{IH_AC}(min)	0.6	—	V/ns
—	Magnitude of GTX_CLK, RX_CLK Slew Rate (falling)[a]	V_{IH_AC}(min) to V_{IL_AC}(max)	0.6	—	V/ns
t_{SETUP}	TXD, TX_EN, TX_ER Setup to ↑ GTX_CLK and RXD, RX_DV, RX_ER Setup to ↑ RX_CLK	—	2.50	—	ns
t_{HOLD}	TXD, TX_EN, TX_ER Hold from ↑ GTX_CLK and RXD, RX_DV, RX_ER Hold from ↑ RX_CLK	—	0.50	—	ns
t_{SETUP} (RCVR)	TXD, TX_EN, TX_ER Setup to ↑ GTX_CLK and RXD, RX_DV, RX_ER Setup to ↑ RX_CLK	—	2.00	—	ns
t_{HOLD} (RCVR)	TXD, TX_EN, TX_ER Hold from ↑ GTX_CLK and RXD, RX_DV, RX_ER Hold from ↑ RX_CLK	—	0.00	—	ns

[a]Clock Skew rate is the instantaneous rate of change of the clock potential with respect to time (dV/dt), not an average value over the entire rise or fall time interval. Conformance with this specification guarantees that the clock signals will rise and fall monotonically through the switching region.

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Two sets of setup and hold time parameters are specified in Table 35–8. The first set, t_{SETUP} and t_{HOLD}, applies to the source of a synchronous GMII signal and its clock and is measured using the "GMII Setup and Hold Time Test Circuit," which has transmission lines with matched propagation delays in the "clock" and "signal" paths. The second set, $t_{SETUP(RCVR)}$ and $t_{HOLD(RCVR)}$, applies to the GMII receiver and specifies the minimum setup and hold times available to the GMII receiver at its input pins. The difference between the two sets of setup and hold time parameters provides margin for a small amount of mismatch in the propagation delays of the "clock" path and the "signal" paths in GMII applications.

The GMII ac specifications in Table 35–8 and the transient performance specifications in Figure 35–22 shall be met under all combination of worst-case GMII driver process and supply potential variation, ambient temperature, transmission line impedance variation, and termination network component impedance variation.

Designers of components containing GMII receivers should note that there is no upper bound specified on the magnitude of the slew rate of signals that may be applied to the input of a GMII receiver. The high-frequency energy in a high slew rate (short rise time) signal can excite the parasitic reactances of the receiver package and input pad to such a degree that the signal at the receiver input pin and the signal at the input pad differ significantly. This is particularly true for GTX_CLK and RX_CLK, which transition at twice the rate of other signals in the interface.

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35.6 Protocol implementation conformance statement (PICS) proforma for Clause 35, Reconciliation Sublayer (RS) and Gigabit Media Independent Interface (GMII)[1]

35.6.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 35, Reconciliation Sublayer (RS) and Gigabit Media Independent Interface (GMII), shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

35.6.2 Identification

35.6.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

35.6.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 35, Reconciliation Sublayer (RS) and Gigabit Media Independent Interface (GMII)
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	No [ ] Yes [ ]

Date of Statement	

[1] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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35.6.2.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*EL	GMII electrical interface	35.5		O	Yes [ ] No [ ]
*G1	PHY support of GMII	35.1.3		O	Yes [ ] No [ ]
G2	Reconciliation sublayer support of GMII	35.1.3		O	Yes [ ] No [ ]
*HD	Half duplex capability	35.2.2.7		O	Yes [ ] No [ ]
*LPI	Implementation of LPI	35.2.2		O	Yes [ ] No [ ]

35.6.3 PICS proforma tables for reconciliation sublayer and Gigabit Media Independent Interface

35.6.3.1 Mapping of PLS service primitives

Item	Feature	Subclause	Value/Comment	Status	Support
PL1	Response to error in frame	35.2.1.5	Must produce FrameCheckError when RX_DV and RX_ER are asserted	M	Yes [ ]
PL2	Response to error in extension	35.2.1.5	Must produce FrameCheckError on received Carrier Extend Error	M	Yes [ ]
PL2a	Propagation of errors in frame	35.2.1.6	Assert TX_ER while TX_EN asserted	O	Yes [ ]
PL3	Propagation of errors in extension	35.2.1.6	Must send ONE or ZERO and assert Carrier Extend Error to propagate error within carrier extension	O	Yes [ ] No [ ]

35.6.3.2 GMII signal functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
SF1					
SF2	RX_CLK frequency	35.2.2.2	125 MHz ±0.01% when received data rate is within tolerance	M	Yes [ ]
SF3	Loss of signal	35.2.2.2	Source RX_CLK from nominal clock	M	Yes [ ]

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35.6.3.2 GMII signal functional specifications *(continued)*

Item	Feature	Subclause	Value/Comment	Status	Support
SF4	RX_CLK min high/low time during transitions between clock sources	35.2.2.2	No decrease of period, or time between adjacent edges, of RX_CLK below limits specified in Table 35–8	M	Yes [ ]
SF5	RX_CLK max high/low time during transitions between clock sources	35.2.2.2	No increase greater than two nominal clock periods between adjacent edges of RX_CLK	M	Yes [ ]
SF6	TX_EN assertion	35.2.2.3	On first octet of preamble	M	Yes [ ]
SF7	TX_EN remains asserted	35.2.2.3	Stay asserted while all octets are transmitted over GMII	M	Yes [ ]
SF8	TX_EN negation	35.2.2.3	Before first GTX_CLK after final octet of frame	M	Yes [ ]
SF9	TX_EN transitions	35.2.2.3	Synchronous with GTX_CLK	M	Yes [ ]
SF10	TXD <7:0> transitions	35.2.2.4	Synchronous with GTX_CLK	M	Yes [ ]
SF11	TXD <7:0> effect on PHY while TX_EN and TX_ER are deasserted	35.2.2.4	No effect	M	Yes [ ]
SF12	Signaling carrier extension	35.2.2.4	Only immediately following frame	M	Yes [ ]
SF13	TX_ER transitions	35.2.2.5	Synchronous with GTX_CLK	M	Yes [ ]
SF14	TX_ER effect on PHY while TX_EN is asserted	35.2.2.5	Cause PHY to emit invalid code-group	M	Yes [ ]
SF15	Transmission of end-of-packet delimiter	35.2.2.5	On deassertion of TX_EN and simultaneous assertion of TX_ER	M	Yes [ ]
SF16	TX_ER implementation	35.2.2.5	At GMII of PHY	M	Yes [ ]
SF17	TX_ER implementation	35.2.2.5	Implemented if half duplex operation supported.	HD:M	Yes [ ] N/A [ ]
SF18	TX_ER driven	35.2.2.5	To valid state even if constant	M	Yes [ ]
SF19	RX_DV transitions	35.2.2.7	Synchronous with RX_CLK	M	Yes [ ]
SF20	RX_DV assertion	35.2.2.7	From first recovered octet to final octet of a frame	M	Yes [ ]
SF21	RX_DV negation	35.2.2.7	Before the first RX_CLK following the final octet of the frame	M	Yes [ ]
SF22	RXD <7:0> transitions	35.2.2.8	Synchronous with RX_CLK	M	Yes [ ]
SF22a	RXD loopback	35.2.2.8	No loopback unless loopback mode selected	M	Yes [ ]
SF23	Signaling carrier extension	35.2.2.8	Only immediately following frame	M	Yes [ ]
SF24	RX_ER transitions	35.2.2.9	Synchronous with RX_CLK	M	Yes [ ]
SF25	RX_ER assertion	35.2.2.9	By PHY to indicate error	M	Yes [ ]

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35.6.3.2 GMII signal functional specifications *(continued)*

Item	Feature	Subclause	Value/Comment	Status	Support
SF26	Generation of EXTEND	35.2.2.9	In response to simultaneous deassertion of RX_DV and assertion of RX_ER by PHY	M	Yes [ ]
SF27	CRS assertion	35.2.2.11	By PHY when either transmit or receive is NON-IDLE	M	Yes [ ]
SF28	CRS deassertion	35.2.2.11	By PHY when both transmit and receive are IDLE	M	Yes [ ]
SF29	CRS assertion during collision	35.2.2.11	Remain asserted throughout	M	Yes [ ]
SF30	CRS assertion—repeater	35.2.2.11	By repeater when receive is NON-IDLE	M	Yes [ ]
SF31	CRS deassertion—repeater	35.2.2.11	By repeater when medium is IDLE	M	Yes [ ]
SF32	COL assertion	35.2.2.12	By PHY upon collision on medium	M	Yes [ ]
SF33	COL remains asserted while collision persists	35.2.2.12		M	Yes [ ]

35.6.3.3 Data stream structure

Item	Feature	Subclause	Value/Comment	Status	Support
DS1	Format of transmitted data stream	35.2.3	Per Figure 35–17	M	Yes [ ]
DS2	Transmission order	35.2.3	Per Figure 35–18	M	Yes [ ]
DS3	Preamble 7 octets long	35.2.3.2	10101010 10101010 10101010 10101010 10101010 10101010 10101010	M	Yes [ ]
DS4	Preamble and SFD transmission	35.2.3.2	Starting at assertion of TX_EN	M	Yes [ ]
DS5	Minimum preamble	35.2.3.2	MAC operates with minimum preamble	M	Yes [ ]
DS6	Data length	35.2.3.3	Set of octets	M	Yes [ ]

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35.6.3.4 LPI functions

Item	Feature	Subclause	Value/Comment	Status	Support
L1	Assertion of LPI in Tx direction	35.2.2.4	As defined in Table 35–1	LPI:M	Yes [ ]
L2	Assertion of LPI in Rx direction	35.2.2.8	As defined in Table 35–2	LPI:M	Yes [ ]
L3	GTX_CLK stoppable during LPI	35.2.2.6	At least 9 cycles after LPI assertion	LPI:O	Yes [ ]
L4	RX_CLK stoppable during LPI	35.2.2.10		LPI:O	Yes [ ]
L5	Terminal count for tw_timer	35.4.2.2	Based on resolved $T_{w_sys_tx}$	LPI:M	Yes [ ]

35.6.3.5 Delay constraints

Item	Feature	Subclause	Value/Comment	Status	Support
DC1	MAC delay	35.2.4	Comply with Table 35–5	M	Yes [ ]

35.6.3.6 Management functions

Item	Feature	Subclause	Value/Comment	Status	Support
MF1	Management registers	35.2.5	Use register set specified in 22.2.4	M	Yes [ ]

35.6.3.7 Electrical characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
EC1	DC specifications	35.5.1	All drivers and receivers per Table 35–7	EL:M	Yes [ ] N/A [ ]
EC3	AC and transient specifications	35.5.2.3	Under all combinations of worst case parameters	EL:M	Yes [ ] N/A [ ]
EC4	Topology input potential	35.5.2.3	Complies with Figure 35–22 at each receiver of topology	EL:M	Yes [ ] N/A [ ]
EC5	Tested driver input potential	35.5.2.3	Complies with Figure 35–22 as tested per Figure 35–24	EL:M	Yes [ ] N/A [ ]
EC6	Test circuit termination	35.5.2.2	As specified by GMII driver implementer	EL:M	Yes [ ] N/A [ ]
EC7	AC specifications	35.5.2.3	Per Table 35–8	EL:M	Yes [ ] N/A [ ]

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36. Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 1000BASE-X

36.1 Overview

36.1.1 Scope

This clause specifies the Physical Coding Sublayer (PCS) and the Physical Medium Attachment (PMA) sublayer that are common to a family of 1000 Mb/s Physical Layer implementations, collectively known as 1000BASE-X.

1000BASE-X is based on the Physical Layer standards developed by ANSI X3.230-1994 (Fibre Channel Physical and Signaling Interface). In particular, this standard uses the same 8B/10B coding as Fibre Channel, a PMA sublayer compatible with speed-enhanced versions of the ANSI 10-bit serializer chip, and similar optical and electrical specifications.

1000BASE-X PCS and PMA sublayers map the interface characteristics of the PMD sublayer (including MDI) to the services expected by the Reconciliation sublayer. 1000BASE-X can be extended to support any other full duplex medium requiring only that the medium be compliant at the PMD level.

36.1.2 Objectives

The following are the objectives of 1000BASE-X:

a) To support the CSMA/CD MAC
b) To support the 1000 Mb/s repeater
c) To provide for Auto-Negotiation among like 1000 Mb/s PMDs
d) To provide 1000 Mb/s data rate at the GMII
e) To support cable plants using 150 Ω balanced copper cabling, or cabled optical fiber compliant with ISO/IEC 11801:1995
f) To allow for a nominal network extent of up to 5 km, including
   1) 150 Ω balanced links of 25 m span
   2) one-repeater networks of 50 m span (using all 150 Ω balanced copper cabling)
   3) one-repeater networks of 200 m span (using fiber)
   4) DTE/DTE links of 5000 m (using fiber)
g) To preserve full duplex behavior of underlying PMD channels
h) To support a BER objective of 10^{-12}

NOTE—The 1000BASE-X PCS and PMA do not constrain the extent of a full duplex network. PMDs in Clause 59 and Clause 60 have ranges beyond 5 km.

36.1.3 Relationship of 1000BASE-X to other standards

Figure 36–1 depicts the relationships among the 1000BASE-X sublayers (shown shaded), the CSMA/CD MAC and reconciliation layers, and the ISO/IEC 8802-2 LLC.

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36.1.4 Summary of 1000BASE-X sublayers

The following provides an overview of the 1000BASE-X sublayers.[2]

36.1.4.1 Physical Coding Sublayer (PCS)

The PCS interface is the Gigabit Media Independent Interface (GMII) that provides a uniform interface to the Reconciliation sublayer for all 1000 Mb/s PHY implementations (e.g., not only 1000BASE-X but also other possible types of gigabit PHY entities). 1000BASE-X provides services to the GMII in a manner analogous to how 100BASE-X provides services to the 100 Mb/s MII.

The 1000BASE-X PCS provides all services required by the GMII, including

a) Encoding (decoding) of GMII data octets to (from) ten-bit code-groups (8B/10B) for communication with the underlying PMA
b) Generating Carrier Sense and Collision Detect indications for use by PHY's half duplex clients
c) Managing the Auto-Negotiation process, and informing the management entity via the GMII when the PHY is ready for use

36.1.4.2 Physical Medium Attachment (PMA) sublayer

The PMA provides a medium-independent means for the PCS to support the use of a range of serial-bit-oriented physical media. The 1000BASE-X PMA performs the following functions:

a) Mapping of transmit and receive code-groups between the PCS and PMA via the PMA Service Interface
b) Serialization (deserialization) of code-groups for transmission (reception) on the underlying serial PMD
c) Recovery of clock from the 8B/10B-coded data supplied by the PMD
d) Mapping of transmit and receive bits between the PMA and PMD via the PMD Service Interface
e) Data loopback at the PMD Service Interface

36.1.4.3 Physical Medium Dependent (PMD) sublayer

1000BASE-X Physical Layer signaling for fiber and copper media is adapted from ANSI X3.230-1994 (FC-PH), Clauses 6 and 7 respectively. These clauses define 1062.5 Mb/s, full duplex signaling systems that accommodate single-mode optical fiber, multimode optical fiber, and 150 Ω balanced copper cabling. 1000BASE-X adapts these basic Physical Layer specifications for use with the PMD sublayer and media specified in Clause 38 and Clause 39.

The MDI, logically subsumed within each PMD subclause, is the actual medium attachment, including connectors, for the various supported media.

Figure 36–1 depicts the relationship between 1000BASE-X and its associated PMD sublayers.

36.1.5 Inter-sublayer interfaces

There are a number of interfaces employed by 1000BASE-X. Some (such as the PMA Service Interface) use an abstract service model to define the operation of the interface. An optional physical instantiation of the PCS Interface has been defined. It is called the GMII (Gigabit Media Independent Interface). An optional

[2]The 1000BASE-X PHY consists of that portion of the Physical Layer between the MDI and GMII consisting of the PCS, PMA, and PMD sublayers. The 1000BASE-X PHY is roughly analogous to the 100BASE-X PHY.

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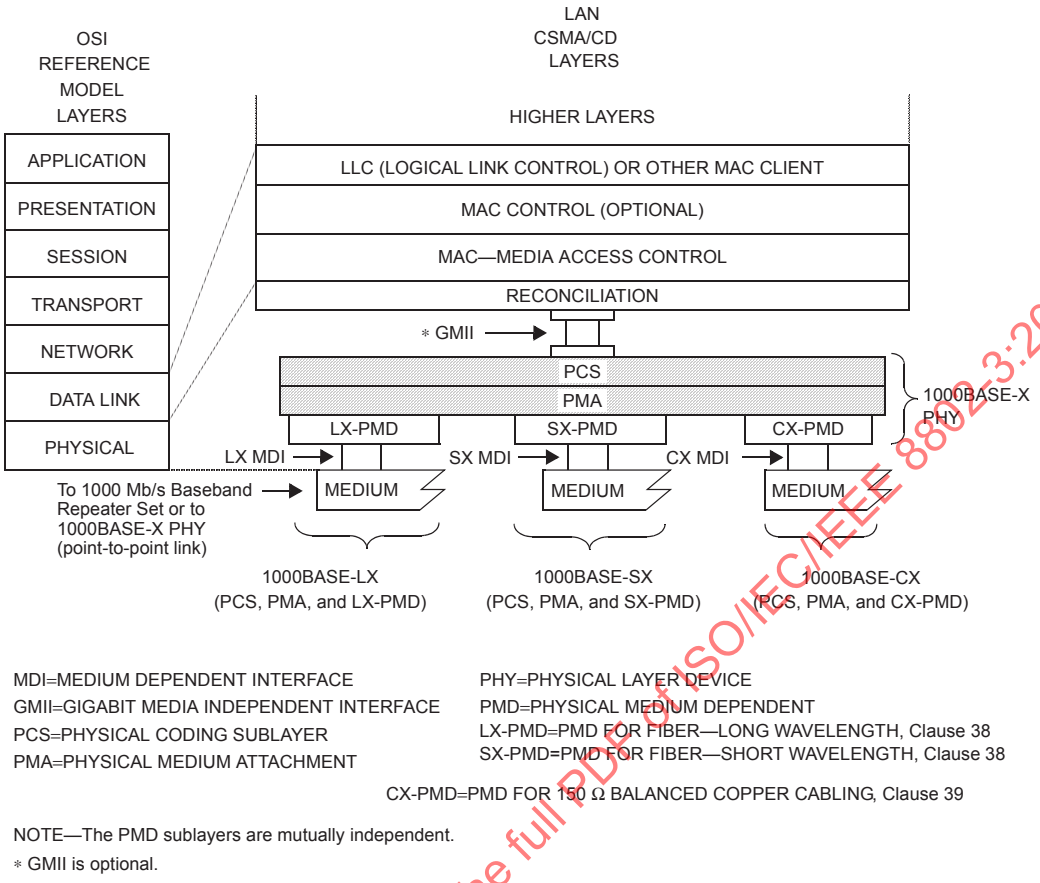

MDI=MEDIUM DEPENDENT INTERFACE
GMII=GIGABIT MEDIA INDEPENDENT INTERFACE
PCS=PHYSICAL CODING SUBLAYER
PMA=PHYSICAL MEDIUM ATTACHMENT
PHY=PHYSICAL LAYER DEVICE
PMD=PHYSICAL MEDIUM DEPENDENT
LX-PMD=PMD FOR FIBER—LONG WAVELENGTH, Clause 38
SX-PMD=PMD FOR FIBER—SHORT WAVELENGTH, Clause 38
CX-PMD=PMD FOR 150 Ω BALANCED COPPER CABLING, Clause 39

NOTE—The PMD sublayers are mutually independent.
* GMII is optional.

Figure 36–1—Relationship of 1000BASE-X and the PMDs

physical instantiation of the PMA Service Interface has also been defined (see 36.3.3). It is adapted from ANSI Technical Report TR/X3.18-1997 (Fibre Channel—10-bit Interface). Figure 36–2 depicts the relationship and mapping of the services provided by all of the interfaces relevant to 1000BASE-X.

It is important to note that, while this specification defines interfaces in terms of bits, octets, and code-groups, implementers may choose other data path widths for implementation convenience. The only exceptions are a) the GMII, which, when implemented at an observable interconnection port, uses an octet-wide data path as specified in Clause 35, b) the PMA Service Interface, which, when physically implemented as the TBI (Ten-Bit Interface) at an observable interconnection port, uses a 10-bit wide data path as specified in 36.3.3, and c) the MDI, which uses a serial, physical interface.

36.1.6 Functional block diagram

Figure 36–2 provides a functional block diagram of the 1000BASE-X PHY.

36.1.7 State diagram conventions

The body of this standard is comprised of state diagrams, including the associated definitions of variables, constants, and functions. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

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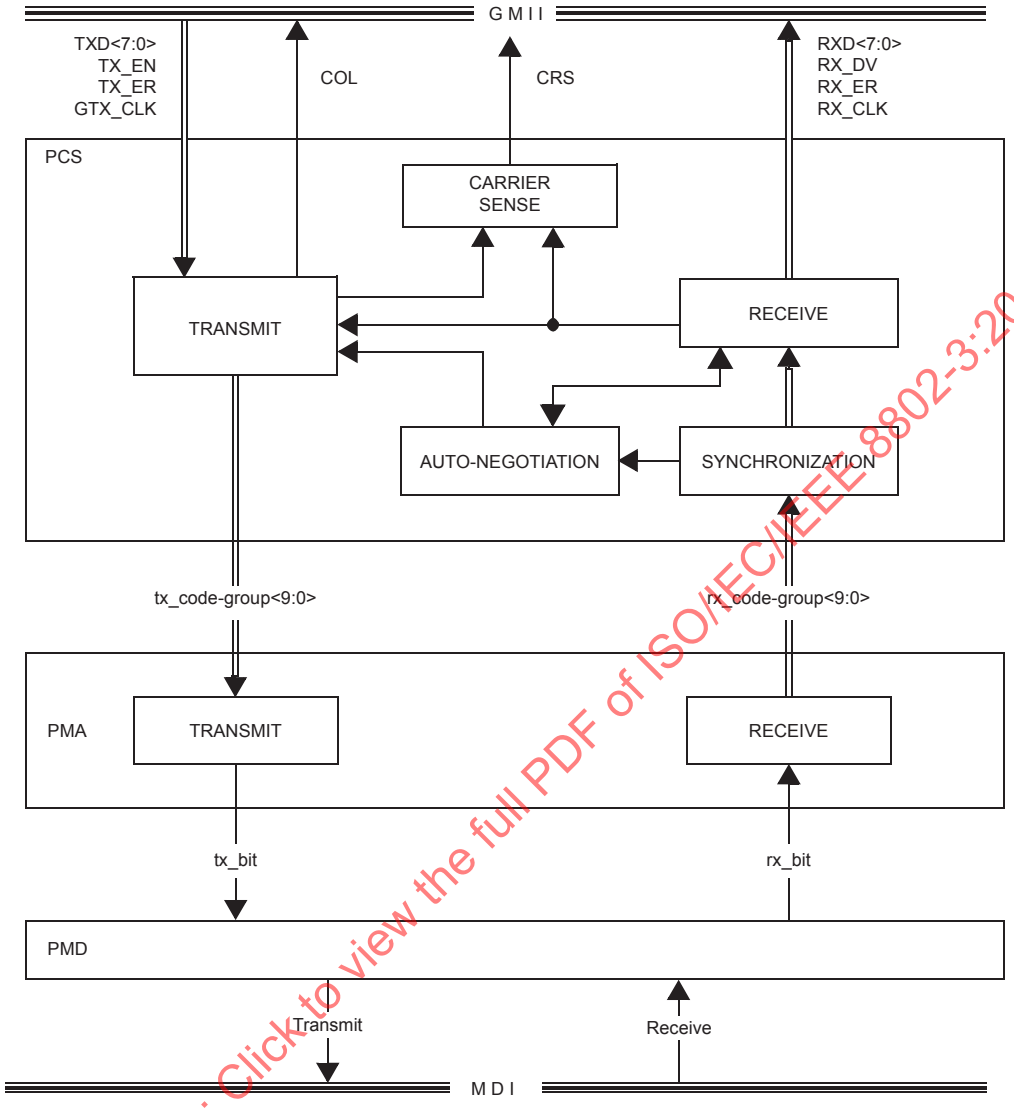

Figure 36–2—Functional block diagram

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The notation used in the state diagrams follows the conventions of 21.5. State diagram timers follow the conventions of 14.2.3.2.

36.2 Physical Coding Sublayer (PCS)

36.2.1 PCS Interface (GMII)

The PCS Service Interface allows the 1000BASE-X PCS to transfer information to and from a PCS client. PCS clients include the MAC (via the Reconciliation sublayer) and repeater. The PCS Interface is precisely defined as the Gigabit Media Independent Interface (GMII) in Clause 35.

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In this clause, the setting of GMII variables to TRUE or FALSE is equivalent, respectively, to “asserting” or “deasserting” them as specified in Clause 35.

36.2.2 Functions within the PCS

The PCS comprises the PCS Transmit, Carrier Sense, Synchronization, PCS Receive, and Auto-Negotiation processes for 1000BASE-X. The PCS shields the Reconciliation sublayer (and MAC) from the specific nature of the underlying channel. When communicating with the GMII, the PCS uses an octet-wide, synchronous data path, with packet delimiting being provided by separate transmit control signals (TX_EN and TX_ER) and receive control signals (RX_DV and RX_ER). When communicating with the PMA, the PCS uses a ten-bit wide, synchronous data path, which conveys ten-bit code-groups. At the PMA Service Interface, code-group alignment and MAC packet delimiting are made possible by embedding special non-data code-groups in the transmitted code-group stream. The PCS provides the functions necessary to map packets between the GMII format and the PMA Service Interface format.

The PCS Transmit process continuously generates code-groups based upon the TXD <7:0>, TX_EN, and TX_ER signals on the GMII, sending them immediately to the PMA Service Interface via the PMA_UNITDATA.request primitive. The PCS Transmit process generates the GMII signal COL based on whether a reception is occurring simultaneously with transmission. Additionally, it generates the internal flag, transmitting, for use by the Carrier Sense process. The PCS Transmit process monitors the Auto-Negotiation process xmit flag to determine whether to transmit data or reconfigure the link.

The Carrier Sense process controls the GMII signal CRS (see Figure 36–8).

The PCS Synchronization process continuously accepts code-groups via the PMA_UNITDATA.indication primitive and conveys received code-groups to the PCS Receive process via the SYNC_UNITDATA.indicate primitive. The PCS Synchronization process sets the sync_status flag to indicate whether the PMA is functioning dependably (as well as can be determined without exhaustive error-ratio analysis).

The PCS Receive process continuously accepts code-groups via the SYNC_UNITDATA.indicate primitive. The PCS Receive process monitors these code-groups and generates RXD <7:0>, RX_DV, and RX_ER on the GMII, and the internal flag, receiving, used by the Carrier Sense and Transmit processes.

The PCS Auto-Negotiation process sets the xmit flag to inform the PCS Transmit process to either transmit normal idles interspersed with packets as requested by the GMII or to reconfigure the link. The PCS Auto-Negotiation process is specified in Clause 37.

36.2.3 Use of code-groups

The PCS maps GMII signals into ten-bit code groups, and vice versa, using an 8B/10B block coding scheme. Implicit in the definition of a code-group is an establishment of code-group boundaries by a PMA code-group alignment function as specified in 36.3.2.4. Code-groups are unobservable and have no meaning outside the PCS. The PCS functions ENCODE and DECODE generate, manipulate, and interpret code-groups as provided by the rules in 36.2.4.

36.2.4 8B/10B transmission code

The PCS uses a transmission code to improve the transmission characteristics of information to be transferred across the link. The encodings defined by the transmission code ensure that sufficient transitions are present in the PHY bit stream to make clock recovery possible at the receiver. Such encoding also greatly increases the likelihood of detecting any single or multiple bit errors that may occur during transmission and reception of information. In addition, some of the special code-groups of the transmission code contain a distinct and easily recognizable bit pattern that assists a receiver in achieving code-group alignment on the

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incoming PHY bit stream. The 8B/10B transmission code specified for use in this standard has a high transition density, is a run-length-limited code, and is DC-balanced. The transition density of the 8B/10B symbols ranges from 3 to 8 transitions per symbol.

The definition of the 8B/10B transmission code in this standard is identical to that specified in ANSI X3.230-1994 (FC-PH), Clause 11. The relationship of code-group bit positions to PMA and other PCS constructs is illustrated in Figure 36–3.

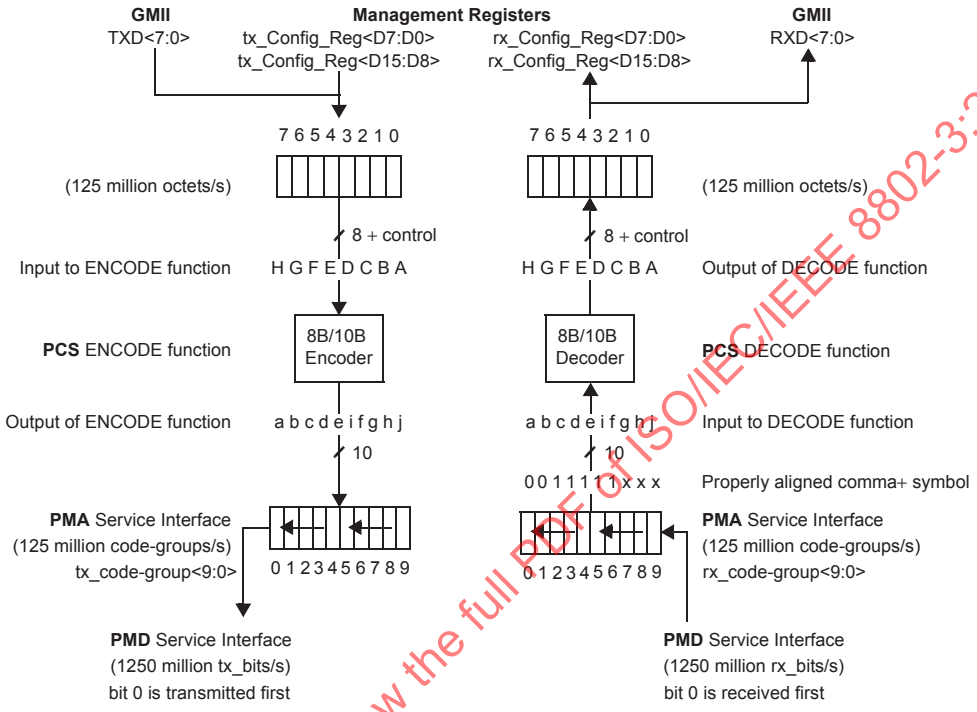

Figure 36–3—PCS reference diagram

36.2.4.1 Notation conventions

8B/10B transmission code uses letter notation for describing the bits of an unencoded information octet and a single control variable. Each bit of the unencoded information octet contains either a binary zero or a binary one. A control variable, Z, has either the value D or the value K. When the control variable associated with an unencoded information octet contains the value D, the associated encoded code-group is referred to as a data code-group. When the control variable associated with an unencoded information octet contains the value K, the associated encoded code-group is referred to as a special code-group.

The bit notation of A,B,C,D,E,F,G,H for an unencoded information octet is used in the description of the 8B/10B transmission code. The bits A,B,C,D,E,F,G,H are translated to bits a,b,c,d,e,i,f,g,h,j of 10-bit transmission code-groups. 8B/10B code-group bit assignments are illustrated in Figure 36–3. Each valid code-group has been given a name using the following convention: /Dx.y/ for the 256 valid data code-groups, and /Kx.y/ for special control code-groups, where x is the decimal value of bits EDCBA, and y is the decimal value of bits HGF.

36.2.4.2 Transmission order

Code-group bit transmission order is illustrated in Figure 36–3.

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Code-groups within multi-code-group ordered sets (as specified in Table 36–3) are transmitted sequentially beginning with the special code-group used to distinguish the ordered set (e.g., /K28.5/) and proceeding code-group by code-group from left to right within the definition of the ordered set until all code-groups of the ordered set are transmitted.

The first code-group of every multi-code-group ordered set is transmitted in an even-numbered code-group position counting from the first code-group after a reset or power-on. Subsequent code-groups continuously alternate as odd and even-numbered code-groups.

The contents of a packet are transmitted sequentially beginning with the ordered set used to denote the Start_of_Packet (the SPD delimiter) and proceeding code-group by code-group from left to right within the definition of the packet until the ordered set used to denote the End_of_Packet (the EPD delimiter) is transmitted.

36.2.4.3 Valid and invalid code-groups

Table 36–1a defines the valid data code-groups (D code-groups) of the 8B/10B transmission code. Table 36–2 defines the valid special code-groups (K code-groups) of the code. The tables are used for both generating valid code-groups (encoding) and checking the validity of received code-groups (decoding). In the tables, each octet entry has two columns that represent two (not necessarily different) code-groups. The two columns correspond to the valid code-group based on the current value of the running disparity (Current RD – or Current RD +). Running disparity is a binary parameter with either the value negative (–) or the value positive (+). Annex 36B provides several 8B/10B transmission code running disparity calculation examples.

36.2.4.4 Running disparity rules

After powering on or exiting a test mode, the transmitter shall assume the negative value for its initial running disparity. Upon transmission of any code-group, the transmitter shall calculate a new value for its running disparity based on the contents of the transmitted code-group.

After powering on or exiting a test mode, the receiver should assume either the positive or negative value for its initial running disparity. Upon the reception of any code-group, the receiver determines whether the code-group is valid or invalid and calculates a new value for its running disparity based on the contents of the received code-group.

The following rules for running disparity shall be used to calculate the new running disparity value for code-groups that have been transmitted (transmitter's running disparity) and that have been received (receiver's running disparity).

Running disparity for a code-group is calculated on the basis of sub-blocks, where the first six bits (abcdei) form one sub-block (six-bit sub-block) and the second four bits (fghj) form the other sub-block (four-bit sub-block). Running disparity at the beginning of the six-bit sub-block is the running disparity at the end of the last code-group. Running disparity at the beginning of the four-bit sub-block is the running disparity at the end of the six-bit sub-block. Running disparity at the end of the code-group is the running disparity at the end of the four-bit sub-block.

Running disparity for the sub-blocks is calculated as follows:

a) Running disparity at the end of any sub-block is positive if the sub-block contains more ones than zeros. It is also positive at the end of the six-bit sub-block if the six-bit sub-block is 000111, and it is positive at the end of the four-bit sub-block if the four-bit sub-block is 0011.

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b) Running disparity at the end of any sub-block is negative if the sub-block contains more zeros than ones. It is also negative at the end of the six-bit sub-block if the six-bit sub-block is 111000, and it is negative at the end of the four-bit sub-block if the four-bit sub-block is 1100.

c) Otherwise, running disparity at the end of the sub-block is the same as at the beginning of the sub-block.

NOTE—All sub-blocks with equal numbers of zeros and ones are disparity neutral. In order to limit the run length of 0's or 1's between sub-blocks, the 8B/10B transmission code rules specify that sub-blocks encoded as 000111 or 0011 are generated only when the running disparity at the beginning of the sub-block is positive; thus, running disparity at the end of these sub-blocks is also positive. Likewise, sub-blocks containing 111000 or 1100 are generated only when the running disparity at the beginning of the sub-block is negative; thus, running disparity at the end of these sub-blocks is also negative.

36.2.4.5 Generating code-groups

The appropriate entry in either Table 36–1a or Table 36–2 is found for each octet for which a code-group is to be generated (encoded). The current value of the transmitter's running disparity shall be used to select the code-group from its corresponding column. For each code-group transmitted, a new value of the running disparity is calculated. This new value is used as the transmitter's current running disparity for the next octet to be encoded and transmitted.

36.2.4.6 Checking the validity of received code-groups

The following rules shall be used to determine the validity of received code groups:

a) The column in Table 36–1a and Table 36–2 corresponding to the current value of the receiver's running disparity is searched for the received code-group.

b) If the received code-group is found in the proper column, according to the current running disparity, then the code-group is considered valid and, for data code-groups, the associated data octet determined (decoded).

c) If the received code-group is not found in that column, then the code-group is considered invalid.

d) Independent of the code-group's validity, the received code-group is used to calculate a new value of running disparity. The new value is used as the receiver's current running disparity for the next received code-group.

Detection of an invalid code-group does not necessarily indicate that the code-group in which the invalid code-group was detected is in error. Invalid code-groups may result from a prior error which altered the running disparity of the PHY bit stream but which did not result in a detectable error at the code-group in which the error occurred.

The number of invalid code-groups detected is proportional to the bit error ratio (BER) of the link. Link error monitoring may be performed by counting invalid code-groups.

36.2.4.7 Ordered sets

Eight ordered sets, consisting of a single special code-group or combinations of special and data code-groups are specifically defined. Ordered sets which include /K28.5/ provide the ability to obtain bit and code-group synchronization and establish ordered set alignment (see 36.2.4.9 and 36.3.2.4). Ordered sets provide for the delineation of a packet and synchronization between the transmitter and receiver circuits at opposite ends of a link. Table 36–3 lists the defined ordered sets. Certain PHYs include an option (see 78.3) to transmit or receive /LI/, /LI1/ and /LI2/ to support Energy-Efficient Ethernet (see Clause 78).

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Table 36–1a—Valid data code-groups

Code Group Name	Octet Value	Octet Bits HGF EDCBA	Current RD –	Current RD +
			abcdei fghj	abcdei fghj
D0.0	00	000 00000	100111 0100	011000 1011
D1.0	01	000 00001	011101 0100	100010 1011
D2.0	02	000 00010	101101 0100	010010 1011
D3.0	03	000 00011	110001 1011	110001 0100
D4.0	04	000 00100	110101 0100	001010 1011
D5.0	05	000 00101	101001 1011	101001 0100
D6.0	06	000 00110	011001 1011	011001 0100
D7.0	07	000 00111	111000 1011	000111 0100
D8.0	08	000 01000	111001 0100	000110 1011
D9.0	09	000 01001	100101 1011	100101 0100
D10.0	0A	000 01010	010101 1011	010101 0100
D11.0	0B	000 01011	110100 1011	110100 0100
D12.0	0C	000 01100	001101 1011	001101 0100
D13.0	0D	000 01101	101100 1011	101100 0100
D14.0	0E	000 01110	011100 1011	011100 0100
D15.0	0F	000 01111	010111 0100	101000 1011
D16.0	10	000 10000	011011 0100	100100 1011
D17.0	11	000 10001	100011 1011	100011 0100
D18.0	12	000 10010	010011 1011	010011 0100
D19.0	13	000 10011	110010 1011	110010 0100
D20.0	14	000 10100	001011 1011	001011 0100
D21.0	15	000 10101	101010 1011	101010 0100
D22.0	16	000 10110	011010 1011	011010 0100
D23.0	17	000 10111	111010 0100	000101 1011
D24.0	18	000 11000	110011 0100	001100 1011
D25.0	19	000 11001	100110 1011	100110 0100
D26.0	1A	000 11010	010110 1011	010110 0100
D27.0	1B	000 11011	110110 0100	001001 1011
D28.0	1C	000 11100	001110 1011	001110 0100
D29.0	1D	000 11101	101110 0100	010001 1011
D30.0	1E	000 11110	011110 0100	100001 1011
D31.0	1F	000 11111	101011 0100	010100 1011
D0.1	20	001 00000	100111 1001	011000 1001
D1.1	21	001 00001	011101 1001	100010 1001
D2.1	22	001 00010	101101 1001	010010 1001
D3.1	23	001 00011	110001 1001	110001 1001
D4.1	24	001 00100	110101 1001	001010 1001
D5.1	25	001 00101	101001 1001	101001 1001
D6.1	26	001 00110	011001 1001	011001 1001
D7.1	27	001 00111	111000 1001	000111 1001
D8.1	28	001 01000	111001 1001	000110 1001
D9.1	29	001 01001	100101 1001	100101 1001
D10.1	2A	001 01010	010101 1001	010101 1001
D11.1	2B	001 01011	110100 1001	110100 1001
D12.1	2C	001 01100	001101 1001	001101 1001
D13.1	2D	001 01101	101100 1001	101100 1001
D14.1	2E	001 01110	011100 1001	011100 1001
D15.1	2F	001 01111	010111 1001	101000 1001
D16.1	30	001 10000	011011 1001	100100 1001
D17.1	31	001 10001	100011 1001	100011 1001
D18.1	32	001 10010	010011 1001	010011 1001
D19.1	33	001 10011	110010 1001	110010 1001
D20.1	34	001 10100	001011 1001	001011 1001
D21.1	35	001 10101	101010 1001	101010 1001
D22.1	36	001 10110	011010 1001	011010 1001
D23.1	37	001 10111	111010 1001	000101 1001
D24.1	38	001 11000	110011 1001	001100 1001
D25.1	39	001 11001	100110 1001	100110 1001
D26.1	3A	001 11010	010110 1001	010110 1001
D27.1	3B	001 11011	110110 1001	001001 1001

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Table 36–1b—Valid data code-groups

Code Group Name	Octet Value	Octet Bits HGF EDCBA	Current RD –	Current RD +
			abcdei fghj	abcdei fghj
D28.1	3C	001 11100	001110 1001	001110 1001
D29.1	3D	001 11101	101110 1001	010001 1001
D30.1	3E	001 11110	011110 1001	100001 1001
D31.1	3F	001 11111	101011 1001	010100 1001
D0.2	40	010 00000	100111 0101	011000 0101
D1.2	41	010 00001	011101 0101	100010 0101
D2.2	42	010 00010	101101 0101	010010 0101
D3.2	43	010 00011	110001 0101	110001 0101
D4.2	44	010 00100	110101 0101	001010 0101
D5.2	45	010 00101	101001 0101	101001 0101
D6.2	46	010 00110	011001 0101	011001 0101
D7.2	47	010 00111	111000 0101	000111 0101
D8.2	48	010 01000	111001 0101	000110 0101
D9.2	49	010 01001	100101 0101	100101 0101
D10.2	4A	010 01010	010101 0101	010101 0101
D11.2	4B	010 01011	110100 0101	110100 0101
D12.2	4C	010 01100	001101 0101	001101 0101
D13.2	4D	010 01101	101100 0101	101100 0101
D14.2	4E	010 01110	011100 0101	011100 0101
D15.2	4F	010 01111	010111 0101	101000 0101
D16.2	50	010 10000	011011 0101	100100 0101
D17.2	51	010 10001	100011 0101	100011 0101
D18.2	52	010 10010	010011 0101	010011 0101
D19.2	53	010 10011	110010 0101	110010 0101
D20.2	54	010 10100	001011 0101	001011 0101
D21.2	55	010 10101	101010 0101	101010 0101
D22.2	56	010 10110	011010 0101	011010 0101
D23.2	57	010 10111	111010 0101	000101 0101
D24.2	58	010 11000	110011 0101	001100 0101
D25.2	59	010 11001	100110 0101	100110 0101
D26.2	5A	010 11010	010110 0101	010110 0101
D27.2	5B	010 11011	110110 0101	001001 0101
D28.2	5C	010 11100	001110 0101	001110 0101
D29.2	5D	010 11101	101110 0101	010001 0101
D30.2	5E	010 11110	011110 0101	100001 0101
D31.2	5F	010 11111	101011 0101	010100 0101
D0.3	60	011 00000	100111 0011	011000 1100
D1.3	61	011 00001	011101 0011	100010 1100
D2.3	62	011 00010	101101 0011	010010 1100
D3.3	63	011 00011	110001 1100	110001 0011
D4.3	64	011 00100	110101 0011	001010 1100
D5.3	65	011 00101	101001 1100	101001 0011
D6.3	66	011 00110	011001 1100	011001 0011
D7.3	67	011 00111	111000 1100	000111 0011
D8.3	68	011 01000	111001 0011	000110 1100
D9.3	69	011 01001	100101 1100	100101 0011
D10.3	6A	011 01010	010101 1100	010101 0011
D11.3	6B	011 01011	110100 1100	110100 0011
D12.3	6C	011 01100	001101 1100	001101 0011
D13.3	6D	011 01101	101100 1100	101100 0011
D14.3	6E	011 01110	011100 1100	011100 0011
D15.3	6F	011 01111	010111 0011	101000 1100
D16.3	70	011 10000	011011 0011	100100 1100
D17.3	71	011 10001	100011 1100	100011 0011
D18.3	72	011 10010	010011 1100	010011 0011
D19.3	73	011 10011	110010 1100	110010 0011
D20.3	74	011 10100	001011 1100	001011 0011
D21.3	75	011 10101	101010 1100	101010 0011
D22.3	76	011 10110	011010 1100	011010 0011
D23.3	77	011 10111	111010 0011	000101 1100

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Table 36–1c—Valid data code-groups

Code Group Name	Octet Value	Octet Bits HGF EDCBA	Current RD –	Current RD +
			abcdei fghj	abcdei fghj
D24.3	78	011 11000	110011 0011	001100 1100
D25.3	79	011 11001	100110 1100	100110 0011
D26.3	7A	011 11010	010110 1100	010110 0011
D27.3	7B	011 11011	110110 0011	001001 1100
D28.3	7C	011 11100	001110 1100	001110 0011
D29.3	7D	011 11101	101110 0011	010001 1100
D30.3	7E	011 11110	011110 0011	100001 1100
D31.3	7F	011 11111	101011 0011	010100 1100
D0.4	80	100 00000	100111 0010	011000 1101
D1.4	81	100 00001	011101 0010	100010 1101
D2.4	82	100 00010	101101 0010	010010 1101
D3.4	83	100 00011	110001 1101	110001 0010
D4.4	84	100 00100	110101 0010	001010 1101
D5.4	85	100 00101	101001 1101	101001 0010
D6.4	86	100 00110	011001 1101	011001 0010
D7.4	87	100 00111	111000 1101	000111 0010
D8.4	88	100 01000	111001 0010	000110 1101
D9.4	89	100 01001	100101 1101	100101 0010
D10.4	8A	100 01010	010101 1101	010101 0010
D11.4	8B	100 01011	110100 1101	110100 0010
D12.4	8C	100 01100	001101 1101	001101 0010
D13.4	8D	100 01101	101100 1101	101100 0010
D14.4	8E	100 01110	011100 1101	011100 0010
D15.4	8F	100 01111	010111 0010	101000 1101
D16.4	90	100 10000	011011 0010	100100 1101
D17.4	91	100 10001	100011 1101	100011 0010
D18.4	92	100 10010	010011 1101	010011 0010
D19.4	93	100 10011	110010 1101	110010 0010
D20.4	94	100 10100	001011 1101	001011 0010
D21.4	95	100 10101	101010 1101	101010 0010
D22.4	96	100 10110	011010 1101	011010 0010
D23.4	97	100 10111	111010 0010	000101 1101
D24.4	98	100 11000	110011 0010	001100 1101
D25.4	99	100 11001	100110 1101	100110 0010
D26.4	9A	100 11010	010110 1101	010110 0010
D27.4	9B	100 11011	110110 0010	001001 1101
D28.4	9C	100 11100	001110 1101	001110 0010
D29.4	9D	100 11101	101110 0010	010001 1101
D30.4	9E	100 11110	011110 0010	100001 1101
D31.4	9F	100 11111	101011 0010	010100 1101
D0.5	A0	101 00000	100111 1010	011000 1010
D1.5	A1	101 00001	011101 1010	100010 1010
D2.5	A2	101 00010	101101 1010	010010 1010
D3.5	A3	101 00011	110001 1010	110001 1010
D4.5	A4	101 00100	110101 1010	001010 1010
D5.5	A5	101 00101	101001 1010	101001 1010
D6.5	A6	101 00110	011001 1010	011001 1010
D7.5	A7	101 00111	111000 1010	000111 1010
D8.5	A8	101 01000	111001 1010	000110 1010
D9.5	A9	101 01001	100101 1010	100101 1010
D10.5	AA	101 01010	010101 1010	010101 1010
D11.5	AB	101 01011	110100 1010	110100 1010
D12.5	AC	101 01100	001101 1010	001101 1010
D13.5	AD	101 01101	101100 1010	101100 1010
D14.5	AE	101 01110	011100 1010	011100 1010
D15.5	AF	101 01111	010111 1010	101000 1010
D16.5	B0	101 10000	011011 1010	100100 1010
D17.5	B1	101 10001	100011 1010	100011 1010
D18.5	B2	101 10010	010011 1010	010011 1010
D19.5	B3	101 10011	110010 1010	110010 1010

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Table 36–1d—Valid data code-groups

Code Group Name	Octet Value	Octet Bits HGF EDCBA	Current RD –	Current RD +
			abcdei fghj	abcdei fghj
D20.5	B4	101 10100	001011 1010	001011 1010
D21.5	B5	101 10101	101010 1010	101010 1010
D22.5	B6	101 10110	011010 1010	011010 1010
D23.5	B7	101 10111	111010 1010	000101 1010
D24.5	B8	101 11000	110011 1010	001100 1010
D25.5	B9	101 11001	100110 1010	100110 1010
D26.5	BA	101 11010	010110 1010	010110 1010
D27.5	BB	101 11011	110110 1010	001001 1010
D28.5	BC	101 11100	001110 1010	001110 1010
D29.5	BD	101 11101	101110 1010	010001 1010
D30.5	BE	101 11110	011110 1010	100001 1010
D31.5	BF	101 11111	101011 1010	010100 1010
D0.6	C0	110 00000	100111 0110	011000 0110
D1.6	C1	110 00001	011101 0110	100010 0110
D2.6	C2	110 00010	101101 0110	010010 0110
D3.6	C3	110 00011	110001 0110	110001 0110
D4.6	C4	110 00100	110101 0110	001010 0110
D5.6	C5	110 00101	101001 0110	101001 0110
D6.6	C6	110 00110	011001 0110	011001 0110
D7.6	C7	110 00111	111000 0110	000111 0110
D8.6	C8	110 01000	111001 0110	000110 0110
D9.6	C9	110 01001	100101 0110	100101 0110
D10.6	CA	110 01010	010101 0110	010101 0110
D11.6	CB	110 01011	110100 0110	110100 0110
D12.6	CC	110 01100	001101 0110	001101 0110
D13.6	CD	110 01101	101100 0110	101100 0110
D14.6	CE	110 01110	011100 0110	011100 0110
D15.6	CF	110 01111	010111 0110	101000 0110
D16.6	D0	110 10000	011011 0110	100100 0110
D17.6	D1	110 10001	100011 0110	100011 0110
D18.6	D2	110 10010	010011 0110	010011 0110
D19.6	D3	110 10011	110010 0110	110010 0110
D20.6	D4	110 10100	001011 0110	001011 0110
D21.6	D5	110 10101	101010 0110	101010 0110
D22.6	D6	110 10110	011010 0110	011010 0110
D23.6	D7	110 10111	111010 0110	000101 0110
D24.6	D8	110 11000	110011 0110	001100 0110
D25.6	D9	110 11001	100110 0110	100110 0110
D26.6	DA	110 11010	010110 0110	010110 0110
D27.6	DB	110 11011	110110 0110	001001 0110
D28.6	DC	110 11100	001110 0110	001110 0110
D29.6	DD	110 11101	101110 0110	010001 0110
D30.6	DE	110 11110	011110 0110	100001 0110
D31.6	DF	110 11111	101011 0110	010100 0110
D0.7	E0	111 00000	100111 0001	011000 1110
D1.7	E1	111 00001	011101 0001	100010 1110
D2.7	E2	111 00010	101101 0001	010010 1110
D3.7	E3	111 00011	110001 1110	110001 0001
D4.7	E4	111 00100	110101 0001	001010 1110
D5.7	E5	111 00101	101001 1110	101001 0001
D6.7	E6	111 00110	011001 1110	011001 0001
D7.7	E7	111 00111	111000 1110	000111 0001
D8.7	E8	111 01000	111001 0001	000110 1110
D9.7	E9	111 01001	100101 1110	100101 0001
D10.7	EA	111 01010	010101 1110	010101 0001
D11.7	EB	111 01011	110100 1110	110100 1000
D12.7	EC	111 01100	001101 1110	001101 0001
D13.7	ED	111 01101	101100 1110	101100 1000
D14.7	EE	111 01110	011100 1110	011100 1000
D15.7	EF	111 01111	010111 0001	101000 1110

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Table 36–1e—Valid data code-groups

Code Group Name	Octet Value	Octet Bits HGF EDCBA	Current RD –	Current RD +
			abcdei fghj	abcdei fghj
D16.7	F0	111 10000	011011 0001	100100 1110
D17.7	F1	111 10001	100011 0111	100011 0001
D18.7	F2	111 10010	010011 0111	010011 0001
D19.7	F3	111 10011	110010 1110	110010 0001
D20.7	F4	111 10100	001011 0111	001011 0001
D21.7	F5	111 10101	101010 1110	101010 0001
D22.7	F6	111 10110	011010 1110	011010 0001
D23.7	F7	111 10111	111010 0001	000101 1110
D24.7	F8	111 11000	110011 0001	001100 1110
D25.7	F9	111 11001	100110 1110	100110 0001
D26.7	FA	111 11010	010110 1110	010110 0001
D27.7	FB	111 11011	110110 0001	001001 1110
D28.7	FC	111 11100	001110 1110	001110 0001
D29.7	FD	111 11101	101110 0001	010001 1110
D30.7	FE	111 11110	011110 0001	100001 1110
D31.7	FF	111 11111	101011 0001	010100 1110

(concluded)

Table 36–2—Valid special code-groups

Code Group Name	Octet Value	Octet Bits HGF EDCBA	Current RD –	Current RD +	Notes
			abcdei fghj	abcdei fghj	
K28.0	1C	000 11100	001111 0100	110000 1011	1
K28.1	3C	001 11100	001111 1001	110000 0110	1,2
K28.2	5C	010 11100	001111 0101	110000 1010	1
K28.3	7C	011 11100	001111 0011	110000 1100	1
K28.4	9C	100 11100	001111 0010	110000 1101	1
K28.5	BC	101 11100	001111 1010	110000 0101	2
K28.6	DC	110 11100	001111 0110	110000 1001	1
K28.7	FC	111 11100	001111 1000	110000 0111	1,2
K23.7	F7	111 10111	111010 1000	000101 0111	
K27.7	FB	111 11011	110110 1000	001001 0111	
K29.7	FD	111 11101	101110 1000	010001 0111	
K30.7	FE	111 11110	011110 1000	100001 0111	

NOTE 1—Reserved.

NOTE 2—Contains a comma.

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36.2.4.7.1 Ordered set rules

Ordered sets are specified according to the following rules:

a) Ordered sets consist of either one, two, or four code-groups.

b) The first code-group of all ordered sets is always a special code-group.

c) The second code-group of all multi-code-group ordered sets is always a data code-group. The second code-group is used to distinguish the ordered set from all other ordered sets. The second code-group provides a high bit transition density.

Table 36–3 lists the defined ordered sets.

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Table 36–3—Defined ordered sets

Code	Ordered Set	Number of Code-Groups	Encoding
/C/	**Configuration**		Alternating /C1/ and /C2/
/C1/	Configuration 1	4	/K28.5/D21.5/Config_Reg[a]
/C2/	Configuration 2	4	/K28.5/D2.2/Config_Reg[a]
/I/	**IDLE**		Correcting /I1/, Preserving /I2/
/I1/	IDLE 1	2	/K28.5/D5.6/
/I2/	IDLE 2	2	/K28.5/D16.2/
	Encapsulation		
/R/	Carrier_Extend	1	/K23.7/
/S/	Start_of_Packet	1	/K27.7/
/T/	End_of_Packet	1	/K29.7/
/V/	Error_Propagation	1	/K30.7/
/LI/	**LPI**		Correcting /LI1/, Preserving /LI2/
/LI1/	LPI 1	2	/K28.5/D6.5/
/LI2/	LPI 2	2	/K28.5/D26.4/

[a]Two data code-groups representing the Config_Reg value.

36.2.4.8 /K28.5/ code-group considerations

The /K28.5/ special code-group is chosen as the first code-group of all ordered sets that are signaled repeatedly and for the purpose of allowing a receiver to synchronize to the incoming bit stream (i.e., /C/ and /I/), for the following reasons:

a) Bits abcdeif make up a comma. The comma can be used to easily find and verify code-group and ordered set boundaries of the rx_bit stream.
b) Bits ghj of the encoded code-group present the maximum number of transitions, simplifying receiver acquisition of bit synchronization.

36.2.4.9 Comma considerations

The seven bit comma string is defined as either b'0011111' (comma+) or b'1100000' (comma-). The /I/ and /C/ ordered sets and their associated protocols are specified to ensure that comma+ is transmitted with either equivalent or greater frequency than comma- for the duration of their transmission. This is done to ensure compatibility with common components.

The comma contained within the /K28.1/, /K28.5/, and /K28.7/ special code-groups is a singular bit pattern, which, in the absence of transmission errors, cannot appear in any other location of a code-group and cannot be generated across the boundaries of any two adjacent code-groups with the following exception:

The /K28.7/ special code-group is used by 1000BASE-X for diagnostic purposes only (see Annex 36A). This code-group, if followed by any of the following special or data code-groups: /K28.x/, /D3.x/, /D11.x/, /D12.x/, /D19.x/, /D20.x/, or /D28.x/, where x is a value in the range 0 to 7, inclusive, causes a comma to be

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generated across the boundaries of the two adjacent code-groups. A comma across the boundaries of any two adjacent code-groups may cause code-group realignment (see 36.3.2.4).

36.2.4.10 Configuration (/C/)

Configuration, defined as the continuous repetition of the ordered sets /C1/ and /C2/, is used to convey the 16-bit Configuration Register (Config_Reg) to the link partner. See Clause 37 for a description of the Config_Reg contents.

The ordered sets, /C1/ and /C2/, are defined in Table 36–3. The /C1/ ordered set is defined such that the running disparity at the end of the first two code-groups is opposite that of the beginning running disparity. The /C2/ ordered set is defined such that the running disparity at the end of the first two code-groups is the same as the beginning running disparity. For a constant Config_Reg value, the running disparity after transmitting the sequence /C1/C2/ will be the opposite of what it was at the start of the sequence. This ensures that K28.5s containing comma+ will be sent during configuration.

36.2.4.11 Data (/D/)

A data code-group, when not used to distinguish or convey information for a defined ordered set, conveys one octet of arbitrary data between the GMII and the PCS. The sequence of data code-groups is arbitrary, where any data code-group can be followed by any other data code-group. Data code-groups are coded and decoded but not interpreted by the PCS. Successful decoding of the data code-groups depends on proper receipt of the Start_of_Packet delimiter, as defined in 36.2.4.14 and the checking of validity, as defined in 36.2.4.6.

36.2.4.12 IDLE (/I/)

IDLE ordered sets (/I/) are transmitted continuously and repetitively whenever the GMII is idle (TX_EN and TX_ER are both inactive). /I/ provides a continuous fill pattern to establish and maintain clock synchronization. /I/ is emitted from, and interpreted by, the PCS. /I/ consists of one or more consecutively transmitted /I1/ or /I2/ ordered sets, as defined in Table 36–3.

The /I1/ ordered set is defined such that the running disparity at the end of the transmitted /I1/ is opposite that of the beginning running disparity. The /I2/ ordered set is defined such that the running disparity at the end of the transmitted /I2/ is the same as the beginning running disparity. The first /I/ following a packet or Configuration ordered set restores the current positive or negative running disparity to a negative value. All subsequent /I/s are /I2/ to ensure negative ending running disparity.

Distinct carrier events are separated by /I/s.

Implementations of this standard may benefit from the ability to add or remove /I2/ from the code-group stream one /I2/ at a time without altering the beginning running disparity associated with the code-group subsequent to the removed /I2/.

A received ordered set that consists of two code-groups, the first of which is /K28.5/ and the second of which is a data code-group other than /D21.5/ or /D2.2/ (or /D6.5/ or /D26.4/ to support EEE capability), is treated as an /I/ ordered set.

36.2.4.13 Low Power Idle (LPI)

LPI is transmitted in the same manner as IDLE. LPI ordered sets (/LI/) are transmitted continuously and repetitively whenever the GMII is indicating “Assert LPI”. See 35.2.2.6 and 35.2.2.10 for corresponding GMII definitions.

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36.2.4.14 Start_of_Packet (SPD) delimiter

A Start_of_Packet delimiter (SPD) is used to delineate the starting boundary of a data transmission sequence and to authenticate carrier events. Upon each fresh assertion of TX_EN by the GMII, and subsequent to the completion of PCS transmission of the current ordered set, the PCS replaces the current octet of the MAC preamble with SPD. Upon initiation of packet reception, the PCS replaces the received SPD delimiter with the data octet value associated with the first preamble octet. A SPD delimiter consists of the code-group /S/, as defined in Table 36–3.

SPD follows /I/ for a single packet or the first packet in a burst.

SPD follows /R/ for the second and subsequent packets of a burst.

36.2.4.15 End_of_Packet delimiter (EPD)

An End_of_Packet delimiter (EPD) is used to delineate the ending boundary of a packet. The EPD is transmitted by the PCS following each deassertion of TX_EN on the GMII, which follows the last data octet comprising the FCS of the MAC packet. On reception, EPD is interpreted by the PCS as terminating a packet. A EPD delimiter consists of the code-groups /T/R/R/ or /T/R/K28.5/. The code-group /T/ is defined in Table 36–3. See 36.2.4.16 for the definition of code-groups used for /R/. /K28.5/ normally occurs as the first code-group of the /I/ ordered set. See 36.2.4.12 for the definition of code-groups used for /I/.

The receiver considers the MAC interpacket gap (IPG) to have begun two octets prior to the transmission of /I/. For example, when a packet is terminated by EPD, the /T/R/ portion of the EPD occupies part of the region considered by the MAC to be the IPG.

36.2.4.15.1 EPD rules

a) The PCS transmits a /T/R/ following the last data octet from the MAC;
b) If the MAC indicates carrier extension to the PCS, Carrier_Extend rules are in effect. See 36.2.4.16.1;
c) If the MAC does not indicate carrier extension to the PCS, perform the following:
    1) If /R/ is transmitted in an even-numbered code-group position, the PCS appends a single additional /R/ to the code-group stream to ensure that the subsequent /I/ is aligned on an even-numbered code-group boundary and EPD transmission is complete;
    2) The PCS transmits /I/.

36.2.4.16 Carrier_Extend (/R/)

Carrier_Extend (/R/) is used for the following purposes:

a) Carrier extension: Used by the MAC to extend the duration of the carrier event. When used for this purpose, carrier extension is emitted from and interpreted by the MAC and coded to and decoded from the corresponding code-group by the PCS. In order to extend carrier, the GMII must deassert TX_EN. The deassertion of TX_EN and simultaneous assertion of TX_ER causes the PCS to emit an /R/ with a two-octet delay, which gives the PCS time to complete its EPD before commencing transmissions. The number of /R/ code-groups emitted from the PCS equals the number of GMII GTX_CLK periods during which it extends carrier;
b) Packet separation: Carrier extension is used by the MAC to separate packets within a burst of packets. When used for this purpose, carrier extension is emitted from and interpreted by the MAC and coded to and decoded from the corresponding code-group by the PCS;
c) EPD2: The first /R/ following the /T/ in the End_of_Packet delimiters /T/R/I/ or /T/R/R/I/;

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d) EPD3: The second /R/ following the /T/ in the End_of_Packet delimiter /T/R/R/I/. This /R/ is used, if necessary, to pad the only or last packet of a burst of packets so that the subsequent /I/ is aligned on an even-numbered code-group boundary. When used for this purpose, Carrier_Extend is emitted from, and interpreted by, the PCS. An EPD of /T/R/R/ results in one /R/ being delivered to the PCS client (see 36.2.4.15.1).

Carrier_Extend consists of one or more consecutively transmitted /R/ ordered sets, as defined in Table 36–3.

36.2.4.16.1 Carrier_Extend rules

a) If the MAC indicates carrier extension to the PCS, the initial /T/R/ is followed by one /R/ for each octet of carrier extension received from the MAC;
b) If the last /R/ is transmitted in an even-numbered code-group position, the PCS appends a single additional /R/ to the code-group stream to ensure that the subsequent /I/ is aligned on an even-numbered code-group boundary.

36.2.4.17 Error_Propagation (/V/)

Error_Propagation (/V/) indicates that the PCS client wishes to indicate a transmission error to its peer entity. The normal use of Error_Propagation is for repeaters to propagate received errors. /V/ is emitted from the PCS, at the request of the PCS client through the use of the TX_ER signal, as described in Clause 35. Error_Propagation is emitted from, and interpreted by, the PCS. Error_Propagation consists of the ordered set /V/, as defined in Table 36–3.

The presence of Error_Propagation or any invalid code-group on the medium denotes a collision artifact or an error condition. Invalid code-groups are not intentionally transmitted onto the medium by DTEs. The PCS processes and conditionally indicates the reception of /V/ or an invalid code-group on the GMII as false carrier, data errors, or carrier extend errors, depending on its current context.

36.2.4.18 Encapsulation

The 1000BASE-X PCS accepts packets from the MAC through the Reconciliation sublayer and GMII. Due to the continuously signaled nature of the underlying PMA, and the encoding performed by the PCS, the 1000BASE-X PCS encapsulates MAC frames into a code-group stream. The PCS decodes the code-group stream received from the PMA, extracts packets from it, and passes the packets to the MAC via the Reconciliation sublayer and GMII.

Figure 36–4 depicts the PCS encapsulation of a MAC packet based on GMII signals.

36.2.4.19 Mapping between GMII, PCS and PMA

Figure 36–3 depicts the mapping of the octet-wide data path of the GMII to the ten-bit-wide code-groups of the PCS, and the one-bit paths of the PMA/PMD interface.

The PCS encodes an octet received from the GMII into a ten-bit code-group, according to Figure 36–3. Code-groups are serialized into a tx_bit stream by the PMA and passed to the PMD for transmission on the underlying medium, according to Figure 36–3. The first transmitted tx_bit is tx_code-group<0>, and the last tx_bit transmitted is tx_code-group<9>. There is no numerical significance ascribed to the bits within a code-group; that is, the code-group is simply a ten-bit pattern that has some predefined interpretation.

Similarly, the PMA deserializes rx_bits received from the PMD, according to Figure 36–3. The PCS Receive process converts rx_code-group<9:0>'s into GMII data octets, according to 36.2.5.2.2.

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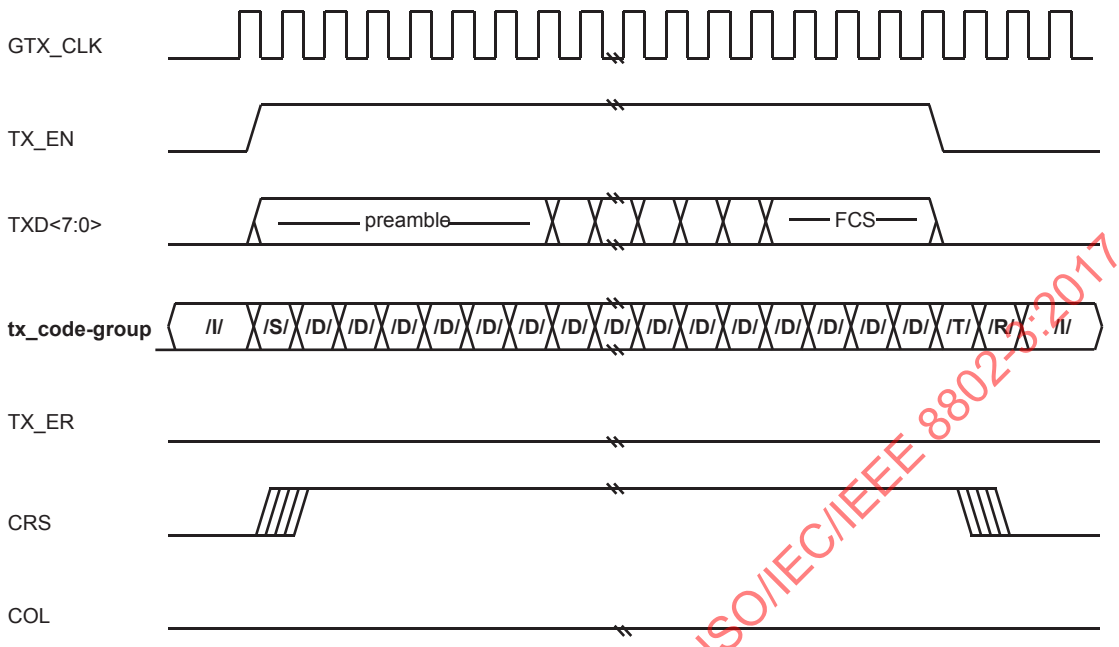

Figure 36–4—PCS encapsulation

36.2.5 Detailed functions and state diagrams

The notation used in the state diagrams in this clause follow the conventions in 21.5. State diagram variables follow the conventions of 21.5.2 except when the variable has a default value. Variables in a state diagram with default values evaluate to the variable default in each state where the variable value is not explicitly set.

Timeless states are employed as an editorial convenience to facilitate the distribution of transition conditions from prior states. No actions are taken within these states. Exit conditions are evaluated for timeless states. Timeless states are as follows:

a) PCS transmit ordered set state TX_PACKET;
b) PCS transmit code-group state GENERATE_CODE_GROUPS;
c) PCS transmit code-group state IDLE_DISPARITY_TEST;
d) PCS receive state RECEIVE;
e) PCS receive state EPD2_CHECK_END.

36.2.5.1 State variables

36.2.5.1.1 Notation conventions

/x/

Denotes the constant code-group specified in 36.2.5.1.2 (valid code-groups must follow the rules of running disparity as per 36.2.4.5 and 36.2.4.6).

[/x/]

Denotes the latched received value of the constant code-group (/x/) specified in 36.2.5.1.2 and conveyed by the SYNC_UNITDATA.indicate message described in 36.2.5.1.6.

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36.2.5.1.2 Constants

/C/
: The Configuration ordered set group, comprising either the /C1/ or /C2/ ordered set, as specified in 36.2.4.10. Conveys the Config_Reg value as tx_Config_Reg<D15:D0> for the PCS Transmit process and rx_Config_Reg<D15:D0> for the PCS Receive process.

/COMMA/
: The set of special code-groups which include a comma as specified in 36.2.4.9 and listed in Table 36–2.

/D/
: The set of 256 code-groups corresponding to valid data, as specified in 36.2.4.11.

/Dx.y/
: One of the set of 256 code-groups corresponding to valid data, as specified in 36.2.4.11.

/I/
: The IDLE ordered set group, comprising either the /I1/ or /I2/ ordered sets, as specified in 36.2.4.12.

/INVALID/
: The set of invalid data or special code-groups, as specified in 36.2.4.6.

/Kx.y/
: One of the set of 12 code-groups corresponding to valid special code-groups, as specified in Table 36–2.

/R/
: The code-group used as either: End_of_Packet delimiter part 2; End_of_Packet delimiter part 3; Carrier_Extend; and /I/ alignment.

/S/
: The code-group corresponding to the Start_of_Packet delimiter (SPD) as specified in 36.2.4.14.

/T/
: The code-group used for the End_of_Packet delimiter part 1.

/V/
: The Error_Propagation code-group, as specified in 36.2.4.17.

The following constant is used only for the EEE capability:

/LI/
: The LP_IDLE ordered set group, comprising either the /LI1/ or /LI2/ ordered sets, as specified in 36.2.4.13.

36.2.5.1.3 Variables

cgbad
: Alias for the following terms: ((rx_code-group∈ /INVALID/) + (rx_code-group=/COMMA/ *rx_even=TRUE)) * PMA_UNITDATA.indication

cggood
: Alias for the following terms: !((rx_code-group∈ /INVALID/) + (rx_code-group=/COMMA/ *rx_even=TRUE)) * PMA_UNITDATA.indication

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COL

The COL signal of the GMII as specified in Clause 35.

CRS

The CRS signal of the GMII as specified in Clause 35.

EVEN

The latched state of the rx_even variable, when rx_even=TRUE, as conveyed by the SYNC_UNITDATA.indicate message described in 36.2.5.1.6.

mr_loopback

A Boolean that indicates the enabling and disabling of data being looped back through the PHY. Loopback of data through the PHY is enabled when Control register bit 0.14 is set to one.

Values: FALSE; Loopback through the PHY is disabled.
TRUE; Loopback through the PHY is enabled.

mr_main_reset

Controls the resetting of the PCS via Control Register bit 0.15.

Values: FALSE; Do not reset the PCS.
TRUE; Reset the PCS.

ODD

The latched state of the rx_even variable, when rx_even=FALSE, as conveyed by the SYNC_UNITDATA.indicate message described in 36.2.5.1.6.

power_on

Condition that is true until such time as the power supply for the device that contains the PCS has reached the operating region. The condition is also true when the device has low power mode set via Control register bit 0.11.

Values: FALSE; The device is completely powered (default).
TRUE; The device has not been completely powered.

NOTE—Power_on evaluates to its default value in each state where it is not explicitly set.

receiving

A Boolean set by the PCS Receive process to indicate carrier activity. Used by the Carrier Sense process, and also interpreted by the PCS Transmit process for indicating a collision. (See also 36.2.5.1.4, carrier_detect(x).)

Values: TRUE; Carrier being received.
FALSE; Carrier not being received.

repeater_mode

A Boolean used to make the assertion of Carrier Sense occur only in response to receive activity when the PCS is used in a CSMA/CD repeater. This variable is set to TRUE in a repeater application, and set to FALSE in all other applications.

Values: TRUE; Allows the assertion of CRS in response to receive activity only.
FALSE; Allows the assertion of CRS in response to either transmit or receive activity.

rx_bit

A binary parameter conveyed by the PMD_UNITDATA.indication service primitive, as specified in 38.1.1.2, to the PMA.

Values: ZERO; Data bit is a logical zero.
ONE; Data bit is a logical one.

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rx_code-group<9:0>
A 10-bit vector represented by the most recently received code-group from the PMA. The element rx_code-group<0> is the least recently received (oldest) rx_bit; rx_code-group<9> is the most recently received rx_bit (newest). When code-group alignment has been achieved, this vector contains precisely one code-group.

rx_Config_Reg<D15:D0>
A 16-bit array that contains the data bits received from a /C/ ordered set as defined in 36.2.4.10. Conveyed by the PCS Receive process to the PCS Auto-Negotiation process. The format of the data bits is context dependent, relative to the state of the Auto-Negotiation function, and is presented in 37.2.1.1 and 37.2.4.3.1. For each element within the array:

Values: ZERO; Data bit is a logical zero.
ONE; Data bit is a logical one.

RX_DV
The RX_DV signal of the GMII as specified in Clause 35. Set by the PCS Receive process.

RX_ER
The RX_ER signal of the GMII as specified in Clause 35. Set by the PCS Receive process.

rx_even
A Boolean set by the PCS Synchronization process to designate received code-groups as either even- or odd-numbered code-groups as specified in 36.2.4.2.

Values: TRUE; Even-numbered code-group being received.
FALSE; Odd-numbered code-group being received.

RXD<7:0>
The RXD<7:0> signal of the GMII as specified in Clause 35. Set by the PCS Receive process.

signal_detect
A Boolean set by the PMD continuously via the PMD_SIGNAL.indication(signal_detect) message to indicate the status of the incoming link signal.

Values: FAIL; A signal is not present on the link.
OK; A signal is present on the link.

sync_status
A parameter set by the PCS Synchronization process to reflect the status of the link as viewed by the receiver. The values of the parameter are defined for code_sync_status. The equation for this parameter is:

sync_status = code_sync_status + rx_lpi_active

NOTE—If EEE is not supported, the variable rx_lpi_active is always false, and this variable is identical to code_sync_status controlled by the synchronization state diagram.

transmitting
A Boolean set by the PCS Transmit process to indicate that packet transmission is in progress. Used by the Carrier Sense process and internally by the PCS Transmit process for indicating a collision.

Values: TRUE; The PCS is transmitting a packet.
FALSE; The PCS is not transmitting a packet.

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tx_bit

A binary parameter used to convey data from the PMA to the PMD via the PMD_UNITDATA.request service primitive as specified in 38.1.1.1.

Values: ZERO; Data bit is a logical zero.
ONE; Data bit is a logical one.

tx_code-group<9:0>

A vector of bits representing one code-group, as specified in Tables 36–1a or 36–2, which has been prepared for transmission by the PCS Transmit process. This vector is conveyed to the PMA as the parameter of a PMD_UNITDATA.request(tx_bit) service primitive. The element tx_code-group<0> is the first tx_bit transmitted; tx_code-group<9> is the last tx_bit transmitted.

tx_Config_Reg<D15:D0>

A 16-bit array that contains the data bits to be transmitted in a /C/ ordered set as defined in 36.2.4.10. Conveyed by the PCS Auto-Negotiation process to the PCS Transmit process. The format of the data bits is context dependent, relative to the state of the Auto-Negotiation function, and is presented in 37.2.1.1 and 37.2.4.3.1. For each element within the array:

Values: ZERO; Data bit is a logical zero.
ONE; Data bit is a logical one.

tx_disparity

A Boolean set by the PCS Transmit process to indicate the running disparity at the end of code-group transmission as a binary value. Running disparity is described in 36.2.4.3.

Values: POSITIVE
NEGATIVE

TX_EN

The TX_EN signal of the GMII as specified in Clause 35.

TX_ER

The TX_ER signal of the GMII as specified in Clause 35.

tx_even

A Boolean set by the PCS Transmit process to designate transmitted code-groups as either even- or odd-numbered code-groups as specified in 36.2.4.2.

Values: TRUE; Even-numbered code-group being transmitted.
FALSE; Odd-numbered code-group being transmitted.

tx_o_set

One of the following defined ordered sets: /C/, /T/, /R/, /I/, /S/, /V/, or the code-group /D/.

TXD<7:0>

The TXD<7:0> signal of the GMII as specified in Clause 35.

xmit

Defined in 37.3.1.1.

The following variables are used only for the EEE capability:

assert_lpidle

Alias used for the optional LPI function, consisting of the following terms:

(TX_EN=FALSE * TX_ER=TRUE * (TXD<7:0>=0x01))

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code_sync_status

A parameter set by the PCS Synchronization process to reflect the status of the link as viewed by the receiver.

Values: FAIL; The receiver is not synchronized to code-group boundaries.
OK; The receiver is synchronized to code-group boundaries.

idle_d

Alias for the following terms:

SUDI(![/D21.5/] * ![/D2.2/])
that uses an alternate form to support the EEE capability:
SUDI(![/D21.5/] * ![/D2.2/] * ![/D6.5/] * ![/D26.4/])

rx_lpi_active

A Boolean variable that is set to TRUE when the receiver is in a low power state and set to FALSE when it is in an active state and capable of receiving data.

rx_quiet

A Boolean variable set to TRUE while in the RX_QUIET state and set to FALSE otherwise.

tx_quiet

A Boolean variable set to TRUE when the transmitter is in the TX_QUIET state and set to FALSE otherwise. When set to TRUE, the PMD will disable the transmitter as described in 70.6.5.

36.2.5.1.4 Functions

carrier_detect

In the PCS Receive process, this function uses for input the latched code-group ([/x/]) and latched rx_even (EVEN/ODD) parameters of the SYNC_UNITDATA.indicate message from the PCS Synchronization process. When SYNC_UNITDATA.indicate message indicates EVEN, the carrier_detect function detects carrier when either:

a) A two or more bit difference between [/x/] and both /K28.5/ encodings exists (see Table 36–2); or

b) A two to nine bit difference between [/x/] and the expected /K28.5/ (based on current running disparity) exists.

Values: TRUE; Carrier is detected.
FALSE; Carrier is not detected.

check_end

Prescient End_of_Packet and Carrier_Extend function used by the PCS Receive process to set RX_ER and RXD<7:0> signals. The check_end function returns the current and next two code-groups in rx_code-group<9:0>.

DECODE ([/x]/)

In the PCS Receive process, this function takes as its argument the latched value of rx_code-group<9:0> ([/x/]) and the current running disparity, and returns the corresponding GMII RXD<7:0>, rx_Config_Reg<D7:D0>, or rx_Config_Reg<D15:D8> octet, per Table 36–1a–e. DECODE also updates the current running disparity per the running disparity rules outlined in 36.2.4.4.

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ENCODE(x)

In the PCS Transmit process, this function takes as its argument (x), where x is a GMII TXD<7:0>, tx_Config_Reg<D7:D0>, or tx_Config_Reg<D15:D8> octet, and the current running disparity, and returns the corresponding ten-bit code-group per Table 36–1a. ENCODE also updates the current running disparity per Table 36–1a–e.

signal_detectCHANGE

In the PCS Synchronization process, this function monitors the signal_detect variable for a state change. The function is set upon state change detection.

Values: TRUE; A signal_detect variable state change has been detected.
FALSE; A signal_detect variable state change has not been detected (default).

NOTE—Signal_detectCHANGE is set by this function definition; it is not set explicitly in the state diagrams. Signal_detectCHANGE evaluates to its default value upon state entry.

VOID(x)

x ∈ /D/, /T/, /R/, /K28.5/. Substitutes /V/ on a per code-group basis as requested by the GMII.

If [TX_EN=FALSE * TX_ER=TRUE * TXD≠(0000 1111)],

then return /V/;

Else if [TX_EN=TRUE * TX_ER=TRUE],

then return /V/;

Else return x.

xmitCHANGE

In the PCS Transmit process, this function monitors the xmit variable for a state change. The function is set upon state change detection.

Values: TRUE; An xmit variable state change has been detected.
FALSE; An xmit variable state change has not been detected (default).

NOTE—XmitCHANGE is set by this function definition; it is not set explicitly in the state diagrams. XmitCHANGE evaluates to its default value upon entry to state TX_TEST_XMIT.

36.2.5.1.5 Counters

good_cgs

Count of consecutive valid code-groups received.

The following counter is used only for the EEE capability:

wake_error_counter

A counter that is incremented each time that the LPI receive state diagram enters the RX_WTF state indicating that a wake time fault has been detected. The counter is reflected in register 3.22 (see 45.2.3.10).

36.2.5.1.6 Messages

PMA_UNITDATA.indication(rx_code-group<9:0>)

A signal sent by the PMA Receive process conveying the next code-group received over the medium (see 36.3.1.2).

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PMA_UNITDATA.request(tx_code-group<9:0>)
A signal sent to the PMA Transmit process conveying the next code-group ready for transmission over the medium (see 36.3.1.1).

PMD_SIGNAL.indication(signal_detect)
A signal sent by the PMD to indicate the status of the signal being received on the MDI.

PUDI
Alias for PMA_UNITDATA.indication(rx_code-group<9:0>).

PUDR
Alias for PMA_UNITDATA.request(tx_code-group<9:0>).

RUDI
Alias for RX_UNITDATA.indicate(parameter).

RX_UNITDATA.indicate(parameter)
A signal sent by the PCS Receive process to the PCS Auto_Negotiation process conveying the following parameters:

Parameters: INVALID; indicates that an error condition has been detected while receiving /C/ or /I/ ordered sets;
/C/; the /C/ ordered set has been received;
/I/; the /I/ ordered set has been received.

SUDI
Alias for SYNC_UNITDATA.indicate(parameters).

SYNC_UNITDATA.indicate(parameters)
A signal sent by the PCS Synchronization process to the PCS Receive process conveying the following parameters:

Parameters: [/x/]; the latched value of the indicated code-group (/x/);
EVEN/ODD; The latched state of the rx_even variable;

Value: EVEN; Passed when the latched state of rx_even=TRUE.
ODD; Passed when the latched state of rx_even=FALSE.

TX_OSET.indicate
A signal sent to the PCS Transmit ordered set process from the PCS Transmit code-group process signifying the completion of transmission of one ordered set.

The following messages are used only for the EEE capability:

PMD_RXQUIET.request(rx_quiet)
A signal sent by the PCS/PMA LPI receive state diagram to the PMD. Note that this message is ignored by devices that do not support EEE capability.

Values: TRUE: The receiver is in a quiet state and is not expecting incoming data.
FALSE: The receiver is ready to receive data.

PMD_TXQUIET.request(tx_quiet)
A signal sent by the PCS/PMA LPI transmit state diagram to the PMD. Note that this message is ignored by devices that do not support the optional LPI mechanism.

Values: TRUE: The transmitter is in a quiet state and may cease to transmit a signal on the medium.
FALSE: The transmitter is ready to transmit data.

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36.2.5.1.7 Timers

cg_timer

A continuous free-running timer.

Values: The condition cg_timer_done becomes true upon timer expiration.

Restart when: immediately after expiration; restarting the timer resets the condition cg_timer_done.

Duration: 8 ns nominal.

If the GMII is implemented, cg_timer shall expire synchronously with the rising edge of GTX_CLK (see tolerance required for GTX_CLK in 35.5.2.3). In the absence of a GMII, cg_timer shall expire every 8 ns ± 0.01%. In the PCS transmit code-group state diagram, the message PMA_UNITDATA.request is issued concurrently with cg_timer_done.

The following timers are used only for the EEE capability:

rx_tq_timer

This timer is started when the PCS receiver enters the START_TQ_TIMER state. The timer terminal count is set to T_{QR}. When the timer reaches terminal count, it will set the rx_tq_timer_done = TRUE.

rx_tw_timer

This timer is started when the PCS receiver enters the RX_WAKE state. The timer terminal count shall not exceed the maximum value of T_{WR} in Table 36–9. When the timer reaches terminal count, it will set the rx_tw_timer_done = TRUE.

rx_wf_timer

This timer is started when the PCS receiver enters the RX_WTF state, indicating that the receiver has encountered a wake time fault. The rx_wf_timer allows the receiver an additional period in which to synchronize or return to the quiescent state before a link failure is indicated. The timer terminal count is set to T_{WTF}. When the timer reaches terminal count, it will set the rx_wf_timer_done = TRUE.

tx_ts_timer

This timer is started when the PCS transmitter enters the TX_SLEEP state. The timer terminal count is set to T_{SL}. When the timer reaches terminal count, it will set the tx_ts_timer_done = TRUE.

tx_tq_timer

This timer is started when the PCS transmitter enters the TX_QUIET state. The timer terminal count is set to T_{QL}. When the timer reaches terminal count, it will set the tx_tq_timer_done = TRUE.

tx_tr_timer

This timer is started when the PCS transmitter enters the TX_REFRESH state. The timer terminal count is set to T_{UL}. When the timer reaches terminal count, it will set the tx_tr_timer_done = TRUE.

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36.2.5.2 State diagrams

36.2.5.2.1 Transmit

The PCS Transmit process is depicted in two state diagrams: PCS Transmit ordered set and PCS Transmit code-group. The PCS shall implement its Transmit process as depicted in Figure 36–5 and Figure 36–6, including compliance with the associated state variables as specified in 36.2.5.1.

The Transmit ordered set process continuously sources ordered sets to the Transmit code-group process. When initially invoked, and when the Auto-Negotiation process xmit flag indicates CONFIGURATION, the Auto-Negotiation process is invoked. When the Auto-Negotiation process xmit flag indicates IDLE, and between packets (as delimited by the GMII), /I/ is sourced. Upon the assertion of TX_EN by the GMII when the Auto-Negotiation process xmit flag indicates DATA, the SPD ordered set is sourced. Following the SPD, /D/ code-groups are sourced until TX_EN is deasserted. Following the deassertion of TX_EN, EPD ordered sets are sourced. If TX_ER is asserted when TX_EN is deasserted and carrier extend error is not indicated by TXD, /R/ ordered sets are sourced for as many GTX_CLK periods as TX_ER is asserted with a delay of two GTX_CLK periods to first source the /T/ and /R/ ordered sets. If carrier extend error is indicated by TXD during carrier extend, /V/ ordered sets are sourced. If TX_EN and TX_ER are both deasserted, the /R/ ordered set may be sourced, after which the sourcing of /I/ is resumed. If, while TX_EN is asserted, the TX_ER signal is asserted, the /V/ ordered set is sourced except when the SPD ordered set is selected for sourcing.

Collision detection is implemented by noting the occurrence of carrier receptions during transmissions, following the models of 10BASE-T and 100BASE-X.

The Transmit code-group process continuously sources tx_code-group<9:0> to the PMA based on the ordered sets sourced to it by the Transmit ordered set process. The Transmit code-group process determines the proper code-group to source based on even/odd-numbered code-group alignment, running disparity requirements, and ordered set format.

36.2.5.2.2 Receive

The PCS shall implement its Receive process as depicted in Figure 36–7a and Figure 36–7b, including compliance with the associated state variables as specified in 36.2.5.1.

The PCS Receive process continuously passes RXD<7:0> and sets the RX_DV and RX_ER signals to the GMII based on the received code-group from the PMA.

When the Auto-Negotiation process xmit flag indicates CONFIGURATION or IDLE, the PCS Receive process continuously passes /C/ and /I/ ordered sets and rx_Config_Reg<D15:D0> to the Auto-Negotiation process.

36.2.5.2.3 State variable function carrier_detect(x)

The detection of carrier on the underlying channel is used both by the MAC (via the GMII CRS signal and the Reconciliation sublayer) for deferral purposes, and by the PCS Transmit process for collision detection. A carrier event, signaled by the assertion of receiving, is indicated by the detection of a difference between the received code-group and /K28.5/ as specified in 36.2.5.1.4.

A carrier event is in error if it does not start with an SPD. The PCS Receive process performs this function by continuously monitoring incoming code-groups for specific patterns that indicate non-/I/ activity such as SPD. The detection of an SPD carrier event causes the PCS to substitute the value (01010101) for the SPD, set RXD<7:0> to this value, and assert RX_DV. The pattern substituted for the SPD is consistent with the preamble pattern expected by the MAC. The detection of a non-SPD carrier event (false carrier) causes the PCS to substitute the value (00001110) for the code-group received, set RXD<7:0> to this value, and assert RX_ER.

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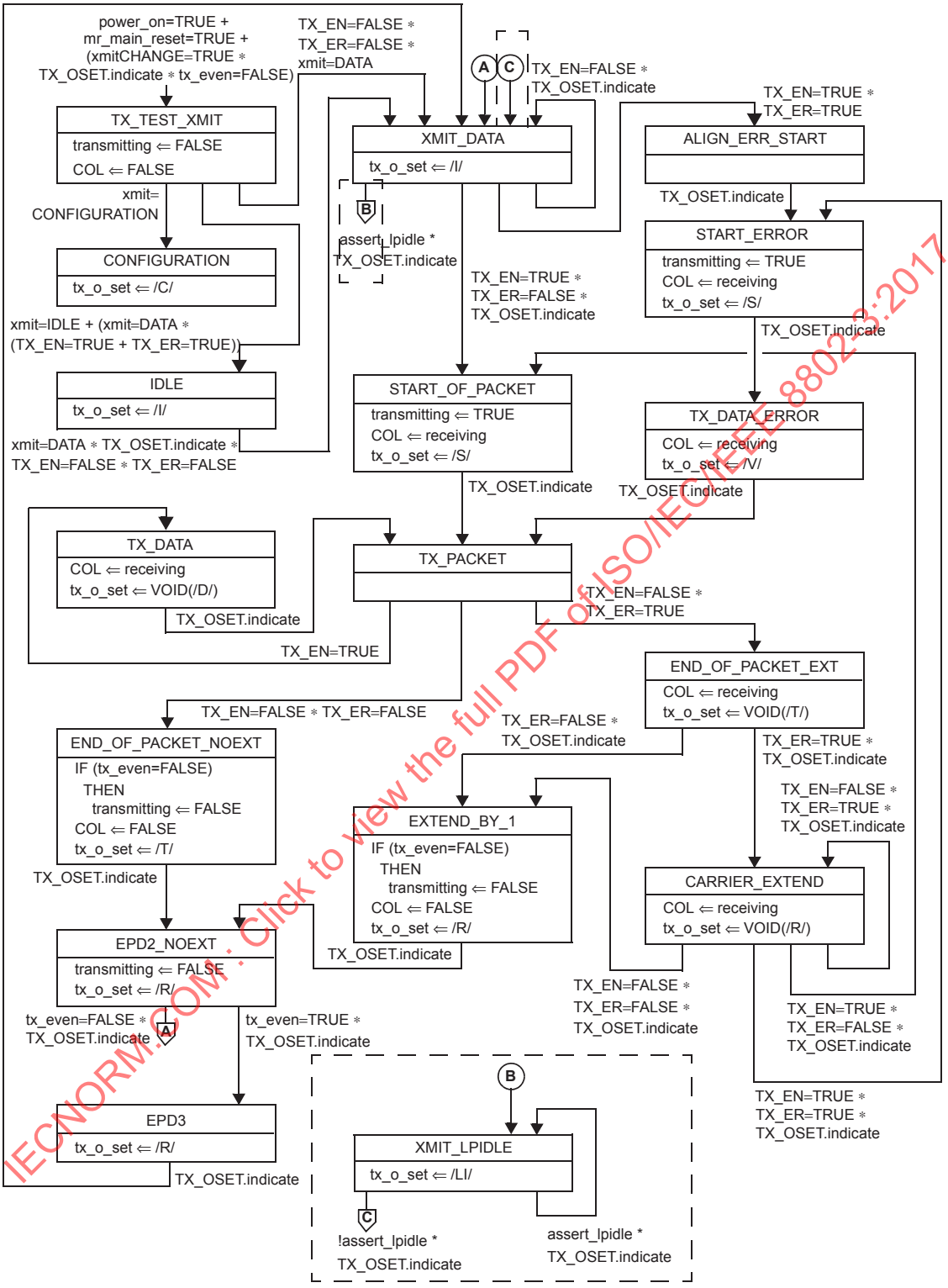

NOTE—Transitions B and C are only required for the EEE capability.

Figure 36–5—PCS transmit ordered set state diagram

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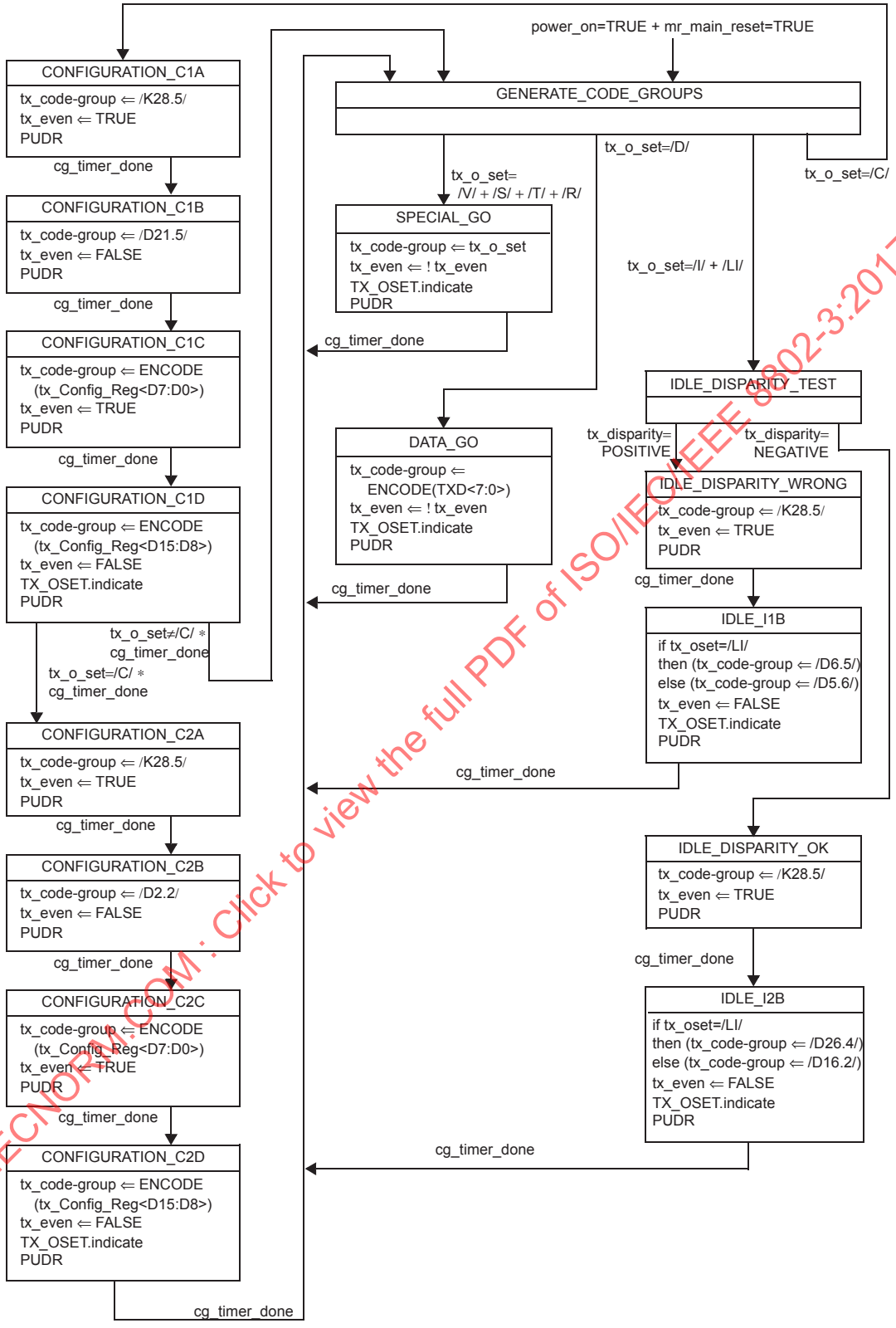

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Figure 36–6—PCS transmit code-group state diagram

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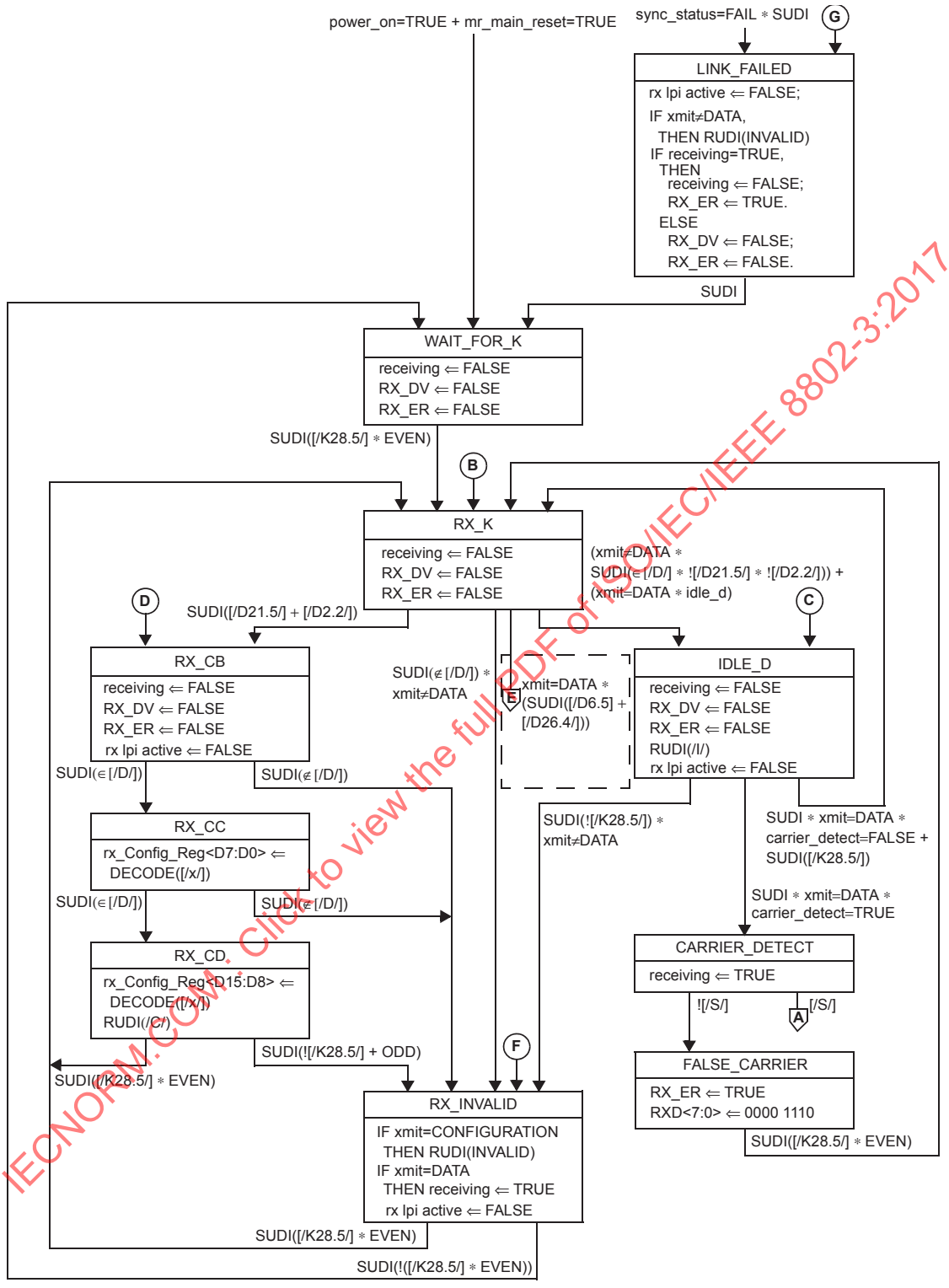

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NOTE—Outgoing arcs leading to labeled polygons flow offpage to corresponding incoming arcs leading from labeled circles on Figure 36–7b and Figure 36–7c, and vice versa.

Figure 36–7a—PCS receive state diagram, part a

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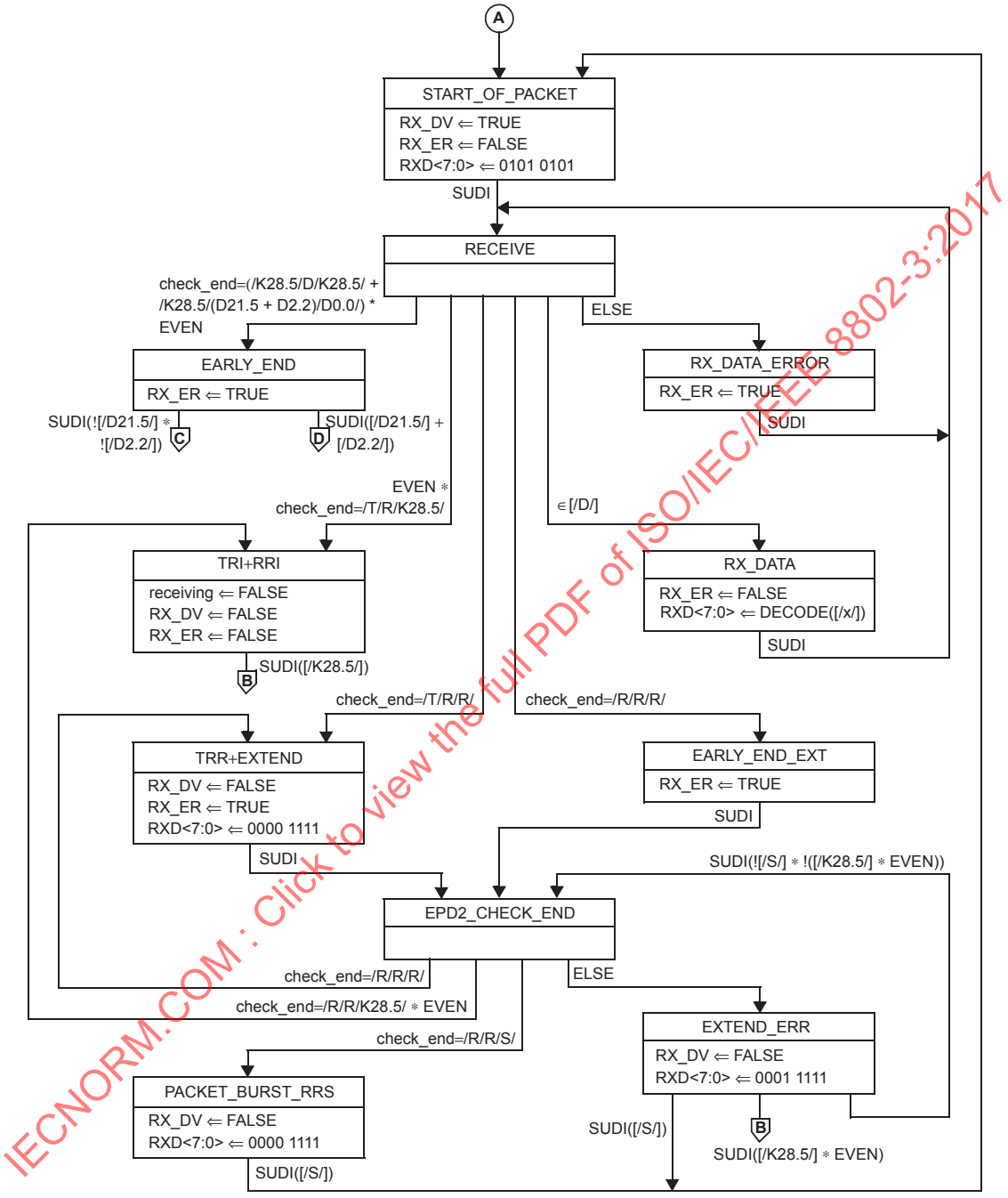

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NOTE 1—Outgoing arcs leading to labeled polygons flow offpage to corresponding incoming arcs leading from labeled circles on Figure 36–7a, and vice versa.

NOTE 2—In the transition from RECEIVE to RX_DATA state the transition condition is a test against the code-group obtained from the SUDI that caused the transition to RECEIVE state.

Figure 36–7b—PCS receive state diagram, part b

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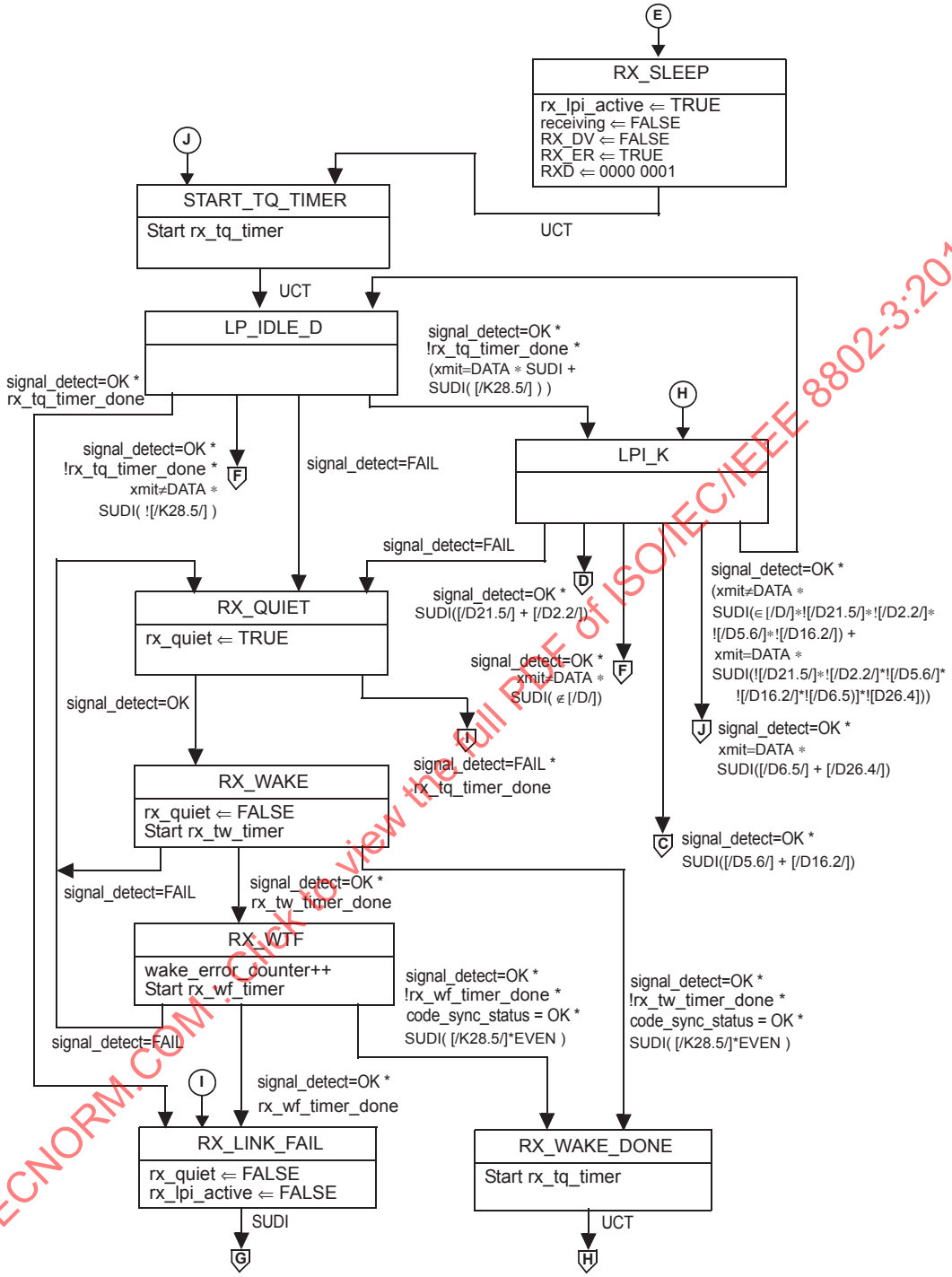

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NOTE—Outgoing arcs leading to labeled polygons flow off page to corresponding incoming arcs leading from labeled circles on Figure 36–7a, and vice versa.

Figure 36–7c—PCS Receive state diagram, part c
(only required for the optional EEE capability)

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36.2.5.2.4 Code-group stream decoding

Subsequent to the detection of an SPD carrier event, the PCS Receive process performs the DECODE function on the incoming code-groups, passing decoded data to the GMII, including those corresponding to the remainder of the MAC preamble and SFD. The GMII signal RX_ER is asserted upon decoding any code-group following the SPD that neither is a valid /D/ code-group nor follows the EPD rules in 36.2.4.15.1.

Packets are terminated with an EPD as specified in 36.2.4.15. The PCS Receive process performs the check_end function to preserve the ability of the MAC to properly delimit the FCS at the end of a packet.

Detection of /T/R/R/ or /T/R/K28.5/ by the check_end function denotes normal (i.e., non-error) packet termination. Detection of /R/R/R/ by the check_end function denotes packet termination with error and Carrier_Extend processing. Detection of /K28.5/D/K28.5/ by the check_end function denotes packet termination with error. Detection of /K28.5/(D21.5 or D2.2)/D0.0 by the check_end function denotes packet termination with error.

36.2.5.2.5 Carrier sense

The Carrier Sense process generates the signal CRS on the GMII, which (via the Reconciliation sublayer) the MAC uses for deferral.

The PCS shall implement the Carrier Sense process as depicted in Figure 36–8 including compliance with the associated state variables as specified in 36.2.5.1.

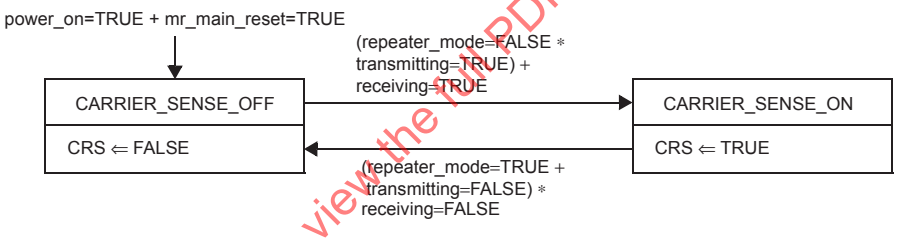

Figure 36–8—Carrier sense state diagram

36.2.5.2.6 Synchronization

The PCS shall implement the Synchronization process as depicted in Figure 36–9 including compliance with the associated state variables as specified in 36.2.5.1. The Synchronization process is responsible for determining whether the underlying receive channel is ready for operation. Failure of the underlying channel typically causes the PMA client to suspend normal actions.

A receiver that is in the LOSS_OF_SYNC state and that has acquired bit synchronization attempts to acquire code-group synchronization via the Synchronization process. Code-group synchronization is acquired by the detection of three ordered sets containing commas in their leftmost bit positions without intervening invalid code-group errors. Upon acquisition of code-group synchronization, the receiver enters the SYNC_ACQUIRED_1 state. Acquisition of synchronization ensures the alignment of multi-code-group ordered sets to even-numbered code-group boundaries.

Once synchronization is acquired, the Synchronization process tests received code-groups in sets of four code-groups and employs multiple sub-states, effecting hysteresis, to move between the SYNC_ACQUIRED_1 and LOSS_OF_SYNC states.

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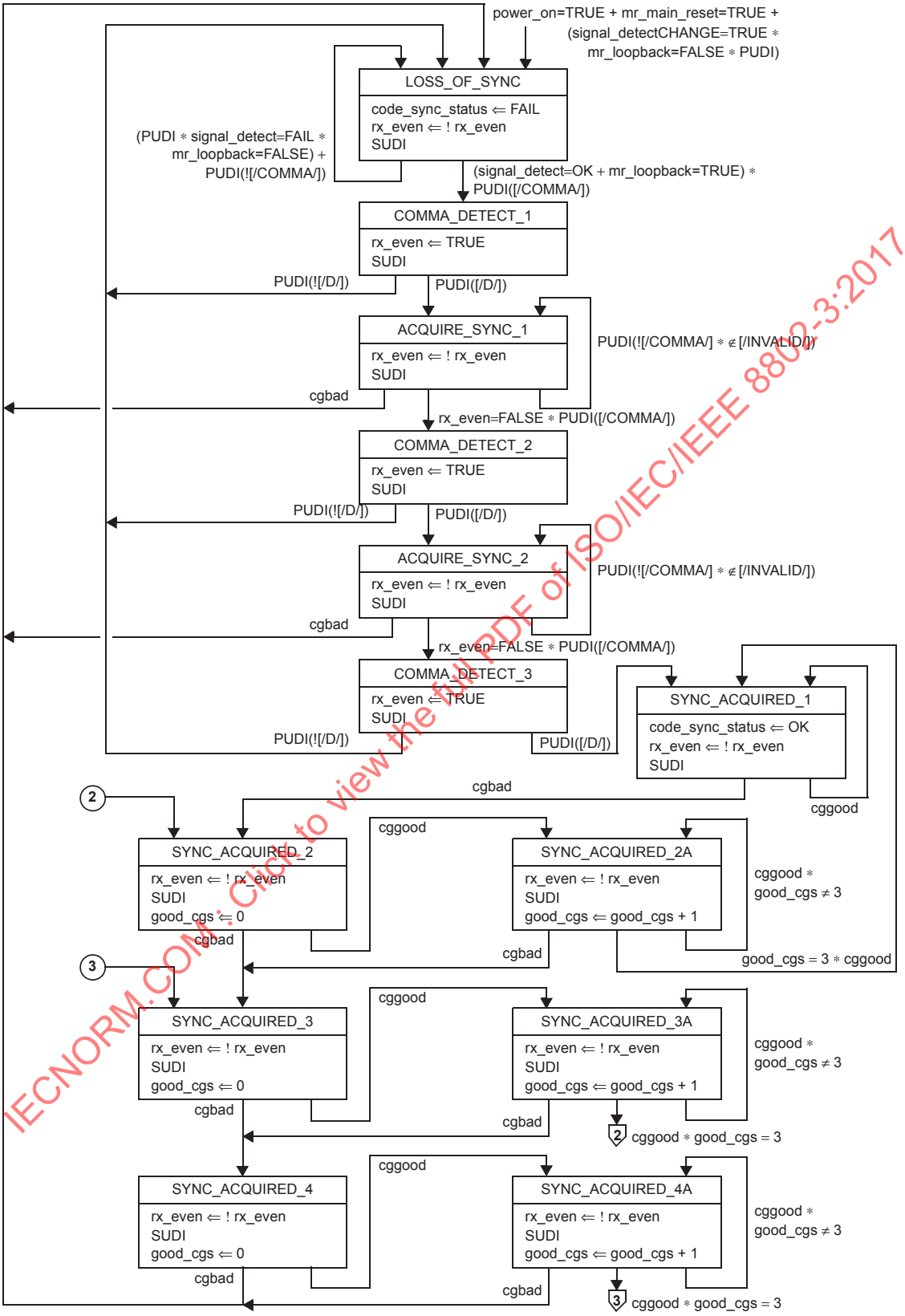

Figure 36–9—Synchronization state diagram

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For EEE capability the relationship between sync_status and code_sync_status is given by Figure 36–7c; otherwise sync_status is identical to code_sync_status.

The condition sync_status=FAIL existing for ten ms or more causes the PCS Auto-Negotiation process to begin and the PCS Transmit process to begin transmission of /C/. Upon reception of three matching /C/s from the link partner, the PCS Auto-Negotiation process begins. The internal signal receiving is deasserted in the PCS Receive process LINK_FAILED state when sync_status=FAIL and a code-group is received.

36.2.5.2.7 Auto-Negotiation process

The Auto-Negotiation process shall provide the means to exchange configuration information between two devices that share a link segment and to automatically configure both devices to take maximum advantage of their abilities. When the PCS is used with a PMD other than 1000BASE-KX, see Clause 37 for a description of the Auto-Negotiation process and Config_Reg contents.

Upon successful completion of the Clause 37 Auto-Negotiation process, the xmit flag is set to DATA and normal link operation is enabled. The Clause 37 Auto-Negotiation process utilizes the PCS Transmit and Receive processes to convey Config_Reg contents.

When the PCS is used with a 1000BASE-KX PMD, see Clause 73 for a description of the Auto-Negotiation process. The following requirements apply to a PCS used with a 1000BASE-KX PMD. The PCS shall support the primitive AN_LINK.indication(link_status) (see 73.9). The parameter link_status shall take the value FAIL when sync_status=FAIL and the value OK when sync_status=OK. The primitive shall be generated when the value of link_status changes. If Clause 37 Auto-Negotiation is not present, xmit shall be DATA. If Clause 37 Auto-Negotiation is present the variable mr_an_enable should be false when 1000BASE-KX operation is negotiated through Clause 73 Auto-Negotiation.

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36.2.5.2.8 LPI state diagram

A PCS that supports the EEE capability shall implement the LPI transmit process as shown in Figure 36–10. The transmit LPI state diagram controls tx_quiet, which disables the transmitter when true.

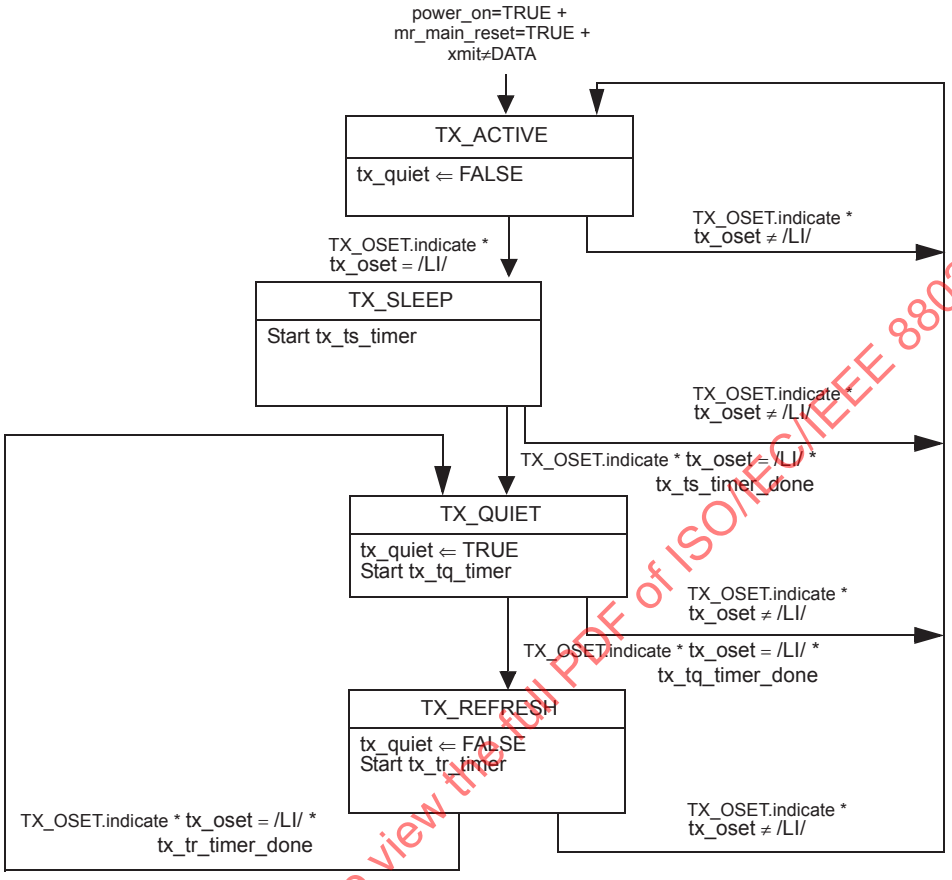

Figure 36–10—LPI Transmit state diagram

The timer values for these state diagrams are shown in Table 36–8 for transmit and Table 36–9 for receive.

Table 36–8—Transmitter LPI timing parameters

Parameter	Description	Min	Max	Units
T_{SL}	Local Sleep Time from entering the TX_SLEEP state to when tx_quiet is set to TRUE	19.9	20.1	µs
T_{QL}	Local Quiet Time from when tx_quiet is set to TRUE to entry into the TX_REFRESH state	2.5	2.6	ms
T_{UL}	Local Refresh Time from entry into the TX_REFRESH state to entry into the TX_QUIET state	19.9	20.1	µs

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Table 36–9—Receiver LPI timing parameters

Parameter	Description	Min	Max	Units
T_{QR}	The time the receiver waits for signal detect to be set to OK while in the LP_IDLE_D, LPI_K and RX_QUIET states before asserting a rx_fault	3	4	ms
T_{WR}	Time the receiver waits in the RX_WAKE state before indicating a wake time fault (WTF)		11	µs
T_{WTF}	Wake time fault recovery time		1	ms

36.2.5.2.9 LPI status and management

For EEE capability, the PCS indicates to the management system that LPI is currently active in the receive and transmit directions using the status variables shown in Table 36–10.

Table 36–10—MDIO status indications

MDIO status variable	Register name	Register address	Note
Tx LPI received	PCS status register 1	3.1.11	Latched version of 3.1.9
Rx LPI received	PCS status register 1	3.1.10	Latched version of 3.1.8
Tx LPI indication	PCS status register 1	3.1.9	TRUE when not in state TX_ACTIVE
Rx LPI indication	PCS status register 1	3.1.8	TRUE when not in state RX_ACTIVE

36.3 Physical Medium Attachment (PMA) sublayer

36.3.1 Service Interface

The PMA provides a Service Interface to the PCS. These services are described in an abstract manner and do not imply any particular implementation. The PMA Service Interface supports the exchange of code-groups between PCS entities. The PMA converts code-groups into bits and passes these to the PMD, and vice versa. It also generates an additional status indication for use by its client.

The following primitives are defined:

PMA_UNITDATA.request(tx_code-group<9:0>)
PMA_UNITDATA.indication(rx_code-group<9:0>)

36.3.1.1 PMA_UNITDATA.request

This primitive defines the transfer of data (in the form of code-groups) from the PCS to the PMA. PMA_UNITDATA.request is generated by the PCS Transmit process.

36.3.1.1.1 Semantics of the service primitive

PMA_UNITDATA.request(tx_code-group<9:0>)

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The data conveyed by PMA_UNITDATA.request is the tx_code-group<9:0> parameter defined in 36.2.5.1.3.

36.3.1.1.2 When generated

The PCS continuously sends, at a nominal rate of 125 MHz, as governed by GTX_CLK, tx_code-group<9:0> to the PMA.

36.3.1.1.3 Effect of receipt

Upon receipt of this primitive, the PMA generates a series of ten PMD_UNITDATA.request primitives, requesting transmission of the indicated tx_bit to the PMD.

36.3.1.2 PMA_UNITDATA.indication

This primitive defines the transfer of data (in the form of code-groups) from the PMA to the PCS. PMA_UNITDATA.indication is used by the PCS Synchronization process.

36.3.1.2.1 Semantics of the service primitive

PMA_UNITDATA.indication(rx_code-group<9:0>)

The data conveyed by PMA_UNITDATA.indication is the rx_code-group<9:0> parameter defined in 36.2.5.1.3.

36.3.1.2.2 When generated

The PMA continuously sends one rx_code-group<9:0> to the PCS corresponding to the receipt of each code-group aligned set of ten PMD_UNITDATA.indication primitives received from the PMD. The nominal rate of the PMA_UNITDATA.indication primitive is 125 MHz, as governed by the recovered bit clock.

36.3.1.2.3 Effect of receipt

The effect of receipt of this primitive by the client is unspecified by the PMA sublayer.

36.3.2 Functions within the PMA

Figure 36–3 depicts the mapping of the octet-wide data path of the GMII to the ten-bit-wide code-groups of the PMA Service Interface, and on to the serial PMD Service Interface. The PMA comprises the PMA Transmit and PMA Receive processes for 1000BASE-X.

The PMA Transmit process serializes tx_code-groups into tx_bits and passes them to the PMD for transmission on the underlying medium, according to Figure 36–3. Similarly, the PMA Receive process deserializes rx_bits received from the PMD according to Figure 36–3. The PMA continuously conveys ten-bit code-groups to the PCS, independent of code-group alignment. After code-group alignment is achieved, based on comma detection, the PCS converts code-groups into GMII data octets, according to 36.2.5.2.2.

The proper alignment of a comma used for code-group synchronization is depicted in Figure 36–3.

NOTE—Strict adherence to manufacturer-supplied guidelines for the operation and use of PMA serializer components is required to meet the jitter specifications of Clause 38 and Clause 39. The supplied guidelines should address the quality of power supply filtering associated with the transmit clock generator, and also the purity of the reference clock fed to the transmit clock generator.

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36.3.2.1 Data delay

The PMA maps a nonaligned one-bit data path from the PMD to an aligned, ten-bit-wide data path to the PCS, on the receive side. Logically, received bits must be buffered to facilitate proper code-group alignment. These functions necessitate an internal PMA delay of at least ten bit times. In practice, code-group alignment may necessitate even longer delays of the incoming rx_bit stream.

36.3.2.2 PMA transmit function

The PMA Transmit function passes data unaltered (except for serializing) from the PCS directly to the PMD. Upon receipt of a PMA_UNITDATA.request primitive, the PMA Transmit function shall serialize the ten bits of the tx_code-group<9:0> parameter and transmit them to the PMD in the form of ten successive PMD_UNITDATA.request primitives, with tx_code-group<0> transmitted first, and tx_code-group<9> transmitted last.

36.3.2.3 PMA receive function

The PMA Receive function passes data unaltered (except for deserializing and possible code-group slipping upon code-group alignment) from the PMD directly to the PCS. Upon receipt of ten successive PMD_UNITDATA.indication primitives, the PMA shall assemble the ten received rx_bits into a single ten-bit value and pass that value to the PCS as the rx_code-group<9:0> parameter of the primitive PMA_UNITDATA.indication, with the first received bit installed in rx_code-group<0> and the last received bit installed in rx_code-group<9>. An exception to this operation is specified in 36.3.2.4.

36.3.2.4 Code-group alignment

In the event the PMA sublayer detects a comma+ within the incoming rx_bit stream, it may realign its current code-group boundary, if necessary, to that of the received comma+ as shown in Figure 36–3. This process is referred to in this document as code-group alignment. The code-group alignment function shall be operational when the EN_CDET signal is active (see 36.3.3.1). During the code-group alignment process, the PMA sublayer may delete or modify up to four, but shall delete or modify no more than four, ten-bit code-groups in order to align the correct receive clock and code-group containing the comma+. This process is referred to as code-group slipping.

In addition, the PMA sublayer is permitted to realign the current code-group boundary upon receipt of a comma-pattern.

36.3.3 A physical instantiation of the PMA Service Interface

The ten-bit interface (TBI) is defined to provide compatibility among devices designed by different manufacturers. There is no requirement for a compliant device to implement or expose the TBI. A TBI implementation shall behave as described in 36.3.3 through 36.3.6.

Figure 36–11 illustrates the TBI functions and interfaces.

As depicted in Figure 36–11, the TBI connects the PCS and PMD sublayers. It is equipped for full duplex transmission of code-groups at 125 MHz. The PCS provides code-groups on tx_code-group<9:0> to the PMA transmit function, which latches the data on the rising edge of the 125 MHz PMA_TX_CLK. An internal Clock Multiplier Unit uses PMA_TX_CLK to generate the internal 1250 MHz bit clock that is used to serialize the latched data out of the PMA outputs, if EWRAP is Low, or internally loop it back to the Receive function input, if EWRAP is High.

The PMA Receive function accepts 1250 Mb/s serial data from either the PMD, if EWRAP is Low, or the PMA transmit function, if EWRAP is High, and extracts a bit clock and recovered data from the serial inputs

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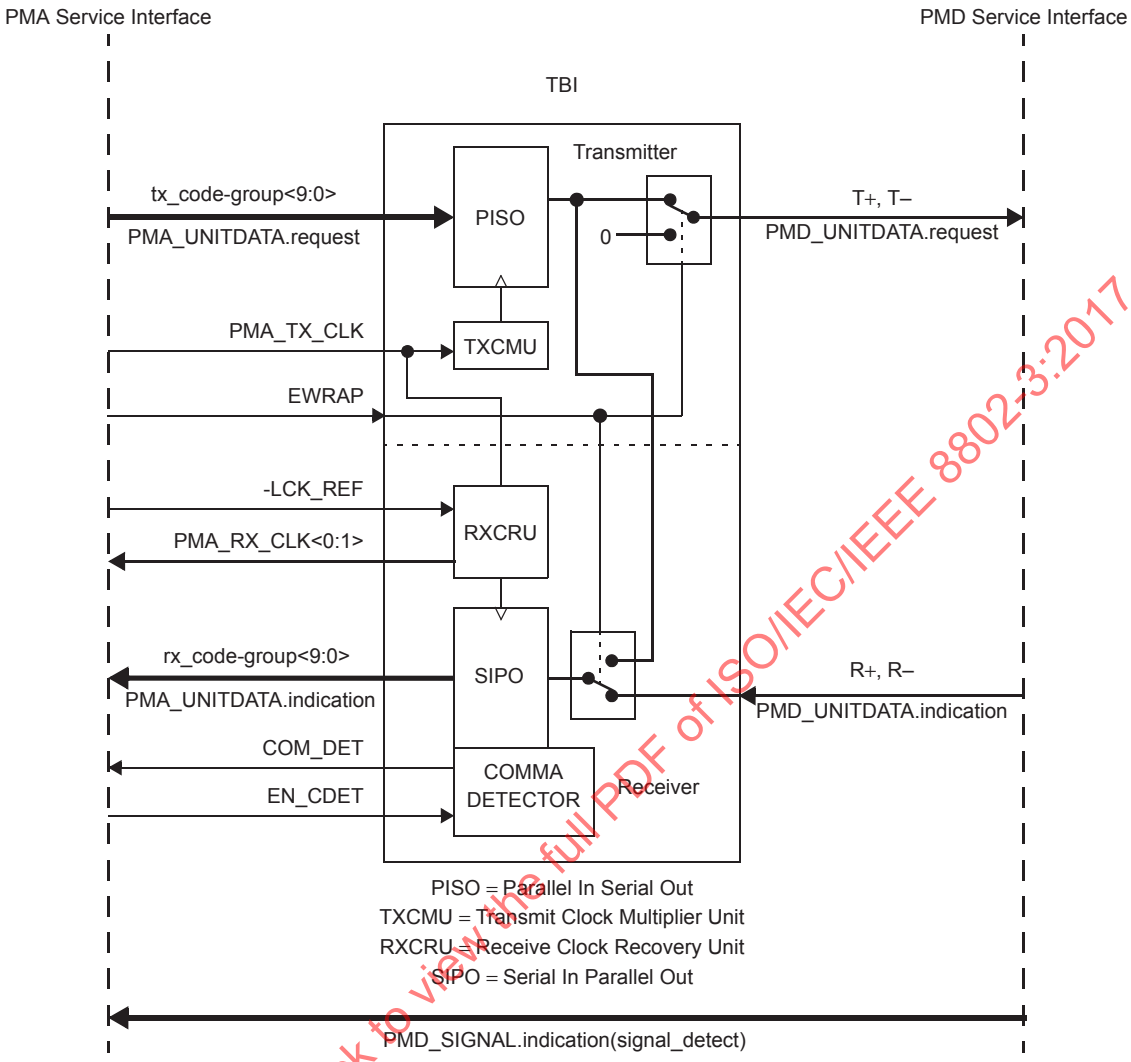

Figure 36–11—TBI reference diagram

in a clock recovery unit. The recovered data is deserialized and conveyed to the PCS on rx_code-group<9:0>. Two recovered clocks, PMA_RX_CLK<0> and PMA_RX_CLK<1>, which are at 1/20th the baud (62.5 MHz), and 180° out-of-phase with one another, are used by the PMA to latch the received 10-bit code-groups. Even and odd-numbered code-groups are latched on successive rising edges of PMA_RX_CLK<1> and PMA_RX_CLK<0>, respectively.

Code-group alignment occurs in the PMA Receive function, if enabled by EN_CDET, when a comma pattern occurs in the PHY bit stream. Upon recognition of the comma pattern, the PMA Receive function outputs the ten-bit code-group containing the comma on rx_code-group<9:0> with the alignment specified in Figure 36–3, and clocked on the rising edge of PMA_RX_CLK<1>.

This TBI provides a Lock_to_Reference_Clock (LCK_REF) input, which may be used to lock the clock recovery unit to PMA_TX_CLK rather than incoming serial data. In the absence of serial data or invalid serial data, the PMA Receive function passes many 8B/10B invalid code-groups across to the PCS. A circuit may be constructed to detect those errors and, using LCK_REF, re-center the receiver clock recovery unit to PMA_TX_CLK in preparation for reacquiring lock on the incoming PHY bit stream.

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36.3.3.1 Required signals

In the event this TBI is made accessible, the signals listed in Table 36–11 are provided, with the meanings described elsewhere in this section. Note that not all of these signals are used by the PCS.

Table 36–11—TBI required signals

Symbol	Signal Name	Signal Type	Active Level
tx_code-group<9:0>	Transmit Data	Input	H
PMA_TX_CLK	Transmit Clock	Input	↑
EWRAP	Enable Wrap	Input	H
rx_code-group<9:0>	Receive Data	Output	H
PMA_RX_CLK<0>	Receive Clock 0	Output	↑
PMA_RX_CLK<1>	Receive Clock 1	Output	↑
COM_DET	Comma Detect	Output	H
-LCK_REF	Lock to Reference	Input	L
EN_CDET	Enable Comma Detect	Input	H

tx_code-group<9:0>
: The 10-bit parallel transmit data presented to the PMA for serialization and transmission onto the media. The order of transmission is tx_bit<0> first, followed by tx_bit<1> through tx_bit<9>.

PMA_TX_CLK
: The 125 MHz transmit code-group clock. This code-group clock is used to latch data into the PMA for transmission. PMA_TX_CLK is also used by the transmitter clock multiplier unit to generate the 1250 MHz bit rate clock. PMA_TX_CLK is also used by the receiver when -LCK_REF is active. PMA_TX_CLK has a ±100 ppm tolerance. PMA_TX_CLK is derived from GMII GTX_CLK.

EWRAP
: EWRAP enables the TBI to electrically loop transmit data to the receiver. The serial outputs on the transmitter are held in a static state during EWRAP operation. EWRAP may optionally be tied low (function disabled).

rx_code-group<9:0>
: Presents the 10-bit parallel receive code-group data to the PCS for further processing. When code-groups are properly aligned, any received code-group containing a comma is clocked by PMA_RX_CLK<1>.

PMA_RX_CLK<0>
: The 62.5 MHz receive clock that the protocol device uses to latch odd-numbered code-groups in the received PHY bit stream. This clock may be stretched during code-group alignment, and is not shortened.

PMA_RX_CLK<1>
: The 62.5 MHz receive clock that the protocol device uses to latch even-numbered code-groups in the received PHY bit stream. PMA_RX_CLK<1> is 180° out-of-phase with PMA_RX_CLK<0>. This clock may be stretched during code-group alignment, and is not shortened.

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COM_DET

An indication that the code-group associated with the current PMA_RX_CLK<1> contains a valid comma. When EN_CDET is asserted, the TBI is required to detect and code-group-align to the comma+ bit sequence. Optionally, the TBI may also detect and code-group-align to the comma- bit sequence. The TBI provides this signal as an output, but it may not be used by the PCS.

-LCK_REF

Causes the TBI clock recovery unit to lock to PMA_TX_CLK. The TBI attains frequency lock within 500 ms. This function is not used by the PCS.

NOTE—Implementers may find it necessary to use this signal in order to meet the clock recovery requirements of the PMA sublayer.

EN_CDET

Enables the TBI to perform the code-group alignment function on a comma (see 36.2.4.9, 36.3.2.4). When EN_CDET is asserted the code-group alignment function is operational. This signal is optionally generated by the PMA client. The PMA sublayer may leave this function always enabled.

36.3.3.2 Summary of control signal usage

Table 36–12 lists all possible combinations of control signals on this TBI, including the valid combinations as well as the undefined combinations.

Table 36–12—TBI combinations of control signals

EWRAP	-LCK_REF	EN_CDET	Interpretation
L	L	L	Undefined
L	L	H	Lock receiver clock recovery unit to PMA_TX_CLK
L	H	L	Normal operation; COM_DET disabled
L	H	H	Normal operation; COM_DET enabled
H	L	L	Undefined
H	L	H	Undefined
H	H	L	Loop transmit data to receiver; COM_DET disabled
H	H	H	Loop transmit data to receiver; COM_DET enabled

36.3.4 General electrical characteristics of the TBI

In the event this TBI is made accessible, the following subclauses specify the general electrical characteristics of the TBI.

36.3.4.1 DC characteristics

Table 36–13 documents the required dc parametric attributes required of all inputs to the TBI and the dc parametric attributes associated with the outputs of the TBI. The inputs levels to the TBI may be greater than the power supply level (i.e., 5 V output driving V_{OH} into a 3.3 V input), tolerance to mismatched input levels is optional. TBI devices not tolerant of mismatched inputs levels that meet Table 36–13 requirements are still regarded as compliant.

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Table 36–13—DC specifications

Symbol	Parameter	Conditions		Min	Typ	Max	Units
V_{OH}	Output High Voltage	I_{OH} = –400 µA	V_{CC} = Min	2.2	3.0	V_{CC}	V
V_{OL}	Output Low Voltage	I_{OL} = 1 mA	V_{CC} = Min	GND	0.25	0.6	V
V_{IH}	Input High Voltage			2.0	—	V_{CC}[a] + 10%	V
V_{IL}	Input Low Voltage			GND	—	0.8	V
I_{IH}	Input High Current	V_{CC} = Max	V_{IN} = 2.4 V	—	—	40	µA
I_{IL}	Input Low Current	V_{CC} = Max	V_{IN} = 0.4 V	—	—	600	µA
C_{IN}	Input Capacitance			—	—	4.0	pf
t_R	Clock Rise Time	0.8 V to 2.0 V		0.7	—	2.4	ns
t_F	Clock Fall Time	2.0 V to 0.8 V		0.7	—	2.4	ns
t_R	Data Rise Time	0.8 V to 2.0 V		0.7	—	—	ns
t_F	Data Fall Time	2.0 V to 0.8 V		0.7	—	—	ns

[a]Refers to the driving device power supply.

36.3.4.2 Valid signal levels

All ac measurements are made from the 1.4 V level of the clock to the valid input or output data levels as shown in Figure 36–12.

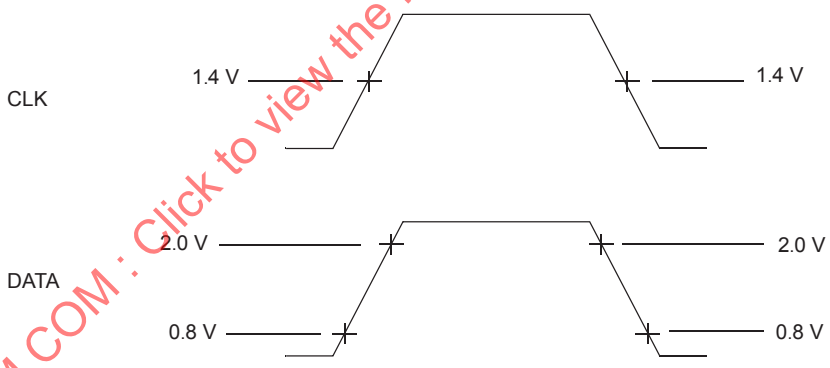

Figure 36–12—Input/output valid level for ac measurements

36.3.4.3 Rise and fall time definition

The rise and fall time definition for PMA_TX-CLK, PMA_RX_CLK<0>, PMA_RX_CLK<1>, and DATA is shown in Figure 36–13.

36.3.4.4 Output load

All ac measurements are assumed to have the output load of 10 pF.

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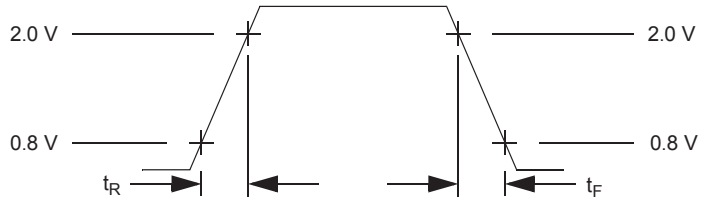

Figure 36–13—Rise and fall time definition

36.3.5 TBI transmit interface electrical characteristics

In the event this TBI is made accessible, the electrical characteristics of the TBI transmit interface are specified in the following subclauses.

36.3.5.1 Transmit data (tx_code-group<9:0>)

The tx_code-group<9:0> signals carry data from the PCS to PMA to be serialized to the PMD in accordance with the transmission order shown in Figure 36–3. All tx_code-group<9:0> data conforms to valid code-groups.

36.3.5.2 TBI transmit interface timing

The TBI transmit interface timings in Table 36–14 defines the TBI input. All transitions in Figure 36–14 are specified from the PMA_TX_CLK reference level (1.4 V), to valid input signal levels.

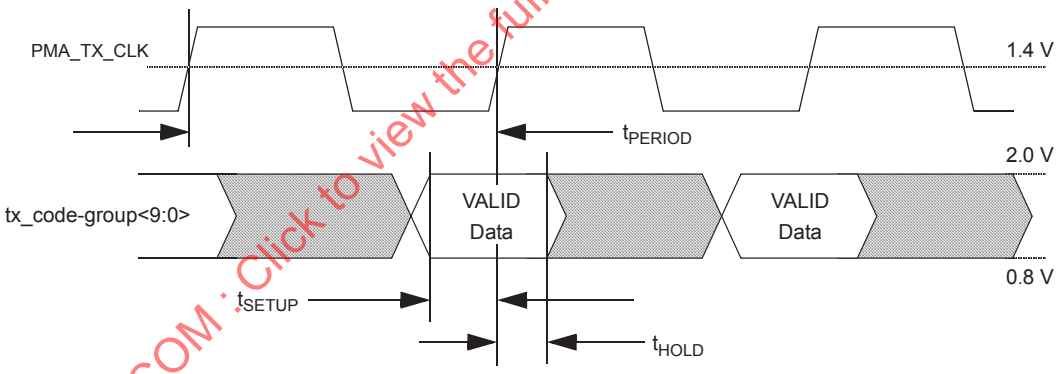

Figure 36–14—TBI transmit interface timing diagram

Table 36–14—Transmit AC specification

Parameter	Description	Min	Typ	Max	Units
t_{PERIOD}	PMA_TX_CLK Period[a]	—	8	—	ns
t_{SETUP}	Data Setup to ↑ PMA_TX_CLK	2.0	—	—	ns
t_{HOLD}	Data Hold from ↑ PMA_TX_CLK	1.0	—	—	ns
t_{DUTY}	PMA_TX_CLK Duty Cycle	40		60	%

[a] ±100 ppm tolerance on PMA_TX_CLK frequency.

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36.3.6 TBI receive interface electrical characteristics

In the event this TBI is made accessible, the electrical characteristics of the TBI receive interface are specified in the following subclauses.

The TBI receive interface timings in Table 36–15 define the TBI output. All transitions in Figure 36–15 are specified from the Receive Clock reference level (1.4 V) to valid output signal levels.

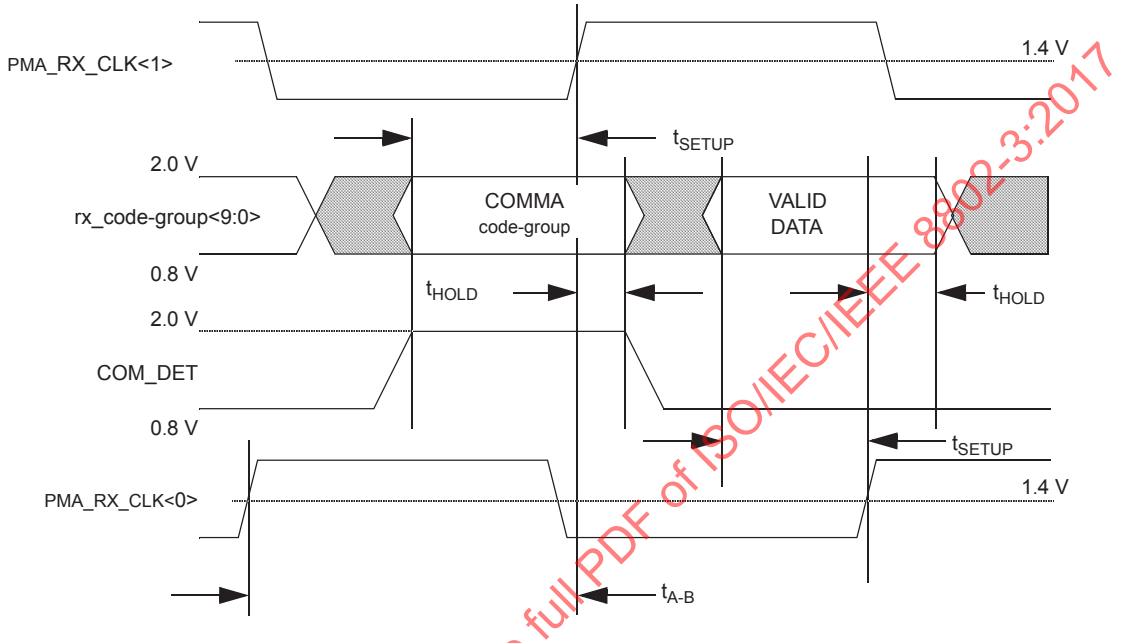

Figure 36–15—TBI receive interface timing diagram

36.3.6.1 Receive data (rx_code-group<9:0>)

The 10 receive data signals rx_code-group<9:0> carry parallel data from the PMA sublayer to the PCS sublayer during the rising edge of the receive clock (i.e., PMA_RX_CLK<1> transitions from Low to High). When properly locked and aligned, data transferred across this interface conforms to valid code-groups.

36.3.6.2 Receive clock (PMA_RX_CLK<0>, PMA_RX_CLK<1>)

The receive clocks supplied to the PCS and GMII are derived from the recovered bit clock. PMA_RX_CLK<0> is 180° out-of-phase with PMA_RX_CLK<1>.

Table 36–15 specifies a receive clock drift (t_{DRIFT}), which is applicable under all input conditions to the receiver (including invalid or absent input signals). However, the restriction does not apply when the receiver is realigning to a new code-group boundary and the receive clocks are being stretched to a new code-group boundary to avoid short pulses. During the code-group alignment process the receive clocks may slow a fixed amount, depending on the bit offset of the new comma and then return to the nominal frequency.

36.3.7 Loopback mode

Loopback mode shall be provided, as specified in this subclause, by the transmitter and receiver of a device as a test function to the device. When Loopback mode is selected, transmission requests passed to the

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Table 36–15—Receive bus AC specification

Parameter	Description	Min	Typ	Max	Units
t_{FREQ}	PMA_RX_CLK Frequency	—	62.5	—	MHz
t_{DRIFT}	PMA_RX_CLK Drift Rate[a]	0.2	—	—	µs/MHz
t_{SETUP}	Data Setup Before ↑PMA_RX_CLK	2.5	—	—	ns
t_{HOLD}	Data Hold After ↑PMA_RX_CLK	1.5	—	—	ns
t_{DUTY}	PMA_RX_CLK Duty Cycle	40	—	60	%
t_{A-B}	PMA_RX_CLK Skew	7.5	—	8.5	ns

[a]t_{DRIFT} is the (minimum) time for PMA_RX_CLK to drift from 63.5 MHz to 64.5 MHz or 60 MHz to 59 MHz from the PMA_RX_CLK lock value. It is applicable under all input signal conditions (except where noted in 36.3.2.4), including invalid or absent input signals, provided that the receive clock recovery unit was previously locked to PMA_TX_CLK or to a valid input signal.

transmitter are shunted directly to the receiver, overriding any signal detected by the receiver on its attached link. A device is explicitly placed in Loopback mode (i.e., Loopback mode is not the normal mode of operation of a device). The method of implementing Loopback mode is not defined by this standard.

NOTE—Loopback mode may be implemented either in the parallel or the serial circuitry of a device.

36.3.7.1 Receiver considerations

A receiver may be placed in Loopback mode. Entry into or exit from Loopback mode may result in a temporary loss of synchronization.

36.3.7.2 Transmitter considerations

A transmitter may be placed in Loopback mode. The external behavior of a transmitter (i.e., the activity of a transmitter with respect to its attached link) in Loopback mode is specified in 22.2.4.1.2.

36.3.8 Test functions

A limited set of test functions may be provided as an implementation option for testing of the transmitter function.

Some test functions that are not defined by this standard may be provided by certain implementations. Compliance with the standard is not affected by the provision or exclusion of such functions by an implementation. Random jitter test patterns for 1000BASE-X are specified in Annex 36A.

A typical test function is the ability to transmit invalid code-groups within an otherwise valid PHY bit stream. Certain invalid PHY bit streams may cause a receiver to lose word and/or bit synchronization. See ANSI X3.230-1994 [B21] (FC-PH), subclause 5.4, for a more detailed discussion of receiver and transmitter behavior under various test conditions.

36.4 Compatibility considerations

There is no requirement for a compliant device to implement or expose any of the interfaces specified for the PCS or PMA. Implementations of a GMII shall comply with the requirements as specified in Clause 35. Implementations of a TBI shall comply with the requirements as specified in 36.3.3.

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36.5 Delay constraints

In half duplex mode, proper operation of a CSMA/CD LAN demands that there be an upper bound on the propagation delays through the network. This implies that MAC, PHY, and repeater implementers must conform to certain delay minima and maxima, and that network planners and administrators conform to constraints regarding the cable topology and concatenation of devices. MAC constraints are contained in 35.2.4 and Table 35–5. Topological constraints are contained in Clause 42.

In full duplex mode, predictable operation of the MAC Control PAUSE operation (Clause 31, Annex 31B) also demands that there be an upper bound on the propagation delays through the network. This implies that MAC, MAC Control sublayer, and PHY implementers must conform to certain delay maxima, and that network planners and administrators conform to constraints regarding the cable topology and concatenation of devices.

The reference point for all MDI measurements is the 50% point of the mid-cell transition corresponding to the reference bit, as measured at the MDI.

36.5.1 MDI to GMII delay constraints

Every 1000BASE-X PHY associated with a GMII shall comply with the bit time delay constraints specified in Table 36–16 for half duplex operation and Table 36–17 for full duplex operation. These figures apply for all 1000BASE-X PMDs. For any given implementation, the assertion and deassertion delays on CRS shall be equal.

Table 36–16—MDI to GMII delay constraints (half duplex mode)

Sublayer measurement points	Event	Min (bit time)	Max (bit time)	Input timing reference	Output timing reference
GMII ⇔ MDI	TX_EN=1 sampled to MDI output	—	136	PMA_TX_CLK rising	1st bit of /S/
	MDI input to CRS assert	—	192	1st bit of /S/	
	MDI input to CRS deassert	—	192	1st bit of /K28.5/	
	MDI input to COL assert	—	192	1st bit of /S/	
	MDI input to COL deassert	—	192	1st bit of /K28.5/	
	TX_EN=1 sampled to CRS assert	—	16	PMA_TX_CLK rising	
	TX_EN=0 sampled to CRS deassert	—	16	PMA_TX_CLK rising	

Table 36–17—MDI to GMII delay constraints (full duplex mode)

Sublayer measurement points	Event	Min (bit time)	Max (bit time)	Input timing reference	Output timing reference
GMII ⇔ MDI	TX_EN=1 sampled to MDI output	—	136	PMA_TX_CLK rising	1st bit of /S/
	MDI input to RX_DV deassert	—	192	1st bit of /T/	RX_CLK rising

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36.5.2 DTE delay constraints (half duplex mode)

Every DTE with a 1000BASE-X PHY shall comply with the bit time delay constraints specified in Table 36–18 for half duplex operation. These figures apply for all 1000BASE-X PMDs.

Table 36–18—DTE delay constraints (half duplex mode)

Sublayer measurement points	Event	Min (bit time)	Max (bit time)	Input timing reference	Output timing reference
MAC ⇔ MDI	MAC transmit start to MDI output	—	184		1st bit of /S/
	MDI input to MDI output (worst-case nondeferred transmit)	—	440	1st bit of /S/	1st bit of /S/
	MDI input to collision detect	—	240	1st bit of /S/	
	MDI input to MDI output = Jam (worst-case collision response)	—	440	1st bit of /S/	1st bit of jam

36.5.3 Carrier deassertion/assertion constraint (half duplex mode)

To ensure fair access to the network, each DTE operating in half duplex mode shall, additionally, satisfy the following:

(MAX MDI to MAC Carrier Deassert Detect) – (MIN MDI to MAC Carrier Assert Detect) < 16 bits

36.6 Environmental specifications

All equipment subject to this clause shall conform to the requirements of 14.7 and applicable sections of ISO/IEC 11801:1995.

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36.7 Protocol implementation conformance statement (PICS) proforma for Clause 36, Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 1000BASE-X[3]

36.7.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 36, Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 1000BASE-X, shall complete the following protocol implementation conformance statement (PICS) proforma. A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

36.7.2 Identification

36.7.2.1 Implementation identification

Supplier (Note 1)	
Contact point for inquiries about the PICS (Note 1)	
Implementation Name(s) and Version(s) (Notes 1 and 3)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s) (Note 2)	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

36.7.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 36, Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 1000BASE-X
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	

Date of Statement	

[3]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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36.7.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*PMA	Ten-bit interface (TBI)	36.4		O	Yes [ ] No [ ]
*GMII	PHY associated with GMII	36.4		O	Yes [ ] No [ ]
*DTE	DTE with PHY not associated with GMII	36.5.2		O	Yes [ ] No [ ]
*FDX	PHY supports full duplex mode	36.5		O	Yes [ ] No [ ]
*HDX	PHY supports half duplex mode	36.5		O	Yes [ ] No [ ]
*LPI	Implementation of LPI	36.2.4.13		O	Yes [ ] No [ ]
NOTE—The following abbreviations are used: *HDGM: HDX and GMII *FDGM: FDX and GMII *HDTE: HDX and DTE					

36.7.4 PICS proforma tables for the PCS and PMA sublayer, type 1000BASE-X

36.7.4.1 Compatibility considerations

Item	Feature	Subclause	Value/Comment	Status	Support
CC1	Test functions Annex 36A support	36.3.8		O	Yes [ ] No [ ]
CC2	Environmental specifications	36.6		M	Yes [ ]

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36.7.4.2 Code-group functions

Item	Feature	Subclause	Value/Comment	Status	Support
CG1	Transmitter initial running disparity	36.2.4.4	Transmitter initial running disparity assumes negative value	M	Yes [ ]
CG2	Transmitter running disparity calculation	36.2.4.4	Running disparity is calculated after each code-group transmitted	M	Yes [ ]
CG3	Validating received code-groups	36.2.4.6		M	Yes [ ]
CG4	Running disparity rules	36.2.4.4	Running disparity is calculated after each code-group reception	M	Yes [ ]
CG5	Transmitted code-group is chosen from the corresponding running disparity	36.2.4.5		M	Yes [ ]

36.7.4.3 State diagrams

Item	Feature	Subclause	Value/Comment	Status	Support
SD1	Transmit ordered set	36.2.5.2.1	Meets the requirements of Figure 36–5	M	Yes [ ]
SD2	Transmit code-group	36.2.5.2.1	Meets the requirements of Figure 36–6	M	Yes [ ]
SD3	Receive	36.2.5.2.2	Meets the requirements of Figures 36–7a and 36–7b	M	Yes [ ]
SD4	Carrier sense	36.2.5.2.5	Meets the requirements of Figure 36–8	M	Yes [ ]
SD5	Synchronization	36.2.5.2.6	Meets the requirements of Figure 36–9	M	Yes [ ]
SD6	Auto-Negotiation	36.2.5.2.7	Described in Clause 37	M	Yes [ ]
SD7*	Support for use with a 1000BASE-KX PMD	36.2.5.2.7	AN technology dependent interface described in Clause 73	O	Yes [ ]
SD8	AN_LINK.indication primitive	36.2.5.2.7	Support of the primitive AN_LINK.indication(link_status), when the PCS is used with 1000BASE-KX PMD	SD7:M	Yes [ ]
SD9	link_status parameter	36.2.5.2.7	Takes the value OK or FAIL, as described in 36.2.5.2.7	SD7:M	Yes [ ]
SD10	Generation of AN_LINK.indication primitive	36.2.5.2.7	Generated when the value of link_status changes	SD7:M	Yes [ ]
SD11	Value of xmit, when the PCS is used with 1000BASE-KX PMD	36.2.5.2.7	The value of xmit is DATA, when Clause 37 Auto-Negotiation is not present as described in 36.2.5.2.7	SD7:M	Yes [ ]

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36.7.4.4 PMA functions

Item	Feature	Subclause	Value/Comment	Status	Support
PMA1	Transmit function	36.3.2.2		M	Yes [ ]
PMA2	Receive function	36.3.2.3		M	Yes [ ]
PMA3	Code-group alignment	36.3.2.4	When EN_CDET is active	M	Yes [ ]
PMA4	Loopback mode	36.3.7		M	Yes [ ]

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36.7.4.5 PMA transmit function

Item	Feature	Subclause	Value/Comment	Status	Support
PMT1	cg_timer expiration	36.2.5.1.7	See 35.5.2.3	GMII:M	Yes [ ] N/A [ ]
PMT2	cg_timer expiration	36.2.5.1.7	8 ns ± 0.01%	!GMII: M	Yes [ ] N/A [ ]

36.7.4.6 PMA code-group alignment function

Item	Feature	Subclause	Value/Comment	Status	Support
CDT1	Code-group alignment to comma-	36.3.2.4		O	Yes [ ] N/A [ ]
CDT2	Code-group slipping limit	36.3.2.4	Deletion or modification of no more than four code-groups	M	Yes [ ]
CDT3	Code-group alignment to comma+	36.3.2.4		O	Yes [ ] N/A [ ]

36.7.4.7 TBI

Item	Feature	Subclause	Value/Comment	Status	Support
TBI1	TBI requirements	36.3.3		PMA:M	Yes [ ] N/A [ ]

36.7.4.8 Delay constraints

Item	Feature	Subclause	Value/Comment	Status	Support
TIM1	Equal carrier deassertion and assertion delay on CRS	36.5.1		HDGM:M	Yes [ ] N/A [ ]
TIM2	MDI to GMII delay constraints for half duplex	36.5.1	Table 36–16	HDGM:M	Yes [ ] N/A [ ]
TIM3	MDI to GMII delay constraints for full duplex	36.5.1	Table 36–17	FDGM:M	Yes [ ] N/A [ ]
TIM4	DTE delay constraints for half duplex	36.5.2	Table 36–18	HDTE:M	Yes [ ] N/A [ ]
TIM5	Carrier deassertion/assertion constraints	36.5.3		HDTE:M	Yes [ ] N/A [ ]

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36.7.4.9 LPI functions

Item	Feature	Subclause	Value/Comment	Status	Support
LP-01	Transmit ordered set state diagram	36.2.5.2.1	Support additions to Figure 36–5 for LPI operation	LPI:M	Yes [ ] No [ ]
LP-02	Receive state diagram	36.2.5.2.2	Support additions to Figure 36–7a, Figure 36–7b for LPI operation	LPI:M	Yes [ ] No [ ]
LP-03	LPI transmit state diagram	36.2.5.2.8	Meets the requirements of Figure 36–10	LPI:M	Yes [ ] No [ ]
LP-04	LPI receive state diagram	36.2.5.2.8	Meets the requirements of Figure 36–7c	LPI:M	Yes [ ] No [ ]
LP-03	LPI transmit timing	36.2.5.2.8	Meets the requirements of Table 36–8	LPI:M	Yes [ ] No [ ]
LP-04	LPI receive timing	36.2.5.2.8	Meets the requirements of Table 36–9	LPI:M	Yes [ ] No [ ]

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37. Auto-Negotiation function, type 1000BASE-X

37.1 Overview

37.1.1 Scope

Clause 37 describes the 1000BASE-X Auto-Negotiation (AN) function that allows a device (local device) to advertise modes of operation it possesses to a device at the remote end of a link segment (link partner) and to detect corresponding operational modes that the link partner may be advertising. Backplane Auto-Negotiation defined in Clause 73 applies to 1000BASE-KX.

The Auto-Negotiation function exchanges information between two devices that share a link segment and automatically configures both devices to take maximum advantage of their abilities. Auto-Negotiation is performed with /C/ and /I/ ordered sets defined in Clause 36, such that no packet or upper layer protocol overhead is added to the network devices. Auto-Negotiation does not test the link segment characteristics (see 37.1.4).

The function allows the devices at both ends of a link segment to advertise abilities, acknowledge receipt and understanding of the common mode(s) of operation that both devices share, and to reject the use of operational modes that are not shared by both devices. Where more than one common mode exists between the two devices, a mechanism is provided to allow the devices to resolve to a single mode of operation using a predetermined priority resolution function (see 37.2.4.2). The Auto-Negotiation function allows the devices to switch between the various operational modes in an ordered fashion, permits management to disable or enable the Auto-Negotiation function, and allows management to select a specific operational mode.

The basic mechanism to achieve Auto-Negotiation is to pass information encapsulated within /C/ ordered sets. /C/ ordered sets are directly analogous to FLP Bursts as defined in Clause 28 that accomplish the same function. Each device issues /C/ ordered sets at power up, on command from management, upon detection of a PHY error, or due to user interaction.

37.1.2 Application perspective/objectives

This Auto-Negotiation function is designed to be expandable and allows 1000BASE-X devices to self-configure a jointly compatible operating mode.

The following are the objectives of Auto-Negotiation:

a) To be reasonable and cost-effective to implement;
b) Must provide a sufficiently extensible code space to
   1) Meet existing and future requirements;
   2) Allow simple extension without impacting the installed base;
   3) Accommodate remote fault signals; and
   4) Accommodate link partner ability detection.
c) Must allow manual or Network Management configuration to override the Auto-Negotiation;
d) Must be capable of operation in the absence of Network Management;
e) Must allow the ability to renegotiate;
f) Must operate when
   1) The link is initially connected;
   2) A device at either end of the link is powered up, reset, or a renegotiation request is made.
g) May be enabled by automatic, manual, or Network Management intervention;
h) To complete the base page Auto-Negotiation function in a bounded time period;

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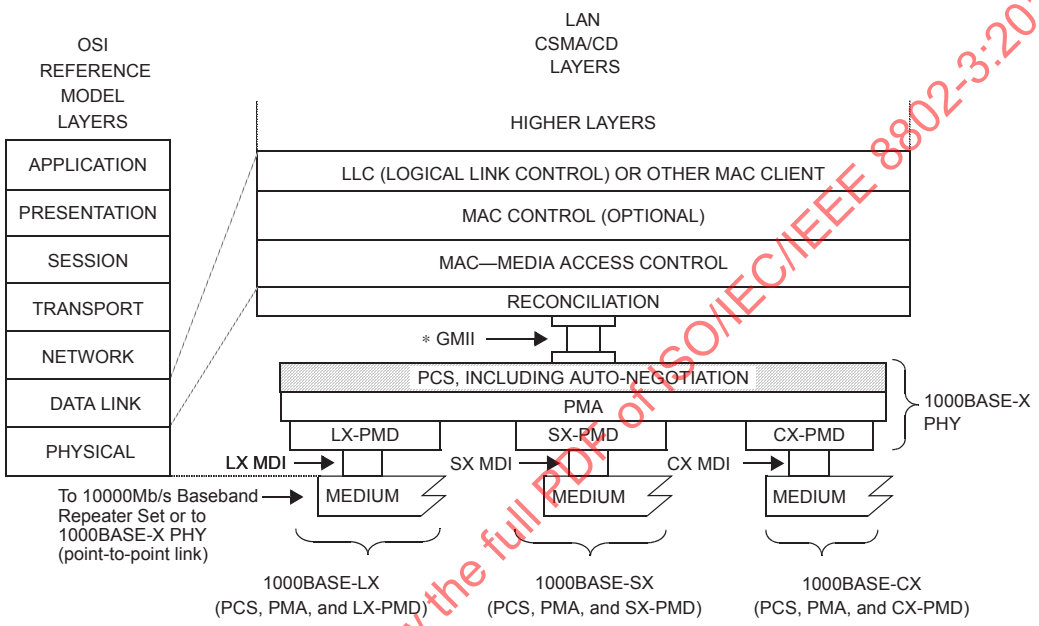
i) To operate using a peer-to-peer exchange of information with no requirement for a master device (not master-slave);
j) Must be robust in the 1000BASE-X MDI cable noise environment;
k) Must not significantly impact EMI/RFI emissions.

37.1.3 Relationship to architectural layering

The Auto-Negotiation function is provided at the PCS sublayer of the Physical Layer of the OSI reference model as shown in Figure 36–1. Devices that support multiple modes of operation may advertise this fact using this function. The transfer of information is observable only at the MDI or on the medium.



MDI=MEDIUM DEPENDENT INTERFACE
GMII=GIGABIT MEDIA INDEPENDENT INTERFACE
PCS=PHYSICAL CODING SUBLAYER
PMA=PHYSICAL MEDIUM ATTACHMENT
PHY=PHYSICAL LAYER DEVICE
PMD=PHYSICAL MEDIUM DEPENDENT
LX-PMD=PMD FOR FIBER—LONG WAVELENGTH, Clause 38
SX-PMD=PMD FOR FIBER—SHORT WAVELENGTH, Clause 38
CX-PMD=PMD FOR 150 Ω BALANCED COPPER CABLING, Clause 39

NOTE—The PMD sublayers are mutually independent.
* GMII is optional.

Figure 37–1—Location of the Auto-Negotiation function

37.1.4 Compatibility considerations

37.1.4.1 Auto-Negotiation

1000BASE-X devices provide the Auto-Negotiation function. Auto-Negotiation does not perform cable tests, such as cable performance measurements. Some PHYs that explicitly require use of high-performance cables, may require knowledge of the cable type, or additional robustness tests (such as monitoring invalid code-groups, CRC, or framing errors) to determine if the link segment is adequate.

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37.1.4.2 Management interface

Manual or automatic invocation of Auto-Negotiation may result in frame loss. Exit from Auto-Negotiation to normal MAC frame processing may also result in frame loss as one link end may resume normal MAC frame processing ahead of its link partner.

37.1.4.2.1 GMII management interface

Auto-Negotiation signaling does not occur across the GMII. Control of the Auto-Negotiation function may be supported through the Management Interface of the GMII or equivalent. If an explicit embodiment of the GMII is supported, the Control and Status registers to support the Auto-Negotiation function shall be implemented in accordance with the definitions in Clause 22 and 37.2.5.

37.1.4.3 Interoperability between Auto-Negotiation compatible devices

An Auto-Negotiation compatible device decodes the Base Page from the received /C/ ordered sets and examines the contents for the highest common ability that both devices share. Both devices acknowledge correct receipt of each other's Base Page by responding with Base Pages containing the Acknowledge Bit set. After both devices complete acknowledgment, and any desired Next Page exchange, both devices enable the highest common mode negotiated. The highest common mode is resolved using the priority resolution hierarchy specified in 37.2.4.2.

37.1.4.4 User Configuration with Auto-Negotiation

Rather than disabling Auto-Negotiation, the following behavior is suggested in order to improve interoperability with other Auto-Negotiation devices. When a device is configured for one specific mode of operation (e.g. 1000BASE-X Full Duplex), it is recommended to continue using Auto-Negotiation but only advertise the specifically selected ability or abilities. This can be done by the Management agent only setting the bits in the advertisement registers that correspond to the selected abilities.

37.2 Functional specifications

The Auto-Negotiation function includes the Auto-Negotiation Transmit, Receive, and Arbitration functions specified in the state diagram of Figure 37–6 and utilizes the PCS Transmit and Receive state diagrams of Clause 36.

The Auto-Negotiation function provides an optional Management function that provides a control and status mechanism. Management may provide additional control of Auto-Negotiation through the Management function, but the presence of a management agent is not required.

37.2.1 Config_Reg encoding

The Config_Reg Base Page, transmitted by a local device or received from a link partner, is encapsulated within a /C/ ordered set and shall convey the encoding shown in Figure 37–2. Auto-Negotiation supports additional pages using the Next Page function. Encodings for the Config_Reg(s) used in Next Page exchange are defined in 37.2.4.3.1. Config_Reg bits labeled as "rsvd" are reserved and shall be set to a logic zero.

37.2.1.1 Base Page to management register mapping

Several Base Page bits shown in Figure 37–2 indicate capabilities that are sourced from management registers. Table 37–1 describes how the management registers map to the management function interface signals. The bit format of the rx_Config_Reg<D15:D0> and tx_Config_Reg<D15:D0> variables is context dependent, relative to the state of the Auto-Negotiation function, and is presented here and in 37.2.4.3.1.

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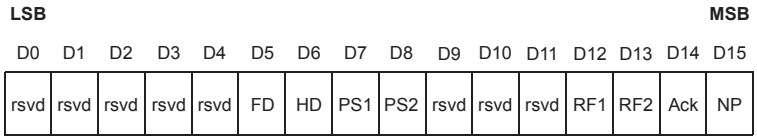

Figure 37–2—Config_Reg Base Page encoding

Table 37–1—Config_Reg Base Page to management register mapping

Config_Reg Base Page bits	Management register bit
Full Duplex (FD)	4.5 Full Duplex
Half Duplex (HD)	4.6 Half Duplex
PAUSE (PS1)	4.7 PAUSE
ASM_DIR (PS2)	4.8 ASM_DIR
Remote Fault (RF2, RF1)	4.13:12 Remote Fault

37.2.1.2 Full duplex

Full Duplex (FD) is encoded in bit D5 of the base Config_Reg.

37.2.1.3 Half duplex

Half Duplex (HD) is encoded in bit D6 of the base Config_Reg.

37.2.1.4 Pause

Pause (PS1, PS2) is encoded in bits D7 and D8 of the base Config_Reg. Pause provides a pause capability exchange mechanism. Pause encoding is specified in Table 37–2.

Table 37–2—Pause encoding

PAUSE (D7)	ASM_DIR(D8)	Capability
0	0	No PAUSE
0	1	Asymmetric PAUSE toward link partner
1	0	Symmetric PAUSE
1	1	Both Symmetric PAUSE and Asymmetric PAUSE toward local device

The PAUSE bit indicates that the device is capable of providing the symmetric PAUSE functions as defined in Annex 31B. The ASM_DIR bit indicates that asymmetric PAUSE operation is supported. The value of the PAUSE bit when the ASM_DIR bit is set indicates the direction PAUSE frames are supported for flow

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across the link. Asymmetric PAUSE configuration results in independent enabling of the PAUSE receive and PAUSE transmit functions as defined by Annex 31B. See 37.2.4.2 for PAUSE configuration resolution.

37.2.1.5 Remote fault

Sensing of faults in a device as well as subsequent association of faults with the Remote Fault function encodings is optional. Remote Fault (RF) is encoded in bits D12 and D13 of the Base Page. The default value is 0b00. Remote Fault provides a standard transport mechanism for the transmission of simple fault and error information. The Remote Fault function may indicate to the link partner that a fault or error condition has occurred. The two Remote Fault bits, RF1 and RF2, shall be encoded as specified in Table 37–3.

Table 37–3—Remote Fault encoding

RF1	RF2	Description
0	0	No error, link OK (default)
0	1	Offline
1	0	Link_Failure
1	1	Auto-Negotiation_Error

If the local device has no mechanism to detect a fault or associate a fault condition with the received Remote Fault function encodings, then it shall transmit the default Remote Fault encoding of 0b00.

A local device may indicate it has sensed a fault to its link partner by setting a nonzero Remote Fault encoding in its Base Page and renegotiating.

If the local device sets the Remote Fault encoding to a nonzero value, it may also use the Next Page function to specify information about the fault that has occurred. Remote Fault Message Page Codes may be specified for this purpose (see Annex 28C).

The Remote Fault encoding shall remain set until after the Auto-Negotiation process transitions into IDLE_DETECT state with the Base Page, at which time the Remote Fault encoding is reset to 0b00. On receipt of a Base Page with a nonzero Remote Fault encoding, the device shall set the Remote Fault bit in the Status register (1.4) to logic one if the GMII management function is present.

37.2.1.5.1 No error, link OK

A Remote Fault encoding of 0b00 indicates that no remote fault or error condition has been detected by the local device.

37.2.1.5.2 Offline

A Remote Fault encoding of 0b01 indicates that the local device is going Offline. A local device may indicate Offline prior to powering off, running transmitter tests, or removing the local device from the active configuration. A local device need not successfully complete the Auto-Negotiation function from the receive perspective after completing the Auto-Negotiation function indicating Offline from its transmit perspective before further action is taken (e.g., powering off, running transmitter tests, removing the local device from the active configuration, etc.).

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37.2.1.5.3 Link_Failure

A Remote Fault encoding of 0b10 indicates that the local device has detected a Link_Failure condition indicated by loss of synchronization. While sync_status = FAIL, remote fault information is not signaled. When sync_status becomes OK, stored remote fault information is signaled (see 36.2.5.1.3 and 36.2.5.2.6). Another indication of a link failure condition is provided by the reception of /C/ ordered sets having rx_Config_Reg<D15:D0> = 0 for a duration exceeding link_timer.

37.2.1.5.4 Auto-Negotiation_Error

A Remote Fault encoding of 0b11 indicates that the local device has detected a Auto-Negotiation_Error. Resolution which precludes operation between a local device and link partner shall be reflected to the link partner by the local device by indicating a Remote Fault code of Auto-Negotiation_Error.

37.2.1.6 Acknowledge

Acknowledge (Ack) is encoded in bit D14 of the base and Next Pages (see Figures 37–2, 37–3, and 37–4). The Ack bit is used by the Auto-Negotiation function to indicate that a device has successfully received its link partner's base or Next Page.

This bit is set to logic one after the device has successfully received at least three consecutive and matching rx_Config_Reg<D15:D0> values (ignoring the Acknowledge bit value), and, for Next Page exchanges, remains set until the Next Page information has been loaded into the AN Next Page transmit register (register 7). After the Auto-Negotiation process COMPLETE_ACKNOWLEDGE state has been entered, the tx_Config_Reg<D15:D0> value is transmitted for the link_timer duration.

37.2.1.7 Next Page

The Base Page and subsequent Next Pages may set the NP bit to a logic one to request Next Page transmission. Subsequent Next Pages may set the NP bit to a logic zero in order to communicate that there is no more Next Page information to be sent (see 37.2.4.3). A device may implement Next Page ability and choose not to engage in a Next Page exchange by setting the NP bit to a logic zero.

37.2.2 Transmit function requirements

The Transmit function provides the ability to transmit /C/ ordered sets. After Power-On, link restart, or renegotiation, the Transmit function transmits /C/ ordered sets containing zeros indicating the restart condition. After sending sufficient zeros, the /C/ ordered sets contain the Config_Reg Base Page value defined in 37.2.1. The local device may modify the Config_Reg value to disable an ability it possesses, but shall not transmit an ability it does not possess. This makes possible the distinction between local abilities and advertised abilities so that devices capable of multiple modes may negotiate to a mode lower in priority than the highest common local ability.

The Transmit function shall utilize the PCS Transmit process specified in 36.2.5.2.1.

37.2.2.1 Transmit function to Auto-Negotiation process interface requirements

The variable tx_Config_Reg<D15:D0> is derived from mr_adv_abilities<16:1> or mr_np_tx<16:1>. This variable is the management representation of the AN advertisement register during Base Page exchange and the AN Next Page transmit register during Next Page exchange.

When the xmit variable is set to CONFIGURATION by the Auto-Negotiation process, the PCS Transmit function encodes the contents of the tx_Config_Reg<D15:D0> into the appropriate /C/ ordered set for transmission onto the MDI. When the xmit variable is set to IDLE by the Auto-Negotiation process, the PCS

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Transmit function transmits /I/ ordered sets onto the MDI. When the xmit variable is set to DATA by the Auto-Negotiation process, the PCS Transmit function transmits /I/ ordered sets interspersed with packets onto the MDI.

37.2.3 Receive function requirements

The PCS Receive function detects /C/ and /I/ ordered sets. For received /C/, the PCS Receive function decodes the information contained within, and stores the data in rx_Config_Reg<D15:D0>.

The Receive function shall utilize the PCS Receive process specified in 36.2.5.2.2.

37.2.3.1 Receive function to Auto-Negotiation process interface requirements

The PCS Receive function provides the Auto-Negotiation process and management function with the results of rx_Config_Reg<D15:D0>. The PCS Auto-Negotiation function generates the ability_match, acknowledge_match, consistency_match, and idle_match signals.

The PCS Receive process sets the RX_UNITDATA.indicate(/C/) message when a /C/ ordered set is received.

The PCS Receive process sets the RX_UNITDATA.indicate(/I/) message when a /I/ ordered set is received.

The PCS Receive process sets the RX_UNITDATA.indicate(INVALID) message when an error condition is detected while not in normal receive processing (when the xmit variable is set to CONFIGURATION). The error conditions are specified in the PCS Receive state diagram of Figure 36–7a.

37.2.4 Arbitration process requirements

The Arbitration process ensures proper sequencing of the Auto-Negotiation function using the Transmit function and Receive function. The Arbitration process enables the Transmit function to advertise and acknowledge abilities. Upon completion of Auto-Negotiation information exchange, the Arbitration process determines the highest common mode using the priority resolution function and enables the appropriate functions.

37.2.4.1 Renegotiation function

A renegotiation request from any entity, such as a management agent, causes the Auto-Negotiation function to be restarted from Auto-Negotiation process state AN_ENABLE.

37.2.4.2 Priority resolution function

Since a local device and a link partner may have multiple common abilities, a mechanism to resolve which mode to configure is necessary. Auto-Negotiation shall provide the Priority Resolution function that defines the hierarchy of supported technologies.

Priority resolution is supported for pause and half/full duplex modes of operation. Full duplex shall have priority over half duplex mode. Priority resolution for pause capability shall be resolved as specified by Table 37–4. Resolution that precludes operation between a local device and link partner is reflected to the link partner by the local device by indicating a Remote Fault code of Auto-Negotiation_Error, if the remote fault function is supported (see 37.2.1.5).

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Table 37–4—Pause priority resolution

Local Device		Link Partner		Local Resolution	Link Partner Resolution
PAUSE	ASM_DIR	PAUSE	ASM_DIR		
0	0	—	—	Disable PAUSE Transmit and Receive	Disable PAUSE Transmit and Receive
0	1	0	—	Disable PAUSE Transmit and Receive	Disable PAUSE Transmit and Receive
0	1	1	0	Disable PAUSE Transmit and Receive	Disable PAUSE Transmit and Receive
0	1	1	1	Enable PAUSE transmit, Disable PAUSE receive	Enable PAUSE receive, Disable PAUSE transmit
1	0	0	—	Disable PAUSE Transmit and Receive	Disable PAUSE Transmit and Receive
1	0	1	—	Enable PAUSE Transmit and Receive	Enable PAUSE Transmit and Receive
1	1	0	0	Disable PAUSE Transmit and Receive	Disable PAUSE Transmit and Receive
1	1	0	1	Enable PAUSE receive, Disable PAUSE transmit	Enable PAUSE transmit, Disable PAUSE receive
1	1	1	—	Enable PAUSE Transmit and Receive	Enable PAUSE Transmit and Receive

37.2.4.3 Next Page function

Support for transmission and reception of additional page encodings beyond the Base Page (Next Pages) is optional. The Next Page function enables the exchange of user or application specific data. Data is carried by Next Pages of information, which follow the transmission and acknowledgment procedures used for the Base Pages. Two types of Next Page encodings are defined:

a) Message Pages (contain an eleven-bit formatted Message Code Field);
b) Unformatted Pages (contain an eleven-bit Unformatted Code Field).

A dual acknowledgment system is used. Acknowledge (Ack) is used to acknowledge receipt of the information (see 37.2.1.6). Acknowledge 2 (Ack2) is used to indicate that the receiver is able to act on the information (or perform the task) defined in the message (see 37.2.4.3.5).

Next Page operation is controlled by the same two mandatory control bits, NP and Ack, used in the Base Page. The Toggle bit is used to ensure proper synchronization between the local device and the link partner.

Next Page exchange occurs after the Base Page exchange has been completed. Next Page exchange consists of using the Auto-Negotiation arbitration process to send Message or Unformatted Next Pages. Unformatted Pages can be combined to send extended messages. Any number of Next Pages may be sent in any order.

Subsequent to Base Page exchange, a Next Page exchange is invoked only if both the local device and its link partner have advertised Next Page ability during the Base Page exchange.

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If the Next Page function is supported by both link ends and a Next Page exchange has been invoked by both link ends, the Next Page exchange ends when both ends of a link segment set their NP bits to logic zero, indicating that neither link end has further pages to transmit. It is possible for the link partner to have more Next Pages to transmit than the local device. Once a local device has completed transmission of its Next Page information, if any, it shall transmit Message Pages with a Null message code (see Annex 28C) and the NP bit set to logic zero while its link partner continues to transmit valid Next Pages. A device shall recognize reception of Message Pages with a Null message code and the NP bit set to logic zero as the end of its link partner's Next Page information. If both the local device and its link partner advertise Next Page ability in their Base Pages, then both devices shall send at least one Next Page. If a device advertises Next Page ability and has no Next Page information to send but is willing to receive Next Pages, and its link partner also advertises Next Page ability, it shall send a Message Page with a Null message code. The variable mr_np_loaded is set to TRUE to indicate that the local device has loaded its Auto-Negotiation Next Page transmit register with Next Page information for transmission.

A local device that requires or expects an Ack2 response from its link partner (to indicate a Next Page transaction has been received and can be acted upon), must terminate the Next Page sequence with a Null message code, in order to allow the link partner to transport the final Ack2 status.

37.2.4.3.1 Next Page encodings

The Next Page shall use the encoding shown in Figure 37–3 and Figure 37–4 for the NP, Ack, MP, Ack2, and T bits. The eleven-bit field <D10:D0> is encoded as a Message Code Field if the MP bit is logic one and an Unformatted Code Field if MP is set to logic zero. The bit format of the rx_Config_Reg<D15:D0> and tx_Config_Reg<D15:D0> variables is context dependent, relative to the state of the Auto-Negotiation function, and is presented here and in 37.2.1.1.

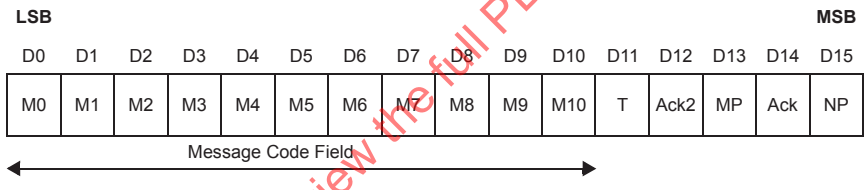

Figure 37–3—Message page encoding

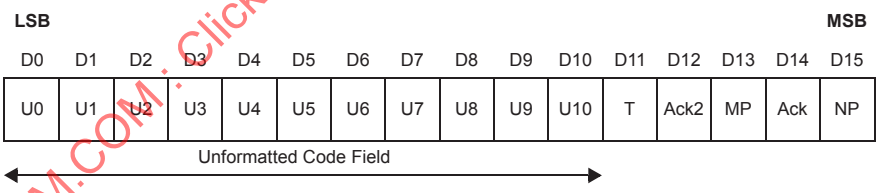

Figure 37–4—Unformatted page encoding

37.2.4.3.2 Next Page

The Next Page (NP) bit is used by the Next Page function to indicate whether or not this is the last Next Page to be transmitted. NP shall be set as follows:

logic zero = Last page.
logic one = Additional Next Page(s) to follow.

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37.2.4.3.3 Acknowledge

As defined in 37.2.1.6.

37.2.4.3.4 Message page

The Message Page (MP) bit is used by the Next Page function to differentiate a Message Page from an Unformatted Page. MP shall be set as follows:

logic zero = Unformatted Page.
logic one = Message Page.

37.2.4.3.5 Acknowledge 2

The Acknowledge 2 (Ack2) bit is used by the Next Page function to indicate that a device has the ability to comply with the message. Ack2 shall be set as follows:

logic zero = Cannot comply with message.
logic one = Can comply with message.

37.2.4.3.6 Toggle

The Toggle (T) bit is used by the Arbitration function to ensure synchronization with the link partner during Next Page exchange. This bit takes the opposite value of the Toggle bit in the previously exchanged page. The initial value of the Toggle bit in the first Next Page transmitted is the inverse of tx_Config_Reg<D11> in the Base Page that preceded the Next Page exchange and, therefore, may assume a value of logic one or zero. The Toggle bit is set as follows:

logic zero = Previous value of tx_Config_Reg<D11> equalled logic one.
logic one = Previous value of tx_Config_Reg<D11> equalled logic zero.

37.2.4.3.7 Message page encoding

Message Pages are formatted pages that carry a single predefined message code, which is enumerated in Annex 28C. There are 2048 message codes available. The allocation of these codes is specified in Annex 28C. If the Message Page bit is set to logic one, the bit encoding of the Config_Reg value is interpreted as a Message Page.

37.2.4.3.8 Message Code Field

Message Code Field (M<10:0>) is an eleven-bit wide field, encoding 2048 possible messages. Message Code Field definitions are shown in Annex 28C. Combinations not specified are reserved for future use. Reserved combinations of the Message Code Field shall not be transmitted.

37.2.4.3.9 Unformatted page encoding

Unformatted Pages carry the messages indicated by Message Pages. Five control bits are predefined, the remaining eleven bits are interpreted based on the preceding message page. If the Message Page bit is set to logic zero, then the bit encoding of the Config_Reg value is interpreted as an Unformatted Page.

37.2.4.3.10 Unformatted Code Field

Unformatted Code Field (U<10:0>) is an eleven-bit wide field, which may contain an arbitrary value.

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37.2.4.3.11 Use of Next Pages

The following rules for Next Page usage shall be observed:

a) A Next Page exchange is invoked when the local device and the link partner advertise (in their Base Pages) that they have Next Page information to transmit;
b) Next Page exchange continues until neither device on a link has more pages to transmit as indicated by the NP bit. A Message Page with a Null Message Code Field value is sent if the device has no other information to transmit;
c) A message code can carry either a specific message or information that defines how following Unformatted Page(s) should be interpreted;
d) If a message code references Unformatted Pages, the Unformatted Pages immediately follow the referencing message code in the order specified by the message code;
e) Unformatted Page users are responsible for controlling the format and sequencing for their Unformatted Pages.

37.2.4.3.12 Management register requirements

The AN Next Page transmit register defined in 37.2.5.1.6 holds the Next Page to be sent by Auto-Negotiation. Received Next Pages are stored in the AN link partner ability Next Page register defined in 37.2.5.1.7.

37.2.5 Management function requirements

The management interface is used to communicate Auto-Negotiation information to the management entity. Mandatory functions specified here reference bits in GMII registers 0, 1, 4, 5, 6, 7, 8, 15. Where an implementation does not use a GMII, equivalent functions to these bits must be included.

37.2.5.1 Management registers

The Auto-Negotiation function shall utilize six dedicated management registers:

a) Control register (Register 0);
b) Status register (Register 1);
c) AN advertisement register (Register 4);
d) AN link partner ability Base Page register (Register 5);
e) AN expansion register (Register 6);
f) Extended Status register (Register 15).

If Next Page is supported, the Auto-Negotiation function shall utilize an additional two management registers:

g) AN Next Page transmit register (Register 7);
h) AN link partner ability Next Page register (Register 8).

37.2.5.1.1 Control register (Register 0)

This register provides the mechanism to enable or disable Auto-Negotiation, restart Auto-Negotiation, and allow for manual configuration when Auto-Negotiation is not enabled. The definition for this register is provided in Clause 22.

When manual configuration is in effect at a local device, manual configuration should also be effected for the link partner to ensure predictable configuration. When manual configuration is in effect, values for the PAUSE bits (PS1, PS2) should result in a valid operational mode between the local device and the link partner.

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37.2.5.1.2 Status register (Register 1)

This register includes information about all modes of operations supported by the local device and the status of Auto-Negotiation. The definition for this register is provided in Clause 22.

37.2.5.1.3 AN advertisement register (Register 4) (R/W)

This register contains the advertised ability of the local device (see Table 37–5). Before Auto-Negotiation starts, this register is configured to advertise the abilities of the local device.

Table 37–5—AN advertisement register bit definitions

Bit(s)	Name	Description	R/W
4.15	Next Page	See 37.2.1.7	R/W
4.14	Reserved	Write as zero, ignore on read	RO
4.13:12	Remote Fault	See 37.2.1.5	R/W
4.11:9	Reserved	Write as zero, ignore on read	RO
4.8:7	Pause	See 37.2.1.4	R/W
4.6	Half Duplex	See 37.2.1.3	R/W
4.5	Full Duplex	See 37.2.1.2	R/W
4.4:0	Reserved	Write as zero, ignore on read	RO

37.2.5.1.4 AN link partner ability Base Page register (Register 5) (RO)

All of the bits in the AN link partner ability Base Page register are read only. A write to the AN link partner ability Base Page register has no effect.

This register contains the advertised ability of the link partner (see Table 37–6). The bit definitions are a direct representation of the link partner's Base Page. Upon successful completion of Auto-Negotiation, the Status register Auto-Negotiation Complete bit (1.5) is set to logic one.

The values contained in this register are guaranteed to be valid either once Auto-Negotiation has successfully completed, as indicated by bit 1.5 or when the Page Received bit (6.1) is set to logic one to indicate that a new Base Page has been received and stored in the Auto-Negotiation link partner ability base register.

37.2.5.1.5 AN expansion register (Register 6) (RO)

All of the bits in the Auto-Negotiation expansion register are read only; a write to the Auto-Negotiation expansion register has no effect.

Bits 6.15:3 and 6.0 are reserved for future Auto-Negotiation expansion.

The Next Page Able bit (6.2) is set to logic one to indicate that the local device supports the Next Page function. The Next Page Able bit is set to logic zero if the Next Page function is not supported by the local device.

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Table 37–6—AN link partner ability Base Page register bit definitions

Bit(s)	Name	Description	R/W
5.15	Next Page	See 37.2.1.7	RO
5.14	Acknowledge	See 37.2.1.6	RO
5.13:12	Remote Fault	See 37.2.1.5	RO
5.11:9	Reserved	Ignore on read	RO
5.8:7	Pause	See 37.2.1.4	RO
5.6	Half Duplex	See 37.2.1.3	RO
5.5	Full Duplex	See 37.2.1.2	RO
5.4:0	Reserved	Ignore on read	RO

Table 37–7—AN expansion register bit definitions

Bit(s)	Name	Description	R/W	Default
6.15:3	Reserved	Ignore on read	RO	0
6.2	Next Page Able	1 = Local device is Next Page able 0 = Local device is not Next Page able	RO	0
6.1	Page Received	1 = A new page has been received 0 = A new page has not been received	RO/ LH	0
6.0	Reserved	Ignore on read	RO	0

The Page Received bit (6.1) is set to logic one to indicate that a new page has been received and stored in the applicable AN link partner ability base or Next Page register.

The Page Received bit shall be reset to logic zero on a read of the AN expansion register (Register 6). Subsequent to the setting of the Page Received bit, and in order to prevent overlay of the AN link partner ability Next Page register, the AN link partner ability Next Page register should be read before the AN Next Page transmit register is written.

37.2.5.1.6 AN Next Page transmit register (Register 7)

This register contains the Next Page value to be transmitted, if required. The definition for this register is provided in 22.2.4.1.6.

37.2.5.1.7 AN link partner ability Next Page register (Register 8)

This register contains the advertised ability of the link partner's Next Page. The definition for this register is provided in 32.5.4.2 for changes to 28.2.4.1.4.

37.2.5.1.8 Extended status register (Register 15)

This register includes additional information about all modes of operations supported by the local device. The definition for this register is provided in Clause 22.

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37.2.5.1.9 State diagram variable to management register mapping

The state diagram of Figure 37–6 generates and accepts variables of the form "mr_x," where x is an individual signal name. These variables comprise a management interface that may be connected to the GMII management function or other equivalent function. Table 37–8 describes how PCS state diagram variables in both Clauses 36 and 37 map to management register bits.

Table 37–8—PCS state diagram variable to management register mapping

State diagram variable	Management register bit
mr_adv_ability<16:1>	4.15:0 Auto-Negotiation advertisement register
mr_an_complete	1.5 Auto-Negotiation complete
mr_an_enable	0.12 Auto-Negotiation enable
mr_loopback	0.14 Loopback (see 36.2.5.1.3)
mr_lp_adv_ability<16:1>	5.15:0 AN link partner ability register
mr_lp_np_rx<16:1>	8.15:0 AN link partner Next Page ability register
mr_main_reset	0.15 Reset
mr_np_able	6.2 Next Page Able
mr_np_loaded	Set on write to the AN Next Page transmit register; cleared by Auto-Negotiation state diagram
mr_np_tx<16:1>	7.15:0 AN Next Page transmit register
mr_page_rx	6.1 Page received
mr_restart_an	0.9 Auto-Negotiation restart
xmit=DATA	1.2 Link status

37.2.5.2 Auto-Negotiation managed object class

The Auto-Negotiation Managed Object Class is defined in Clause 30.

37.2.6 Absence of management function

In the absence of any management function, the advertised abilities shall be provided through a logical equivalent of mr_adv_ability<16:1>.

37.3 Detailed functions and state diagrams

The notation used in the state diagram in Figure 37–6 follows the conventions in 21.5. State diagram variables follow the conventions of 21.5.2 except when the variable has a default value. Variables in a state diagram with default values evaluate to the variable default in each state where the variable value is not explicitly set. Variables using the "mr_x" notation do not have state diagram defaults; however, their appropriate initialization conditions when mapped to the management interface are covered in 22.2.4. The variables, timers, and counters used in the state diagrams are defined in 37.3.1.

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Auto-Negotiation shall implement the Auto-Negotiation state diagram and meet the Auto-Negotiation state diagram interface requirements of the Receive and Transmit functions. Additional requirements to these state diagrams are made in the respective functional requirements sections. In the case of any ambiguity between stated requirements and the state diagrams, the state diagrams take precedence. A functional reference diagram of Auto-Negotiation is shown in Figure 37–5.

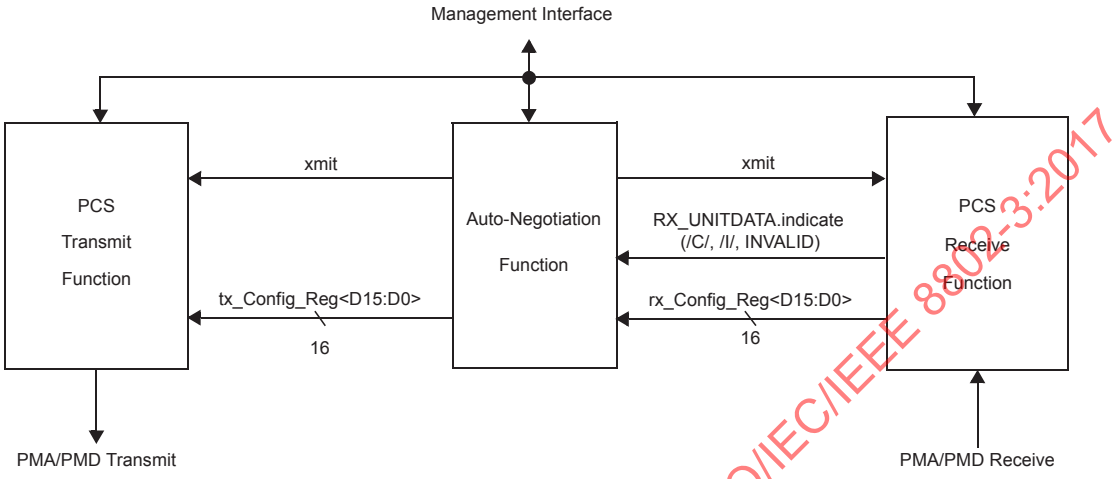

Figure 37–5—Functional reference diagram

37.3.1 State diagram variables

Variables with <16:1> or <D15:D0> appended to the end of the variable name indicate arrays that can be mapped to 16-bit management registers. For these variables, "<x>" indexes an element or set of elements in the array, where "x" may be as follows:

- Any integer or set of integers.
- Any variable that takes on integer values.
- NP; represents the index of the Next Page bit.
- ACK; represents the index of the Acknowledge bit.
- RF; represents the index of the Remote Fault bits.

Variables of the form "mr_x," where x is a label, comprise a management interface that is intended to be connected to the GMII Management function. However, an implementation-specific management interface may provide the control and status function of these bits.

37.3.1.1 Variables

an_sync_status
: Qualified version of sync_status for use by Auto-Negotiation to detect a sync_status timeout condition.

  Values: OK; The variable sync_status defined in 36.2.5.1.3 is OK.
  FAIL; The variable sync_status defined in 36.2.5.1.3 is FAIL for a duration greater than or equal to the link timer.

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mr_adv_ability<16:1>
A 16-bit array that contains the advertised ability Base Page of the local device to be conveyed to tx_Config_Reg<D15:D0> for transmission to the link partner. For each element within the array:

Values: ZERO; Data bit is logical zero.
ONE; Data bit is logical one.

mr_an_complete
Status indicating whether Auto-Negotiation has completed or not.

Values: FALSE; Auto-Negotiation has not completed.
TRUE; Auto-Negotiation has completed.

mr_an_enable
Controls the enabling and disabling of the Auto-Negotiation function for 1000BASE-X. Auto-Negotiation function for 1000BASE-X is enabled when Control register bit 0.12 is set to one.

Values: FALSE; Auto-Negotiation is disabled.
TRUE; Auto-Negotiation is enabled.

mr_lp_adv_ability<16:1>
A 16-bit array that contains the advertised ability Base Page of the link partner conveyed from rx_Config_Reg<D15:D0>. For each element within the array:

Values: ZERO; Data bit is logical zero.
ONE; Data bit is logical one.

mr_lp_np_rx<16:1>
A 16-bit array that contains the advertised ability of the link partner's Next Page conveyed from rx_Config_Reg<D15:D0>. For each element within the array:

Values: ZERO; Data bit is logical zero.
ONE; Data bit is logical one.

mr_main_reset
Controls the resetting of the Auto-Negotiation function.

Values: FALSE; Do not reset the Auto-Negotiation function.
TRUE; Reset the Auto-Negotiation function.

mr_np_able
Status indicating whether the local device supports Next Page exchange.

Values: FALSE; The local device does not support Next Page exchange.
TRUE; The local device supports Next Page exchange.

mr_np_loaded
Status indicating whether a new page has been loaded into the AN Next Page transmit register (register 7).

Values: FALSE; A new page has not been loaded.
TRUE; A new page has been loaded.

mr_np_tx<16:1>
A 16-bit array that contains the new Next Page to transmit. If a Next Page exchange is invoked, this array is conveyed to tx_Config_Reg<D15:D0> for transmission to the link partner. For each element within the array:

Values: ZERO; Data bit is logical zero.
ONE; Data bit is logical one.

mr_page_rx
Status indicating whether a new page has been received. A new page has been successfully received when acknowledge_match=TRUE and consistency_match=TRUE and the

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rx_Config_Reg<D15:D0> value has been written to mr_lp_adv_ability<16:1> or mr_lp_np_rx<16:1>, depending on whether the page received was a base or Next Page, respectively.

Values: FALSE; A new page has not been received.
TRUE; A new page has been received.

NOTE—For the first setting of mr_page_rx, mr_lp_adv_ability is valid but need not be read as it is preserved through a Next Page operation. On subsequent settings of mr_page_rx, mr_lp_np_rx must be read prior to loading mr_np_tx register in order to avoid the overlay of Next Page information.

mr_restart_an

Controls renegotiation via management control.

Values: FALSE; Do not restart Auto-Negotiation.
TRUE; Restart Auto-Negotiation.

np_rx

Flag to hold value of rx_Config_Reg<NP> upon entry to state COMPLETE_ACKNOWLEDGE. This value is associated with the value of rx_Config_Reg<NP> when acknowledge_match was last set.

Values: ZERO; The local device np_rx bit equals logic zero.
ONE; The local device np_rx bit equals logic one.

power_on

Condition that is true until such time as the power supply for the device that contains the Auto-Negotiation function has reached the operating region. The condition is also true when the device has low power mode set via Control register bit 0.11.

Values: FALSE; The device is completely powered (default).
TRUE; The device has not been completely powered.

NOTE—Power_on evaluates to its default value in each state where it is not explicitly set.

resolve_priority

Controls the invocation of the priority resolution function specified in Table 37–4.

Values: OFF; The priority resolution function is not invoked (default).
ON; The priority resolution function is invoked.

NOTE—Resolve_priority evaluates to its default value in each state where it is not explicitly set.

rx_Config_Reg<D15:D0>

Defined in 36.2.5.1.3.

sync_status

Defined in 36.2.5.1.3.

toggle_rx

Flag to keep track of the state of the link partner Toggle bit.

Values: ZERO; The link partner Toggle bit equals logic zero.
ONE; The link partner Toggle bit equals logic one.

toggle_tx

Flag to keep track of the state of the local device Toggle bit.

Values: ZERO; The local device Toggle bit equals logic zero.
ONE; The local device Toggle bit equals logic one.

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tx_Config_Reg<D15:D0>
Defined in 36.2.5.1.3. This array may be loaded from mr_adv_ability or mr_np_tx.

xmit
A parameter set by the PCS Auto-Negotiation process to reflect the source of information to the PCS Transmit process.

Values: CONFIGURATION: Tx_Config_Reg<D15:D0> information is being sourced from the PCS Auto-Negotiation process.
DATA: /I/, sourced from the PCS, is interspersed with packets sourced from the MAC.
IDLE: /I/ is being sourced from the PCS Auto-Negotiation process.

37.3.1.2 Functions

ability_match
For a stream of /C/ and /I/ ordered sets, this function continuously indicates whether the last three consecutive rx_Config_Reg<D15,D13:D0> values match. Three consecutive rx_Config_Reg<D15,D13:D0> values are any three rx_Config_Reg<D15,D13:D0> values received one after the other, regardless of whether the rx_Config_Reg<D15,D13:D0> value has already been used in a rx_Config_Reg<D15,D13:D0> match comparison or not. The match count is reset upon receipt of /I/. The match count is reset upon receipt of a second or third consecutive rx_Config_Reg<D15,D13:D0> value which does not match the rx_Config_Reg<D15,D13:D0> values for which the match count was set to one.

Values: FALSE; Three matching consecutive rx_Config_Reg<D15,D13:D0> values have not been received (default).
TRUE; Three matching consecutive rx_Config_Reg<D15,D13:D0> values have been received.

NOTE—Ability_match is set by this function definition; it is not set explicitly in the state diagrams. Ability_match evaluates to its default value upon state entry.

acknowledge_match
For a stream of /C/ and /I/ ordered sets, this function continuously indicates whether the last three consecutive rx_Config_Reg<D15:D0> values match and have the Acknowledge bit set. Three consecutive rx_Config_Reg<D15:D0> values are any three rx_Config_Reg<D15:D0> values contained within three /C/ ordered sets received one after the other, regardless of whether the rx_Config_Reg<D15:D0> value has already been used in a rx_Config_Reg<D15:D0> match comparison or not. The match count is reset upon receipt of /I/. The match count is reset upon receipt of a second or third consecutive rx_Config_Reg<D15:D0> value which does not match the rx_Config_Reg<D15:D0> values for which the match count was set to one.

Values: FALSE; Three matching and consecutive rx_Config_Reg<D15:D0> values have not been received with the Acknowledge bit set (default).
TRUE; Three matching and consecutive rx_Config_Reg<D15:D0> values have been received with the Acknowledge bit set.

NOTE—Acknowledge_match is set by this function definition; it is not set explicitly in the state diagrams. Acknowledge_match evaluates to its default value upon state entry.

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an_enableCHANGE

This function monitors the mr_an_enable variable for a state change. The function is set to TRUE on state change detection.

Values: TRUE; A mr_an_enable variable state change has been detected.
FALSE; A mr_an_enable variable state change has not been detected (default).

NOTE—An_enableCHANGE is set by this function definition; it is not set explicitly in the state diagrams. An_enableCHANGE evaluates to its default value upon state entry.

consistency_match

Indicates that the rx_Config_Reg<D15,D13:D0> value that caused ability_match to be set, for the transition from states ABILITY_DETECT or NEXT_PAGE_WAIT to state ACKNOWLEDGE_DETECT, is the same as the rx_Config_Reg<D15,D13:D0> value that caused acknowledge_match to be set.

Values: FALSE; The rx_Config_Reg<D15,D13:D0> value that caused ability_match to be set is not the same as the rx_Config_Reg<D15,D13:D0> value that caused acknowledge_match to be set, ignoring the Acknowledge bit value.
TRUE; The rx_Config_Reg<D15,D13:D0> value that caused ability_match to be set is the same as the rx_Config_Reg<D15,D13:D0> value that caused acknowledge_match to be set, independent of the Acknowledge bit value.

NOTE—Consistency_match is set by this function definition; it is not set explicitly in the state diagrams.

idle_match

For a stream of /C/ and /I/ ordered sets, this function continuously indicates whether three consecutive /I/ ordered sets have been received. The match count is reset upon receipt of /C/.

Values: FALSE; Three consecutive /I/ ordered sets have not been received (default).
TRUE; Three consecutive /I/ ordered sets have been received.

NOTE—Idle_match is set by this function definition; it is not set explicitly in the state diagrams. Idle_match evaluates to its default value upon state entry.

37.3.1.3 Messages

RUDI

Alias for RX_UNITDATA.indicate(parameter). Defined in 36.2.5.1.6.

RX_UNITDATA.indicate

Defined in 36.2.5.1.6.

37.3.1.4 Timers

All timers operate in the manner described in 14.2.3.2.

link_timer

Timer used to ensure Auto-Negotiation protocol stability and register read/write by the management interface.

Duration: 10 ms, tolerance +10 ms, –0 s.

37.3.1.5 State diagrams

The Auto-Negotiation state diagram is specified in Figure 37–6.

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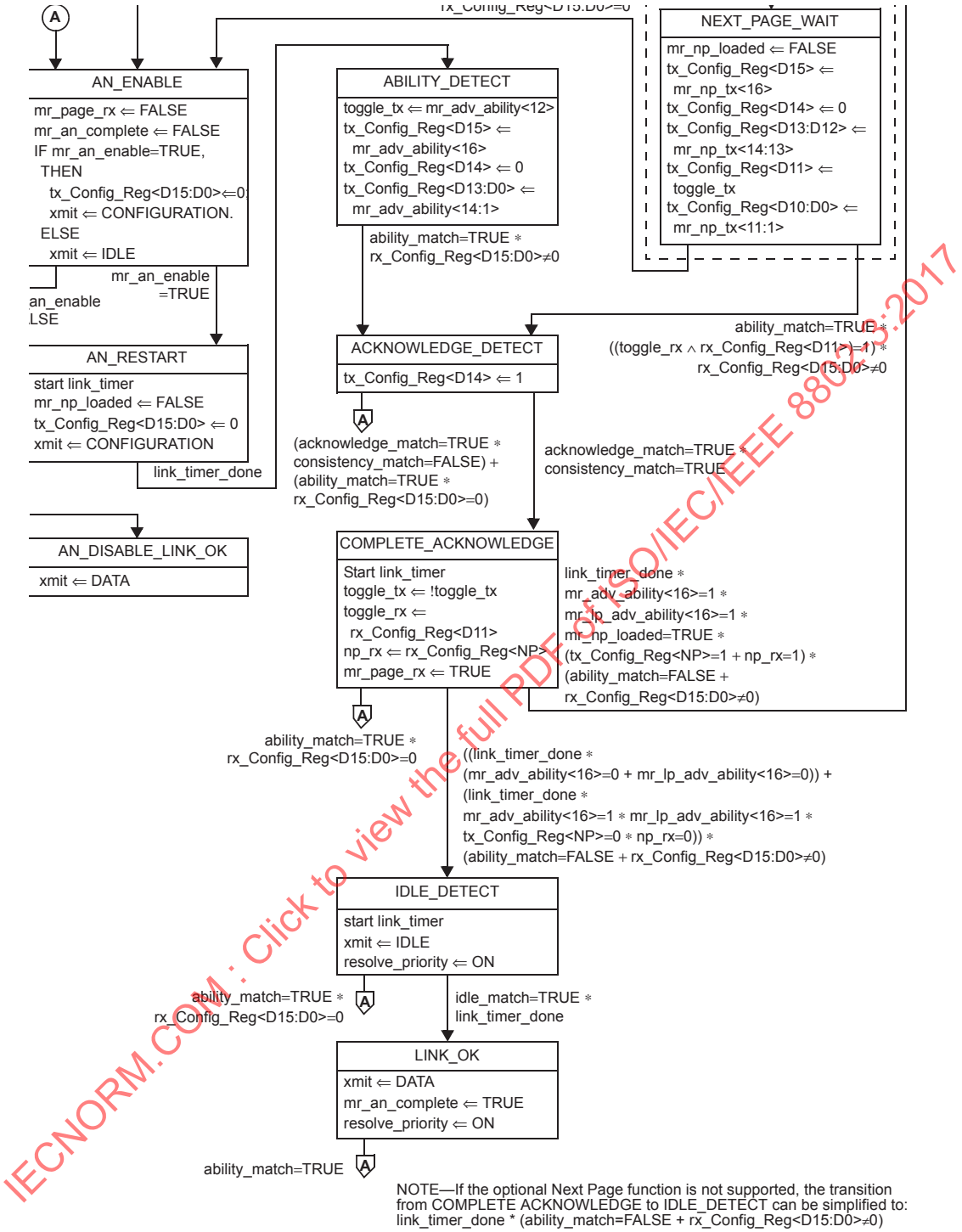

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Figure 37–6—Auto-Negotiation state diagram

37.4 Environmental specifications

All equipment subject to this clause shall conform to the requirements of 14.7 and applicable sections of ISO/IEC 11801:1995.

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37.5 Protocol implementation conformance statement (PICS) proforma for Clause 37, Auto-Negotiation function, type 1000BASE-X[4]

37.5.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 37, Auto-Negotiation function, type 1000BASE-X, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

37.5.2 Identification

37.5.2.1 Implementation identification

Supplier (Note 1)	
Contact point for inquiries about the PICS (Note 1)	
Implementation Name(s) and Version(s) (Notes 1 and 3)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s) (Note 2)	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

37.5.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 37, Auto-Negotiation function, type 1000BASE-X
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	No [ ] Yes [ ]

Date of Statement	

[4]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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37.5.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*GMII	GMII Management Interface	37.1.4.2.1		O	Yes [ ] No [ ]
*RF	Remote Fault function	37.2.1.5		O	Yes [ ] No [ ]
*NP	Next Page function	37.2.4.3		O	Yes [ ] No [ ]

In addition, the following predicate name is defined for use when different implementations from the set above have common parameters:

*NPM: GMII and NP

37.5.4 PICS proforma tables for the Auto-Negotiation function, type 1000BASE-X

37.5.4.1 Compatibility considerations

Item	Feature	Subclause	Value/Comment	Status	Support
CC1	Provision of logical equivalent of mr_adv_ability<16:1>	37.2.6	In the absence of any management function	M	Yes [ ]
CC2	Environmental specifications	37.4		M	Yes [ ]

37.5.4.2 Auto-Negotiation functions

Item	Feature	Subclause	Value/Comment	Status	Support
AN1	Config_Reg encoding	37.2.1		M	Yes [ ]
AN2	Priority Resolution function	37.2.4.2		M	Yes [ ]
AN3	Auto-Negotiation state diagram	37.3		M	Yes [ ]

37.5.4.2.1 Config_Reg

Item	Feature	Subclause	Value/Comment	Status	Support
CR1	Reserved bits	37.2.1	Set to zero	M	Yes [ ]
CR2	Default encoding of Remote Fault bits	37.2.1.5	0b00	M	Yes [ ]

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37.5.4.2.2 Remote Fault functions

Item	Feature	Subclause	Value/Comment	Status	Support
RF1	Remote Fault encoding	37.2.1.5		RF:M	Yes [ ] N/A [ ]
RF2	Use of Remote Fault Message Page code	37.2.1.5	To signal additional fault information	RF:O	Yes [ ] No [ ]
RF3	Notification duration	37.2.1.5	Remains set until transition to IDLE_DETECT state, then reset to 0b00	RF:M	Yes [ ] N/A [ ]
RF4	Status Register RF bit (1.4)	37.2.1.5	Upon detection of nonzero Remote Fault encoding	RF:M	Yes [ ] N/A [ ]
RF5	Offline indication	37.2.1.5.2	0b01	RF:O	Yes [ ] No [ ]
RF6	Link_Failure indication	37.2.1.5.3	0b10	RF:O	Yes [ ] No [ ]
RF7	Auto-Negotiation_Error	37.2.1.5.4	0b11	RF:M	Yes [ ] N/A [ ]

37.5.4.2.3 AN transmit functions

Item	Feature	Subclause	Value/Comment	Status	Support
TX1	PCS Transmit function support	37.2.2		M	Yes [ ]
TX2	Transmission of non-possessive abilities	37.2.2	A device shall not transmit an ability it does not possess.	M	Yes [ ]

37.5.4.2.4 AN receive functions

Item	Feature	Subclause	Value/Comment	Status	Support
RX1	PCS Receive function support	37.2.3		M	Yes [ ]

37.5.4.2.5 Priority resolution functions

Item	Feature	Subclause	Value/Comment	Status	Support
PR1	Full duplex priority over half duplex	37.2.4.2		M	Yes [ ]
PR2	Priority resolution for pause capability	37.2.4.2	Specified in Table 37–4	M	Yes [ ]

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37.5.4.2.6 Next Page functions

Item	Feature	Subclause	Value/Comment	Status	Support
NP1	Transmission of Message Pages with a Null message code	37.2.4.3	Upon local device completion of Next Page requests	NP:M	Yes [ ] N/A [ ]
NP2	Recognition of Message Pages with a Null message code	37.2.4.3	Signifies the end of link partner Next Page information	NP:M	Yes [ ] N/A [ ]
NP3	Initial Next Page exchange	37.2.4.3	Upon advertisement of NP ability by both devices	NP:M	Yes [ ] N/A [ ]
NP4	Next Page Receipt Ability	37.2.4.3	Indicated by advertising NP ability via the NP bit	NP:M	Yes [ ] N/A [ ]
NP5	Next Page Config_Reg encoding	37.2.4.3.1		NP:M	Yes [ ] N/A [ ]
NP6	Next Page (NP) bit setting	37.2.4.3.2	For link_timer after entry into COMPLETE_ACKNOWLEDGE state	NP:M	Yes [ ] N/A [ ]
NP7	Message Page (MP) bit setting	37.2.4.3.4		NP:M	Yes [ ] N/A [ ]
NP8	Acknowledge 2 (Ack2) bit setting	37.2.4.3.5		NP:M	Yes [ ] N/A [ ]
NP9	Message Code Field combinations	37.2.4.3.8	Reserved combinations shall not be transmitted.	NP:M	Yes [ ] N/A [ ]
NP10	Next Page usage rules	37.2.4.3.11		NP:M	Yes [ ] N/A [ ]

37.5.4.2.7 Management registers

Item	Feature	Subclause	Value/Comment	Status	Support
MR1	Control and Status registers	37.1.4.2.1		GMII:M	Yes [ ] N/A [ ]
MR2	Register usage	37.2.5.1	Logical equivalent of Registers 0, 1, 4, 5, 6 and 15	GMII:M	Yes [ ] N/A [ ]
MR3	Next Page Register usage	37.2.5.1	Logical equivalent of Registers 7 and 8	NPM:M	Yes [ ] N/A [ ]
MR4	Page Received resetting	37.2.5.1.5	Reset upon read to AN expansion register	M	Yes [ ]

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38. Physical Medium Dependent (PMD) sublayer and baseband medium, type 1000BASE-LX (long wavelength laser) and 1000BASE-SX (short wavelength laser)

38.1 Overview

This clause specifies the 1000BASE-SX PMD and the 1000BASE-LX PMD (including MDI) and baseband medium for multimode and single-mode fiber. In order to form a complete Physical Layer, it shall be integrated with the 1000BASE-X PCS and PMA of Clause 36, and integrated with the management functions which are accessible through the Management Interface defined in Clause 35, which are hereby incorporated by reference.

38.1.1 Physical Medium Dependent (PMD) sublayer service interface

The following specifies the services provided by the 1000BASE-SX and 1000BASE-LX PMD. These PMD sublayers are described in an abstract manner and do not imply any particular implementation. It should be noted that these services are based on similar interfaces defined in ANSI X3.230-1994 [B21] (FC-PH).

The PMD Service Interface supports the exchange of encoded 8B/10B characters between PMA entities. The PMD translates the encoded 8B/10B characters to and from signals suitable for the specified medium.

The following primitives are defined:

PMD_UNITDATA.request
PMD_UNITDATA.indication
PMD_SIGNAL.indication

NOTE—Delay requirements from the MDI to GMII that include the PMD layer are specified in Clause 36. Of this budget, 4 ns is reserved for each of the transmit and receive functions of the PMD.

38.1.1.1 PMD_UNITDATA.request

This primitive defines the transfer of data (in the form of encoded 8B/10B characters) from the PMA to the PMD.

38.1.1.1.1 Semantics of the service primitive

PMD_UNITDATA.request (tx_bit)

The data conveyed by PMD_UNITDATA.request is a continuous sequence of encoded 8B/10B characters. The tx_bit parameter can take one of two values: ONE or ZERO.

38.1.1.2 When generated

The PMA continuously sends the appropriate encoded 8B/10B characters to the PMD for transmission on the medium, at a nominal 1.25 GBd signaling speed.

38.1.1.1.3 Effect of receipt

Upon receipt of this primitive, the PMD converts the specified encoded 8B/10B characters into the appropriate signals on the MDI.

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38.1.1.2 PMD_UNITDATA.indication

This primitive defines the transfer of data (in the form of encoded 8B/10B characters) from the PMD to the PMA.

38.1.1.2.1 Semantics of the service primitive

PMD_UNITDATA.indication (rx_bit)

The data conveyed by PMD_UNITDATA.indication is a continuous sequence of encoded 8B/10B characters. The rx_bit parameter can take one of two values: ONE or ZERO.

38.1.1.2.2 When generated

The PMD continuously sends encoded 8B/10B characters to the PMA corresponding to the signals received from the MDI.

38.1.1.2.3 Effect of receipt

The effect of receipt of this primitive by the client is unspecified by the PMD sublayer.

38.1.1.3 PMD_SIGNAL.indication

This primitive is generated by the PMD to indicate the status of the signal being received from the MDI.

38.1.1.3.1 Semantics of the service primitive

PMD_SIGNAL.indication(SIGNAL_DETECT)

The SIGNAL_DETECT parameter can take on one of two values: OK or FAIL, indicating whether the PMD is detecting light at the receiver (OK) or not (FAIL). When SIGNAL_DETECT = FAIL, then rx_bit is undefined, but consequent actions based on PMD_UNITDATA.indication, where necessary, interpret rx_bit as a logic ZERO.

NOTE—SIGNAL_DETECT = OK does not guarantee that rx_bit is known good. It is possible for a poor quality link to provide sufficient light for a SIGNAL_DETECT = OK indication and still not meet the 10^{-12} BER objective.

38.1.1.3.2 When generated

The PMD generates this primitive to indicate a change in the value of SIGNAL_DETECT.

38.1.1.3.3 Effect of receipt

The effect of receipt of this primitive by the client is unspecified by the PMD sublayer.

38.1.2 Medium Dependent Interface (MDI)

The MDI, a physical interface associated with a PMD, is comprised of an electrical or optical medium connection.

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38.2 PMD functional specifications

The 1000BASE-X PMDs perform the Transmit and Receive functions that convey data between the PMD service interface and the MDI.

38.2.1 PMD block diagram

For purposes of system conformance, the PMD sublayer is standardized at the following points. The optical transmit signal is defined at the output end of a patch cord (TP2), between 2 and 5 m in length, of a type consistent with the link type connected to the transmitter receptacle defined in 38.11.2. If a single-mode fiber offset-launch mode-conditioning patch cord is used, the optical transmit signal is defined at the end of this single-mode fiber offset-launch mode-conditioning patch cord at TP2. Unless specified otherwise, all transmitter measurements and tests defined in 38.6 are made at TP2. The optical receive signal is defined at the output of the fiber optic cabling (TP3) connected to the receiver receptacle defined in 38.11.2. Unless specified otherwise, all receiver measurements and tests defined in 38.6 are made at TP3.

TP1 and TP4 are standardized reference points for use by implementers to certify component conformance. The electrical specifications of the PMD service interface (TP1 and TP4) are not system compliance points (these are not readily testable in a system implementation). It is expected that in many implementations, TP1 and TP4 will be common between 1000BASE-SX, 1000BASE-LX, and 1000BASE-CX (Clause 39).

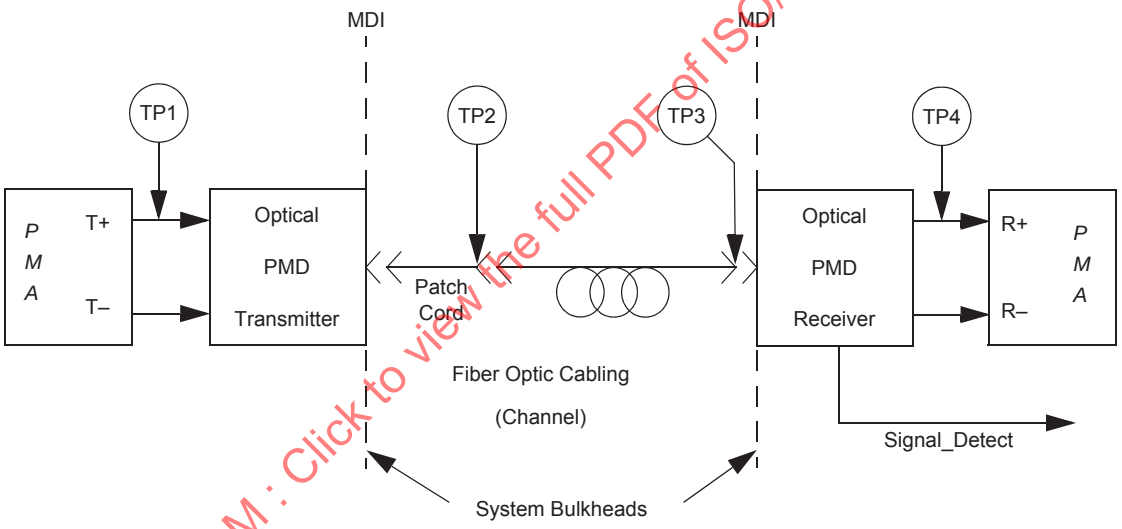

Figure 38–1—1000BASE-X block diagram

38.2.2 PMD transmit function

The PMD Transmit function shall convey the bits requested by the PMD service interface message PMD_UNITDATA.request(tx_bit) to the MDI according to the optical specifications in this clause. The higher optical power level shall correspond to tx_bit = ONE.

38.2.3 PMD receive function

The PMD Receive function shall convey the bits received from the MDI according to the optical specifications in this clause to the PMD service interface using the message PMD_UNITDATA.indication(rx_bit). The higher optical power level shall correspond to rx_bit = ONE.

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38.2.4 PMD signal detect function

The PMD Signal Detect function shall report to the PMD service interface, using the message PMD_SIGNAL.indication(SIGNAL_DETECT), which is signaled continuously. PMD_SIGNAL.indication is intended to be an indicator of optical signal presence.

The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 38–1. The PMD receiver is not required to verify whether a compliant 1000BASE-X signal is being received. This standard imposes no response time requirements on the generation of the SIGNAL_DETECT parameter.

Table 38–1—SIGNAL_DETECT value definition

Receive conditions	Signal detect value
Input_optical_power ≤ –30 dBm	FAIL
Input_optical_power ≥ Receive sensitivity AND compliant 1000BASE-X signal input	OK
All other conditions	Unspecified

As an unavoidable consequence of the requirements for the setting of the SIGNAL_DETECT parameter, implementations must provide adequate margin between the input optical power level at which the SIGNAL_DETECT parameter is set to OK, and the inherent noise level of the PMD due to cross talk, power supply noise, etc.

Various implementations of the Signal Detect function are permitted by this standard, including implementations which generate the SIGNAL_DETECT parameter values in response to the amplitude of the 8B/10B modulation of the optical signal and implementations that respond to the average optical power of the 8B/10B-modulated optical signal.

38.3 PMD to MDI optical specifications for 1000BASE-SX

The operating range for 1000BASE-SX is defined in Table 38–2. A 1000BASE-SX compliant transceiver supports both multimode fiber media types listed in Table 38–2 (i.e., both 50 µm and 62.5 µm multimode fiber) according to the specifications defined in 38.11. A transceiver that exceeds the operational range requirement while meeting all other optical specifications is considered compliant (e.g., a 50 µm solution operating at 600 m meets the minimum range requirement of 2 to 550 m).

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Table 38–2—Operating range for 1000BASE-SX over each optical fiber type

Fiber type	Modal bandwidth @ 850 nm (min. overfilled launch) (MHz · km)	Minimum range (m)
62.5 µm MMF	160	2 to 220
62.5 µm MMF	200	2 to 275
50 µm MMF	400	2 to 500
50 µm MMF	500	2 to 550
SMF	N/A	Not supported

38.3.1 Transmitter optical specifications

The 1000BASE-SX transmitter shall meet the specifications defined in Table 38–3 per measurement techniques defined in 38.6. It shall also meet a transmit mask of the eye measurement as defined in 38.6.5.

Table 38–3—1000BASE-SX transmit characteristics

Description	62.5 µm MMF	50 µm MMF	Unit
Transmitter type	Shortwave Laser		
Signaling speed (range)	1.25 ± 100 ppm		GBd
Wavelength (λ, range)	770 to 860		nm
T_{rise}/T_{fall} (max; 20%-80%; λ > 830 nm)	0.26		ns
T_{rise}/T_{fall} (max; 20%-80%; λ ≤ 830 nm)	0.21		ns
RMS spectral width (max)	0.85		nm
Average launch power (max)	See footnote [a]		dBm
Average launch power (min)	–9.5		dBm
Average launch power of OFF transmitter (max)[b]	–30		dBm
Extinction ratio (min)	9		dB
RIN (max)	–117		dB/Hz
Coupled Power Ratio (CPR) (min)[c]	9 < CPR		dB

[a]The 1000BASE-SX launch power shall be the lesser of the Hazard Level 1 safety limit as defined by 38.7.2 or the average receive power (max) defined by Table 38–4.
[b]Examples of an OFF transmitter are: no power supplied to the PMD, laser shutdown for safety conditions, activation of a "transmit disable" or other optional module laser shut down conditions. During all conditions when the PMA is powered, the ac signal (data) into the transmit port will be valid encoded 8B/10B patterns (this is a requirement of the PCS layers) except for short durations during system power-on-reset or diagnostics when the PMA is placed in a loopback mode.
[c]Radial overfilled launches as described in 38A.2, while they may meet CPR ranges, should be avoided.

The CPR specification provides sufficient mode volume so that individual multimode fiber (MMF) modes do not dominate fiber performance. This reduces the effect of peak-to-peak differential mode delay (DMD) between the launched mode groups and diminishes the resulting pulse-splitting-induced nulls in the frequency response.

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38.3.2 Receive optical specifications

The 1000BASE-SX receiver shall meet the specifications defined in Table 38–4 per measurement techniques defined in 38.6. The sampling instant is defined to occur at the eye center. The receive sensitivity includes the extinction ratio penalty.

Table 38–4—1000BASE-SX receive characteristics

Description	62.5 μm MMF	50 μm MMF	Unit
Signaling Speed (range)	1.25 ± 100 ppm		GBd
Wavelength (range)	770 to 860		nm
Average receive power (max)	0		dBm
Receive sensitivity	–17		dBm
Return loss (min)	12		dB
Stressed receive sensitivity[a, b]	–12.5	–13.5	dBm
Vertical eye-closure penalty[c]	2.60	2.20	dB
Receive electrical 3 dB upper cutoff frequency (max)	1500		MHz

[a]Measured with conformance test signal at TP3 (see 38.6.11) for BER = 10^{-12} at the eye center.
[b]Measured with a transmit signal having a 9 dB extinction ratio. If another extinction ratio is used, the stressed receive sensitivity should be corrected for the extinction ratio penalty.
[c]Vertical eye-closure penalty is a test condition for measuring stressed receive sensitivity. It is not a required characteristic of the receiver.

38.3.3 Worst-case 1000BASE-SX link power budget and penalties (informative)

The worst-case power budget and link penalties for a 1000BASE-SX channel are shown in Table 38–5.

Table 38–5—Worst-case 1000BASE-SX link power budget and penalties[a]

Parameter	62.5 μm MMF		50 μm MMF		Unit
Modal bandwidth as measured at 850 nm (minimum, overfilled launch)	160	200	400	500	MHz · km
Link power budget	7.5	7.5	7.5	7.5	dB
Operating distance	220	275	500	550	m
Channel insertion loss[b, c]	2.38	2.60	3.37	3.56	dB
Link power penalties[c]	4.27	4.29	4.07	3.57	dB
Unallocated margin in link power budget[c]	0.84	0.60	0.05	0.37	dB

[a]Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.
[b]Operating distances used to calculate the channel insertion loss (see 1.4) are the maximum values specified in Table 38–2.
[c]A wavelength of 830 nm is used to calculate channel insertion loss, link power penalties, and unallocated margin.

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38.4 PMD to MDI optical specifications for 1000BASE-LX

The operating range for 1000BASE-LX is defined in Table 38–6. A 1000BASE-LX compliant transceiver supports all media types listed in Table 38–6 (i.e., 50 µm and 62.5 µm multimode fiber, and single-mode fiber) according to the specifications defined in 38.11. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant (e.g., a single-mode solution operating at 5500 m meets the minimum range requirement of 2 to 5000 m).

Table 38–6—Operating range for 1000BASE-LX over each optical fiber type

Fiber type	Modal bandwidth @ 1300 nm (min. overfilled launch) (MHz · km)	Minimum range (m)
62.5 µm MMF	500	2 to 550
50 µm MMF	400	2 to 550
50 µm MMF	500	2 to 550
SMF	N/A	2 to 5000

38.4.1 Transmitter optical specifications

The 1000BASE-LX transmitter shall meet the specifications defined in Table 38–7 per measurement techniques defined in 38.6. It shall also meet a transmit mask of the eye measurement as defined in 38.6.5. To ensure that the specifications of Table 38–7 are met with MMF links, the 1000BASE-LX transmitter output shall be coupled through a single-mode fiber offset-launch mode-conditioning patch cord, as defined in 38.11.4.

Table 38–7—1000BASE-LX transmit characteristics

Description	62.5 µm MMF	50 µm MMF	SMF	Unit
Transmitter type	Longwave Laser			
Signaling speed (range)	1.25 ± 100 ppm			GBd
Wavelength (range)	1270 to 1355			nm
T_{rise}/T_{fall} (max, 20-80% response time)	0.26			ns
RMS spectral width (max)	4			nm
Average launch power (max)	–3			dBm
Average launch power (min)	–11.5	–11.5	–11.0	dBm
Average launch power of OFF transmitter (max)	–30			dBm
Extinction ratio (min)	9			dB
RIN (max)	–120			dB/Hz
Coupled Power Ratio (CPR)[a]	28 < CPR< 40	12 < CPR < 20	N/A	dB

[a]Due to the dual media (single-mode and multimode) support of the LX transmitter, fulfillment of this specification requires a single-mode fiber offset-launch mode-conditioning patch cord described in 38.11.4 for MMF operation. This patch cord is not used for single-mode operation.

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Conditioned launch (CL) produces sufficient mode volume so that individual multimode fiber (MMF) modes do not dominate fiber performance. This reduces the effect of peak-to-peak differential mode delay (DMD) between the launched mode groups and diminishes the resulting pulse-splitting-induced nulls in the frequency response.

A CL is produced by using a single-mode fiber offset-launch mode-conditioning patch cord, inserted at both ends of a full duplex link, between the optical PMD MDI and the remainder of the link segment. The single-mode fiber offset-launch mode-conditioning patch cord contains a fiber of the same type as the cable (i.e., 62.5 µm or 50 µm fiber) connected to the optical PMD receiver input MDI and a specialized fiber/connector assembly connected to the optical PMD transmitter output.

38.4.2 Receive optical specifications

The 1000BASE-LX receiver shall meet the specifications defined in Table 38–8 per measurement techniques defined in 38.6. The sampling instant is defined to occur at the eye center. The receive sensitivity includes the extinction ratio penalty.

Table 38–8—1000BASE-LX receive characteristics

Description	Value	Unit
Signaling speed (range)	1.25 ± 100 ppm	GBd
Wavelength (range)	1270 to 1355	nm
Average receive power (max)	–3	dBm
Receive sensitivity	–19	dBm
Return loss (min)	12	dB
Stressed receive sensitivity[a, b]	–14.4	dBm
Vertical eye-closure penalty[c]	2.60	dB
Receive electrical 3 dB upper cutoff frequency (max)	1500	MHz

[a]Measured with conformance test signal at TP3 (see 38.6.11) for BER = 10^{-12} at the eye center.
[b]Measured with a transmit signal having a 9 dB extinction ratio. If another extinction ratio is used, the stressed receive sensitivity should be corrected for the extinction ratio penalty.
[c]Vertical eye-closure penalty is a test condition for measuring stressed receive sensitivity. It is not a required characteristic of the receiver.

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38.4.3 Worst-case 1000BASE-LX link power budget and penalties (informative)

The worst-case power budget and link penalties for a 1000BASE-LX channel are shown in Table 38–9.

Table 38–9—Worst-case 1000BASE-LX link power budget and penalties[a]

Parameter	62.5μm MMF	50 μm MMF		SMF	Unit
Modal bandwidth as measured at 1300 nm (minimum, overfilled launch)	500	400	500	N/A	MHz · km
Link power budget	7.5	7.5	7.5	8.0	dB
Operating distance	550	550	550	5000	m
Channel insertion loss[b, c]	2.35	2.35	2.35	4.57	dB
Link power penalties[c]	3.48	5.08	3.96	3.27	dB
Unallocated margin in link power budget[c]	1.67	0.07	1.19	0.16	dB

[a]Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.
[b]Operating distances used to calculate the channel insertion loss (see 1.4) are the maximum values specified in Table 38–6.
[c]A wavelength of 1270 nm is used to calculate channel insertion loss, link power penalties, and unallocated margin.

38.5 Jitter specifications for 1000BASE-SX and 1000BASE-LX

Numbers in the Table 38–10 represent high-frequency jitter (above 637 kHz) and do not include low-frequency jitter or wander. Implementations shall conform to the normative values highlighted **in bold** in Table 38–10 (see measurement procedure in 38.6.8). All other values are informative.

Table 38–10—1000BASE-SX and 1000BASE-LX jitter budget

Compliance point	Total jitter[a]		Deterministic jitter	
	UI	ps	UI	ps
TP1	**0.240**	**192**	0.100	80
TP1 to TP2	0.284	227	0.100	80
TP2	**0.431**	**345**	0.200	160
TP2 to TP3	0.170	136	0.050	40
TP3	**0.510**	**408**	0.250	200
TP3 to TP4	0.332	266	0.212	170
TP4[b]	**0.749**	**599**	0.462	370

[a] Total jitter is composed of both deterministic and random components. The allowed random jitter equals the allowed total jitter minus the actual deterministic jitter at that point.
[b]Measured with a conformance test signal at TP3 (see 38.6.11) set to an average optical power 0.5 dB greater than the stressed receive sensitivity from Table 38–4 for 1000BASE-SX and Table 38–8 for 1000BASE-LX.

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38.6 Optical measurement requirements

All optical measurements shall be made through a short patch cable, between 2 and 5 m in length. If a single-mode fiber offset-launch mode-conditioning patch cord is used, the optical transmit signal is defined at the output end (TP2) of the single-mode fiber offset-launch mode-conditioning patch cord.

38.6.1 Center wavelength and spectral width measurements

The center wavelength and spectral width (RMS) shall be measured using an optical spectrum analyzer per TIA-455-127-A. Center wavelength and spectral width shall be measured under modulated conditions using a valid 1000BASE-X signal.

38.6.2 Optical power measurements

Optical power shall be measured using the methods specified in ANSI/EIA-455-95-1986 [B9]. This measurement may be made with the node transmitting any valid encoded 8B/10B data stream.

38.6.3 Extinction ratio measurements

Extinction ratio shall be measured using the methods specified in IEC 61280-2-2. This measurement may be made with the node transmitting a data pattern defined in 36A.2. This is a repeating K28.7 data pattern. The extinction ratio is measured under fully modulated conditions with worst-case reflections.

NOTE—A repeating K28.7 data pattern generates a 125 MHz square wave.

38.6.4 Relative Intensity Noise (RIN)

This procedure describes a component test which may not be appropriate for a system level test depending on the implementation. RIN shall be measured according to 58.7.7 with the following exceptions:

1) the low pass filter bandwidth is 937.5 MHz
2) step d) of the test procedure is replaced by measuring the value of the photocurrent of the optical to electrical converter I_{oe}
3) step e) of the test procedure is replaced by using the following equation to evaluate RIN:

$$\mathrm{RIN} = 10\log_{10}\frac{P_N}{BW \times I_{oe}^2 \times R} - G \ \ (\mathrm{dB/Hz})$$

where:

RIN	is the relative intensity noise,
P_N	is the electrical noise power in Watts with modulation off,
BW	is the low-pass bandwidth of apparatus – high-pass bandwidth of apparatus due to DC-blocking capacitor,
I_{oe}	is the photocurrent of the optical to electrical converter,
R	is the effective load impedance of the optical to electrical converter (for example, a 50 ohm detector load in parallel with a 50 ohm power meter would give R equal to 25),
G	is the Gain in dB of any amplifier in the noise measurement path.

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38.6.5 Transmitter optical waveform (transmit eye)

The required transmitter pulse shape characteristics are specified in the form of a mask of the transmitter eye diagram as shown in Figure 38–2. The transmit mask is not used for response time and jitter specification.

Normalized amplitudes of 0.0 and 1.0 represent the amplitudes of logic ZERO and ONE, respectively.

The eye shall be measured with respect to the mask of the eye using a fourth-order Bessel-Thomson filter having a transfer function given by

$$H(p) = \frac{105}{105 + 105y + 45y^2 + 10y^3 + y^4}$$

where

$$y = 2.114p\ ; \quad p = \frac{j\omega}{\omega_r}\ ; \quad \omega_r = 2\pi f_r\ ; \quad f_r = 0.9375\text{GHz}$$

and where the filter response vs. frequency range for this fourth order Bessel-Thomson filter is defined in ITU-T G.957, along with the allowed tolerances (STM-16 values) for its physical implementation.

NOTE 1—This Bessel-Thomson filter is not intended to represent the noise filter used within an optical receiver, but is intended to provide uniform measurement conditions at the transmitter.

NOTE 2—The fourth-order Bessel-Thomson filter is reactive. In order to suppress reflections, a 6 dB attenuator may be required at the filter input and/or output.

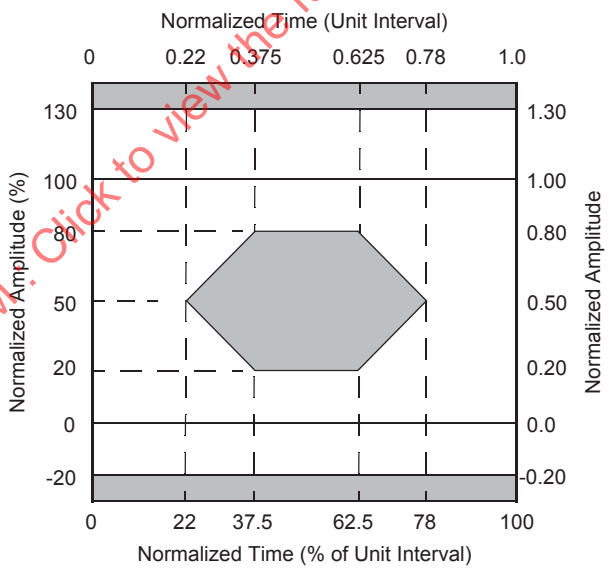

Figure 38–2—Transmitter eye mask definition

38.6.6 Transmit rise/fall characteristics

Optical response time specifications are based on unfiltered waveforms. Some lasers have overshoot and ringing on the optical waveforms which, if unfiltered, reduce the accuracy of the measured 20–80%

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response times. For the purpose of standardizing the measurement method, measured waveforms shall conform to the mask defined in Figure 38–2. If a filter is needed to conform to the mask, the filter response should be removed using the equation:

$$T_{\text{rise,fall}} = \sqrt{(T_{\text{rise,fall_measured}})^2 - (T_{\text{rise,fall_filter}})^2}$$

where the filter may be different for rise and fall. Any filter should have an impulse response equivalent to a fourth order Bessel-Thomson filter. The fourth-order Bessel-Thomson filter defined in 38.6.5 may be a convenient filter for this measurement; however, its low bandwidth adversely impacts the accuracy of the $T_{\text{rise,fall}}$ measurements.

38.6.7 Receive sensitivity measurements

The receive sensitivity shall be measured using a worst-case extinction ratio penalty while sampling at the eye center.

The stressed receive sensitivity shall be measured using the conformance test signal at TP3, as specified in 38.6.11. After correcting for the extinction ratio of the source, the stressed receive sensitivity shall meet the conditions specified in Table 38–4 for 1000BASE-SX and in Table 38–8 for 1000BASE-LX.

38.6.8 Total jitter measurements

All total jitter measurements shall be made according to the method in ANSI X3.230-1994 [B21] (FC-PH), Annex A, A.4.2, *Active output interface eye opening measurement*. Total jitter at TP2 shall be measured utilizing a BERT (Bit Error Ratio Test) test set. References to use of the Bessel-Thomson filter shall substitute use of the Bessel-Thomson filter defined in this clause (see 38.6.5). The test shall utilize the mixed frequency test pattern specified in 36A.3.

Total jitter at TP4 shall be measured using the conformance test signal at TP3, as specified in 38.6.11. The optical power shall be 0.5 dB greater than (to account for eye opening penalty) the stressed receive sensitivity level in Table 38–4 for 1000BASE-SX and in Table 38–8 for 1000BASE-LX. This power level shall be corrected if the extinction ratio differs from the specified extinction ratio (min) of 9 dB. Measurements shall be taken directly at TP4 without additional Bessel-Thomson filters.

Jitter measurement may use a clock recovery unit (commonly referred to in the industry as a “golden PLL”) to remove low-frequency jitter from the measurement as shown in Figure 38–3. The clock recovery unit has a low-pass filter with 20 dB/decade rolloff with –3 dB point of 637 kHz. For this measurement, the recovered clock will run at the signaling speed. The golden PLL is used to approximate the PLL in the deserializer function of the PMA. The PMA deserializer is able to track a large amount of low-frequency jitter (such as drift or wander) below its bandwidth. This low-frequency jitter would create a large measurement penalty, but does not affect operation of the link.

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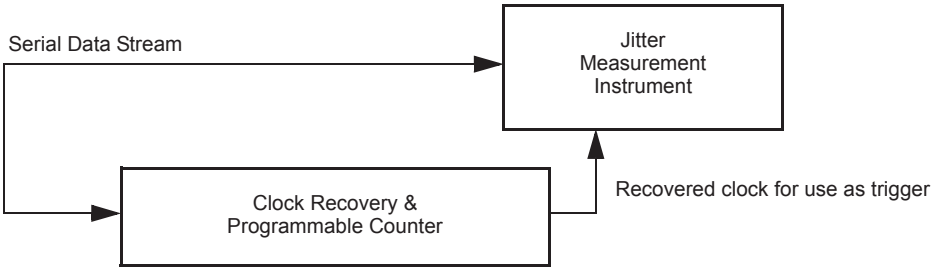

Figure 38–3—Utilization of clock recovery unit during measurement

38.6.9 Deterministic jitter measurement (informative)

Deterministic jitter should be measured according to ANSI X3.230-1994 [B21] (FC-PH), Annex A, A.4.3, *DJ Measurement.* The test utilizes the mixed frequency test pattern specified in 36A.3. This method utilizes a digital sampling scope to measure actual vs. predicted arrival of bit transitions of the 36A.3 data pattern (alternating K28.5 code-groups).

It is convenient to use the clock recovery unit described in 38.6.8 for purposes of generating a trigger for the test equipment. This recovered clock should have a frequency equivalent to 1/20th of the signaling speed.

38.6.10 Coupled Power Ratio (CPR) measurements

Coupled Power Ratio (CPR) is measured in accordance with ANSI/EIA/TIA-526-14A [B15]. Measured CPR values are time averaged to eliminate variation from speckle fluctuations. The coupled power ratio shall be measured for compliance with Table 38–3 and Table 38–7.

38.6.11 Conformance test signal at TP3 for receiver testing

Receivers being tested for conformance to the stressed receive sensitivity requirements of 38.6.7 and the total jitter requirements of 38.6.8 shall be tested using a conformance test signal at TP3 conforming to the requirements described in Figure 38–4. The conformance test signal shall be generated using the short continuous random test pattern defined in 36A.5. The conformance test signal is conditioned by applying deterministic jitter (DJ) and intersymbol interference (ISI). The conditioned conformance test signal is shown schematically in Figure 38–4. The horizontal eye closure (reduction of pulse width) caused by the duty cycle distortion (DCD) component of DJ shall be no less than 65 ps. The vertical eye-closure penalty shall be greater than or equal to the value specified in Table 38–4 for 1000BASE-SX and Table 38–8 for 1000BASE-LX. The DJ cannot be added with a simple phase modulation, which does not account for the DCD component of DJ.

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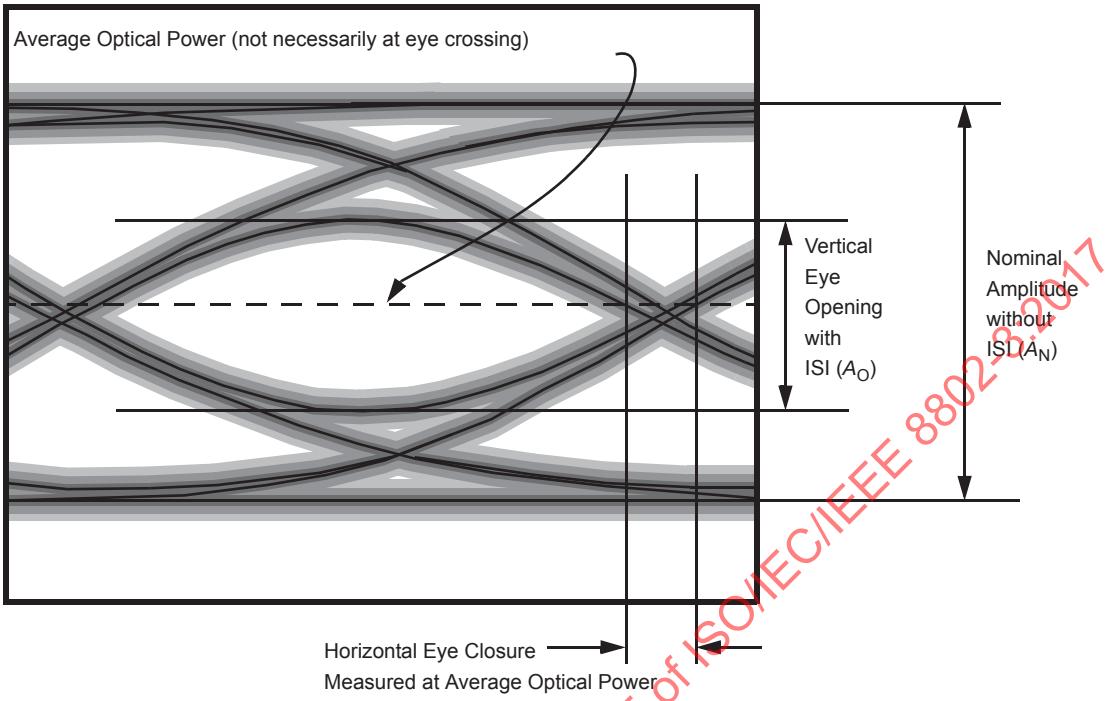

Figure 38–4—Required characteristics of the conformance test signal at TP3

The vertical eye-closure penalty is given by

$$\text{Vertical eye-closure penalty [dB]} = 10\log\frac{A_N}{A_O}$$

where A_O is the amplitude of the eye opening, and A_N is the normal amplitude without ISI, as measured in Figure 38–4.

Figure 38–5 shows the recommended test set up for producing the conformance test signal at TP3. The coaxial cable is adjusted in length to produce the correct DCD component of DJ. Since the coaxial cable can produce the incorrect ISI, a limiting amplifier is used to restore fast rise and fall times. A Bessel-Thomson filter is selected to produce the minimum ISI induced eye closure as specified per Table 38–4 for 1000BASE-SX and Table 38–8 for 1000BASE-LX. This conditioned signal is used to drive a high bandwidth linearly modulated laser source.

The vertical and horizontal eye closures to be used for receiver conformance testing are verified using a fast photodetector and amplifier. The bandwidth of the photodetector shall be at least 2.5 GHz and be coupled through a 1.875 GHz fourth-order Bessel-Thomson filter to the oscilloscope input. Special care should be taken to ensure that all the light from the fiber is collected by the fast photodetector and that there is negligible mode selective loss, especially in the optical attenuator.

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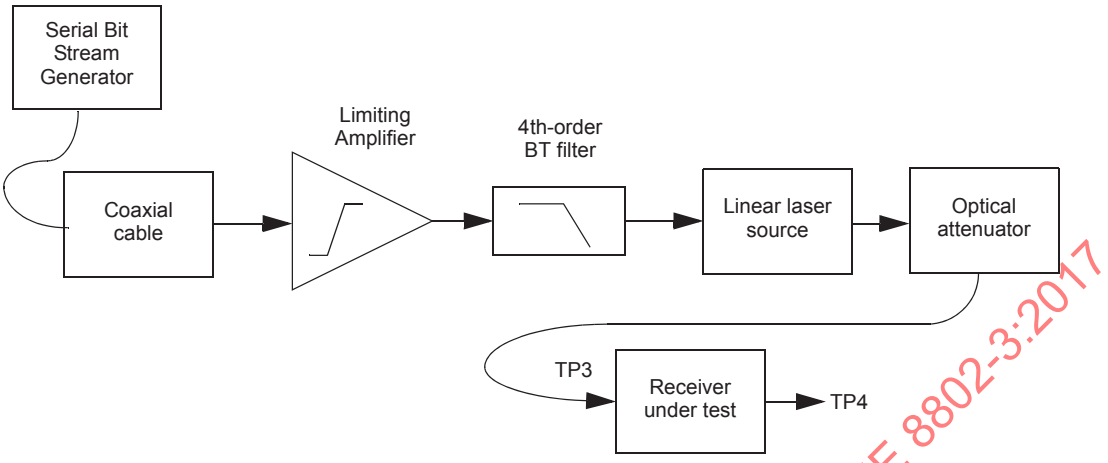

Figure 38–5—Apparatus for generating receiver conformance test signal at TP3

38.6.12 Measurement of the receiver 3 dB electrical upper cutoff frequency

The receiver 3 dB electrical upper cutoff frequency shall be measured as described below. The test setup is shown in Figure 38–6. The test is performed with a laser that is suitable for analog signal transmission. The laser is modulated by a digital data signal. In addition to the digital modulation, the laser is modulated with an analog signal. The analog and digital signals should be asynchronous. The data pattern to be used for this test is the short continuous random test pattern defined in 36A.5. The frequency response of the laser must be sufficient to allow it to respond to both the digital modulation and the analog modulation. The laser should be biased so that it remains linear when driven by the combined signals.

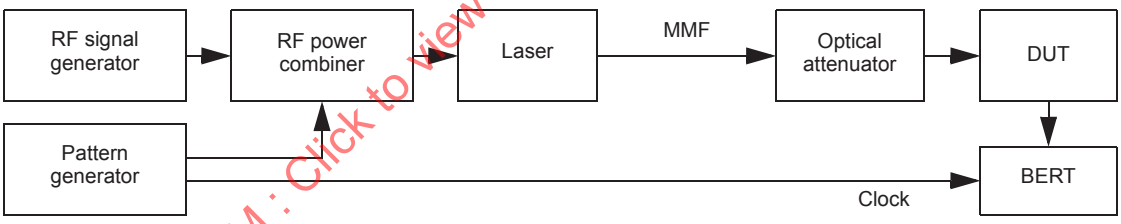

Figure 38–6—Test setup for receiver bandwidth measurement

The 3 dB upper cutoff frequency is measured using the following steps a) through e):

a) Calibrate the frequency response characteristics of the test equipment including the analog radio frequency (RF) signal generator, RF power combiner, and laser source. Measure the laser's extinction ratio according to 38.6.3. With the exception of extinction ratio, the optical source shall meet the requirements of Clause 38.

b) Configure the test equipment as shown in Figure 38–6. Take care to minimize changes to the signal path that could affect the system frequency response after the calibration in step a. Connect the laser output with no RF modulation applied to the receiver under test through an optical attenuator and taking into account the extinction ratio of the source, set the optical power to a level that approximates the stressed receive sensitivity level in Table 38–4 for 1000BASE-SX and in Table 38–8 for 1000BASE-LX.

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c) Locate the center of the eye with the BERT. Turn on the RF modulation while maintaining the same average optical power established in step b.
d) Measure the necessary RF modulation amplitude (in dBm) required to achieve a constant BER (e.g., 10^{-8}) for a number of frequencies.
e) The receiver 3 dB electrical upper cutoff frequency is that frequency where the corrected RF modulation amplitude (the measured amplitude in "d" corrected with the calibration data in "a") increases by 3 dB (electrical). If necessary, interpolate between the measured response values.

38.7 Environmental specifications

38.7.1 General safety

All equipment meeting this standard shall conform to IEC-60950:1991.

38.7.2 Laser safety

1000BASE-X optical transceivers shall be Hazard Level 1 laser certified under any condition of operation. This includes single fault conditions whether coupled into a fiber or out of an open bore. Transceivers shall be certified to be in conformance with IEC 60825-1 and IEC 60825-2.

Conformance to additional laser safety standards may be required for operation within specific geographic regions.

Laser safety standards and regulations require that the manufacturer of a laser product provide information about the product's laser, safety features, labeling, use, maintenance and service. This documentation shall explicitly define requirements and usage restrictions on the host system necessary to meet these safety certifications.[5]

38.7.3 Installation

Sound installation practice, as defined by applicable local codes and regulations, shall be followed in every instance in which such practice is applicable.

38.8 Environment

Normative specifications in this clause shall be met by a system integrating a 1000BASE-X PMD over the life of the product while the product operates within the manufacturer's range of environmental, power, and other specifications.

It is recommended that manufacturers indicate in the literature associated with the PHY the operating environmental conditions to facilitate selection, installation, and maintenance.

It is recommended that manufacturers indicate, in the literature associated with the components of the optical link, the distance and operating environmental conditions over which the specifications of this clause will be met.

38.8.1 Electromagnetic emission

A system integrating a 1000BASE-X PMD shall comply with applicable local and national codes for the limitation of electromagnetic interference.

[5]A host system that fails to meet the manufacturers requirements and/or usage restrictions may emit laser radiation in excess of the safety limits of one or more safety standards. In such a case, the host manufacturer is required to obtain its own laser safety certification.

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38.8.2 Temperature, humidity, and handling

The optical link is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

38.9 PMD labeling requirements

It is recommended that each PHY (and supporting documentation) be labeled in a manner visible to the user with at least the following parameters, according to the PMD-MDI type.

PMD MDI type 1000BASE-SX:

a) 1000BASE-SX
b) Applicable safety warnings

PMD MDI type 1000BASE-LX:

a) 1000BASE-LX
b) Applicable safety warnings

Labeling requirements for Hazard Level 1 lasers are given in the laser safety standards referenced in 38.7.2.

38.10 Fiber optic cabling model

The fiber optic cabling model is shown in Figure 38–7.

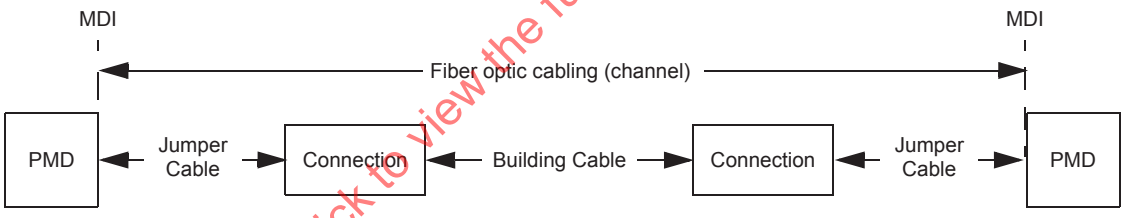

Figure 38–7—Fiber optic cabling model

The channel insertion loss is given in Table 38–11. Insertion loss measurements of installed fiber cables are made in accordance with ANSI/TIA/EIA-526-14A [B15], method B; and ANSI/TIA/EIA-526-7 [B16], method A-1. The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment. The term channel is used here for consistency with generic cabling standards.

38.11 Characteristics of the fiber optic cabling

The 1000BASE-SX and 1000BASE-LX fiber optic cabling shall meet the specifications defined in Table 38–12. The fiber optic cabling consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together. It also includes a connector plug at each end to connect to the MDI. The fiber optic cabling spans from one MDI to another MDI, as shown in Figure 38–7.

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Table 38–11—Channel insertion loss

Description	62.5 μm MMF			50 μm MMF			SMF	Unit
Wavelength	850	850	1300	850	850	1300	1310	nm
Modal bandwidth (min; overfilled launch)	160	200	500	400	500	400 or 500	N/A	MHz · km
Operating distance	220	275	550	500	550	550	5000	m
Channel insertion loss[a] [b]	2.33	2.53	2.32	3.25	3.43	2.32	4.5	dB

[a]These channel insertion loss numbers are based on the nominal operating wavelength.
[b]Operating distances used to calculate channel insertion loss are those listed in this table.

38.11.1 Optical fiber and cable

The fiber optic cable requirements are satisfied by the fibers specified in IEC 60793-2:1992. Types A1a (50/125 μm multimode), A1b (62.5/125 μm multimode), and B1 (single-mode) with the exceptions noted in Table 38–12.

Table 38–12—Optical fiber and cable characteristics

Description	62.5 μm MMF		50 μm MMF		SMF	Unit
Nominal fiber specification wavelength	**850**	**1300**	**850**	**1300**	**1310**	**nm**
Fiber cable attenuation (max)	3.75[a]	1.5	3.5	1.5	0.5	dB/km
Modal Bandwidth (min; overfilled launch)	160	500	400	400	N/A	MHz · km
	200	500	500	500	N/A	MHz · km
Zero dispersion wavelength (λ_0)	$1320 \le \lambda_0 \le 1365$		$1295 \le \lambda_0 \le 1320$		$1300 \le \lambda_0 \le 1324$	nm
Dispersion slope (max) (S_0)	0.11 for $1320 \le \lambda_0 \le 1348$ and $0.001(1458 - \lambda_0)$ for $1348 \le \lambda_0 \le 1365$		0.11 for $1300 \le \lambda_0 \le 1320$ and $0.001(\lambda_0 - 1190)$ for $1295 \le \lambda_0 \le 1300$		0.093	ps / nm^2 · km

[a]This value of attenuation is a relaxation of the standard (IEC 60793-2, type A1b, category less than or equal to 3.5 dB/km).

38.11.2 Optical fiber connection

An optical fiber connection as shown in Figure 38–7 consists of a mated pair of optical connectors. The 1000BASE-SX or 1000BASE-LX PMD is coupled to the fiber optic cabling through a connector plug into the MDI optical receptacle, as shown in 38.11.3.

38.11.2.1 Connection insertion loss

The insertion loss is specified for a connection, which consists of a mated pair of optical connectors.

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The maximum link distances for multimode fiber are calculated based on an allocation of 1.5 dB total connection and splice loss. For example, this allocation supports three connections with an average insertion loss equal to 0.5 dB (or less) per connection, or two connections (as shown in Figure 38–7) with a maximum insertion loss of 0.75 dB. Connections with different loss characteristics may be used provided the requirements of Table 38–11 and Table 38–12 are met.

The maximum link distances for single-mode fiber are calculated based on an allocation of 2.0 dB total connection and splice loss. For example, this allocation supports four connections with an average insertion loss per connection of 0.5 dB. Connections with different loss characteristics may be used provided the requirements of Table 38–11 and Table 38–12 are met.

38.11.2.2 Connection return loss

The return loss for multimode connections shall be greater than 20 dB.

The return loss for single-mode connections shall be greater than 26 dB.

38.11.3 Medium Dependent Interface (MDI)

The 1000BASE-SX and 1000BASE-LX PMD is coupled to the fiber optic cabling through a connector plug into the MDI optical receptacle. The 1000BASE-SX and 1000BASE-LX MDI optical receptacles shall be the duplex SC, meeting the following requirements:

a) Meet the dimension and interface specifications of IEC 61754-4 [B39] and IEC 61754-4, Interface 4-2.
b) Meet the performance specifications as specified in ISO/IEC 11801.
c) Ensure that polarity is maintained.
d) The receive side of the receptacle is located on the left when viewed looking into the transceiver optical ports with the keys on the bottom surface.

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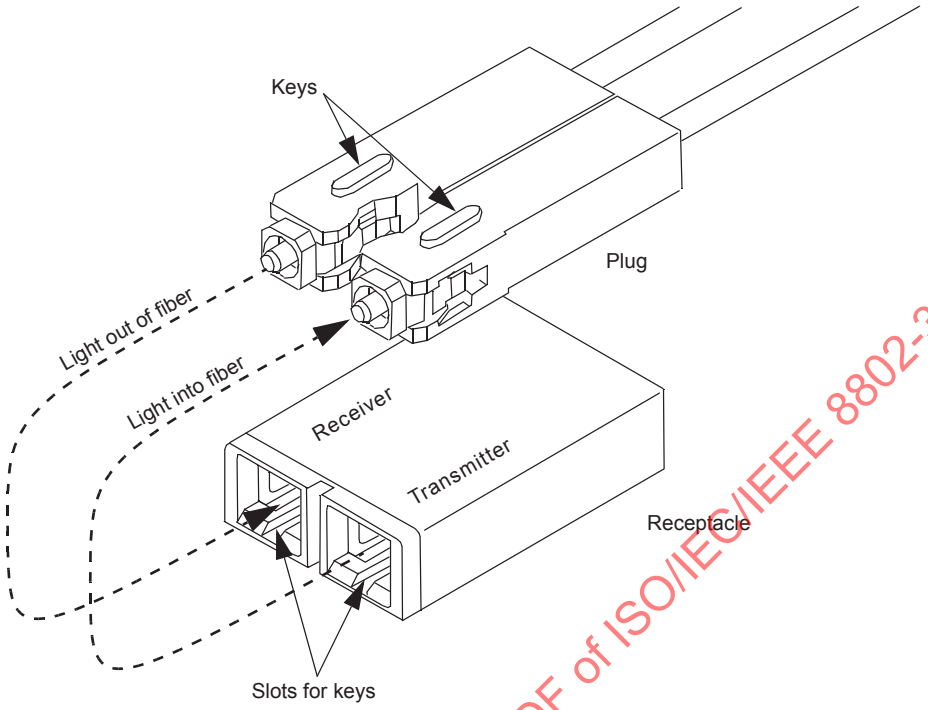
A sample drawing of a duplex SC connector and receptacle is provided in Figure 38–8.



NOTE—Connector keys are used for transmit/receive polarity only. The connector keys do not differentiate between single-mode and multimode connectors.

Figure 38–8—Duplex SC connector and receptacle (informative)

38.11.4 Single-mode fiber offset-launch mode-conditioning patch cord for MMF operation of 1000BASE-LX

This subclause specifies an example embodiment of a mode conditioner for 1000BASE-LX operation with MMF cabling. The MMF cabling should meet all of the specifications of 38.10. For 1000BASE-LX the mode conditioner consists of a single-mode fiber permanently coupled off-center to a graded index fiber. This example embodiment of a patch cord is not intended to exclude other physical implementations of offset-launch mode conditioners. However, any implementation of an offset-launch mode conditioner used for 1000BASE-LX shall meet the specifications of Table 38–13. The offset launch must be contained within the patch cord assembly and is not adjustable by the user.

Table 38–13—Single-mode fiber offset-launch mode conditioner specifications

Description	62.5 μm MMF	50 μm MMF	Unit
Maximum insertion loss	0.5	0.5	dB
Coupled Power Ratio (CPR)	28 < CPR < 40	12 < CPR < 20	dB
Optical center offset between SMF and MMF	17 < Offset < 23	10 < Offset < 16	μm
Maximum angular offset	1	1	degree

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All patch cord connecting ferrules containing the single-mode-to-multimode offset launch shall have single-mode tolerances (IEC 61754-4 [B39] grade 1 ferrule).

The single-mode fiber used in the construction of the single-mode fiber offset-launch mode conditioner shall meet the requirements of 38.11.1. The multimode fiber used in the construction of the single-mode fiber offset-launch mode conditioner shall be of the same type as the cabling over which the 1000BASE-LX link is to be operated. If the cabling is 62.5 µm MMF then the MMF used in the construction of the mode conditioner should be of type 62.5 µm MMF. If the cabling is 50 µm MMF, then the MMF used in the construction of the mode conditioner should be of type 50 µm MMF.

Figure 38–9 shows the preferred embodiment of the single-mode fiber offset-launch mode-conditioning patch cord. This patch cord consists of duplex fibers including a single-mode-to-multimode offset launch fiber connected to the transmitter MDI and a second conventional graded index MMF connected to the receiver MDI. The preferred configuration is a plug-to-plug patch cord since it maximizes the power budget margin of the 1000BASE-LX link. The single-mode end of the patch cord shall be labeled "To Equipment". The multimode end of the patch cord shall be labeled "To Cable". The color identifier of the single-mode fiber connector shall be blue. The color identifier of all multimode fiber connector plugs shall be beige. The patch cord assembly is labeled "Offset-launch mode-conditioning patch cord assembly". Labelling identifies which size multimode fiber is used in the construction of the patch cord. The keying of the SC duplex optical plug ensures that the single-mode fiber end is automatically aligned to the transmitter MDI.

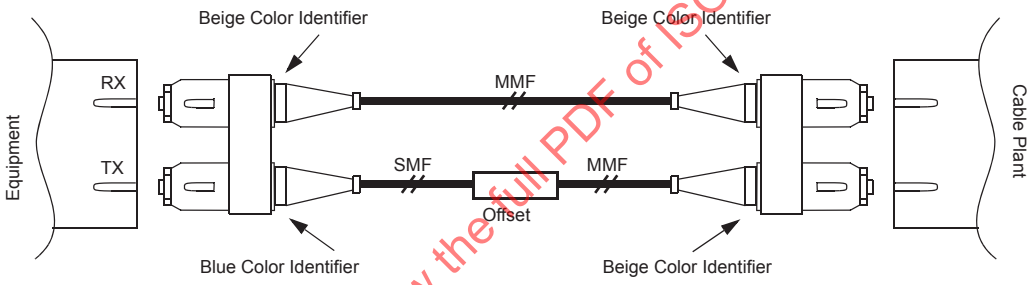

Figure 38–9—1000BASE-LX single-mode fiber offset-launch mode-conditioning patch cord assembly

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38.12 Protocol implementation conformance statement (PICS) proforma for Clause 38, Physical Medium Dependent (PMD) sublayer and baseband medium, type 1000BASE-LX (Long Wavelength Laser) and 1000BASE-SX (Short Wavelength Laser)[6]

38.12.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 38, Physical Medium Dependent (PMD) sublayer and baseband medium, type 1000BASE-LX (Long Wavelength Laser) and 1000BASE-SX (Short Wavelength Laser), shall complete the following protocol implementation conformance statement (PICS) proforma. A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

38.12.2 Identification

38.12.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

38.12.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 38, Physical Medium Dependent (PMD) sublayer and baseband medium, type 1000BASE-LX (Long Wavelength Laser) and 1000BASE-SX (Short Wavelength Laser)
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	No [ ] Yes [ ]

Date of Statement	

[6]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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38.12.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*LX	1000BASE-LX PMD	38.1	Device supports long wavelength operation (1270–1355 nm).	O/1	Yes [ ] No [ ]
*SX	1000BASE-SX PMD	38.1	Device supports short wavelength operation (770–860 nm). Either this option, or option LX, must be checked.	O/1	Yes [ ] No [ ]
*INS	Installation / cable	38.10	Items marked with INS include installation practices and cable specifications not applicable to a PHY manufacturer.	O	Yes [ ] No [ ]
*OFP	Single-mode offset-launch mode-conditioning patch cord	38.11.4	Items marked with OFP include installation practices and cable specifications not applicable to a PHY manufacturer.	O	Yes [ ] No [ ]
*TP1	Standardized reference point TP1 exposed and available for testing.	38.2.1	This point may be made available for use by implementers to certify component conformance.	O	Yes [ ] No [ ]
*TP4	Standardized reference point TP4 exposed and available for testing.	38.2.1	This point may be made available for use by implementers to certify component conformance.	O	Yes [ ] No [ ]

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38.12.4 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and baseband medium, type 1000BASE-LX (Long Wavelength Laser) and 1000BASE-SX (Short Wavelength Laser)

38.12.4.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FN1	Integration with 1000BASE-X PCS and PMA and management functions	38.1		M	Yes [ ]
FN2	Transmit function	38.2.2	Convey bits requested by PMD_UNITDATA.request() to the MDI	M	Yes [ ]
FN3	Mapping between optical signal and logical signal for transmitter	38.2.2	Higher optical power is a logical 1.	M	Yes [ ]
FN4	Receive function	38.2.3	Convey bits received from the MDI to PMD_UNITDATA.indication()	M	Yes [ ]
FN5	Mapping between optical signal and logical signal for receiver	38.2.3	Higher optical power is a logical 1.	M	Yes [ ]
FN6	Signal detect function	38.2.4	Report to the PMD service interface the message PMD_SIGNAL.indication(SIGNAL_DETECT)	M	Yes [ ]
FN7	Signal detect behavior	38.2.4	Meets requirements of Table 38–1	M	Yes [ ]

38.12.4.2 PMD to MDI optical specifications for 1000BASE-SX

Item	Feature	Subclause	Value/Comment	Status	Support
PMS1	Transmitter meets specifications in Table 38–3	38.3.1	Per measurement techniques in 38.6	SX:M	Yes [ ] N/A [ ]
PMS2	Transmitter eye measurement	38.3.1	Per 38.6.5	SX:M	Yes [ ] N/A [ ]
PMS3	Launch power	38.3.1	Lesser of Hazard Level 1 safety limit per 38.7.2 or maximum receive power in Table 38–4	SX:M	Yes [ ] N/A [ ]
PMS4	Receiver meets specifications in Table 38–4	38.3.2	Per measurement techniques in 38.6	SX:M	Yes [ ] N/A [ ]

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38.12.4.3 PMD to MDI optical specifications for 1000BASE-LX

Item	Feature	Subclause	Value/Comment	Status	Support
PML1	Transmitter meets specifications in Table 38–7	38.4.1	Per measurement techniques in 38.6	LX:M	Yes [ ] N/A [ ]
PML2	Transmitter eye measurement	38.4.1	Per 38.6.5	LX:M	Yes [ ] N/A [ ]
PML3	Offset-launch mode-conditioning patch cord	38.4.1	Required for LX multimode operation	LX:M	Yes [ ] N/A [ ]
PML4	Receiver meets specifications in Table 38–8	38.4.2	Per measurement techniques in 38.6	LX:M	Yes [ ] N/A [ ]

38.12.4.4 Jitter specifications

Item	Feature	Subclause	Value/Comment	Status	Support
JT1	Total jitter specification at TP1	38.5	Meets specification of bold entries in Table 38–10	TP1:M	Yes [ ] N/A [ ]
JT2	Total jitter specification at TP2	38.5	Meets specification of bold entries in Table 38–10	M	Yes [ ]
JT3	Total jitter specification at TP3	38.5	Meets specification of bold entries in Table 38–10	INS:M	Yes [ ] N/A [ ]
JT4	Total jitter specification at TP4	38.5	Meets specification of bold entries in Table 38–10	TP4:M	Yes [ ] N/A [ ]

38.12.4.5 Optical measurement requirements

Item	Feature	Subclause	Value/Comment	Status	Support
OR1	Length of patch cord used for measurements	38.6	2 to 5 m	M	Yes [ ]
OR2	Center wavelength and spectral width measurement conditions	38.6.1	Using optical spectrum analyzer per TIA-455-127-A	M	Yes [ ]
OR3	Center wavelength and spectral width measurement conditions	38.6.1	Under modulated conditions using a valid 1000BASE-X signal	M	Yes [ ]
OR4	Optical power measurement conditions	38.6.2	Per ANSI/EIA-455-95-1986 [B9]	M	Yes [ ]
OR5	Extinction ratio measurement conditions	38.6.3	Per IEC 61280-2-2 using patch cable per 38.6	M	Yes [ ]
OR6	RIN test methods	38.6.4	58.7.7 as modified by 38.6.4 using patch cable per 38.6	M	Yes [ ]
OR7	Transmit eye mask measurement conditions	38.6.5	Using fourth-order Bessel-Thomson filter per 38.6.5, using patch cable per 38.6	M	Yes [ ]

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38.12.4.5 Optical measurement requirements *(continued)*

Item	Feature	Subclause	Value/Comment	Status	Support
OR8	Transmit rise/fall measurement conditions	38.6.6	Waveforms conform to mask in Figure 38–2, measure from 20% to 80%, using patch cable per 38.6	M	Yes [ ]
OR9	Receive sensitivity measurement conditions	38.6.7	Worst-case extinction ratio penalty while sampling at the eye center using patch cable per 38.6	M	Yes [ ]
OR10	Stressed receive sensitivity	38.6.7	Per 38.6.11, using patch cable per 38.6	M	Yes [ ]
OR11	Stressed receive sensitivity	38.6.7	Meet Table 38–4	SX:M	Yes [ ] N/A [ ]
OR12	Stressed receive sensitivity	38.6.7	Meet Table 38–8	LX:M	Yes [ ] N/A [ ]
OR13	Total jitter measurement conditions	38.6.8	ANSI X3.230-1994 [B21] (FC-PH), Annex A, Subclause A.4.2	M	Yes [ ]
OR14	Total jitter measurement conditions at TP2	38.6.8	Using BERT	M	Yes [ ]
OR15	Total jitter measurement conditions at TP2	38.6.8	Using Bessel-Thomson filter defined in 38.6.5	M	Yes [ ]
OR16	Total jitter measurement conditions	38.6.8	Using mixed frequency pattern specified in 36A.3	M	Yes [ ]
OR17	Total jitter measurement conditions at TP4	38.6.8	Using conformance test signal at TP3 (see 38.6.11)	M	Yes [ ]
OR18	Optical power used for total jitter measurement at TP4	38.6.8	0.5 dB greater than stressed receive sensitivity given in Table 38–4 (for SX) or (for LX)	M	Yes [ ]
OR19	Optical power used for total jitter measurement at TP4	38.6.8	Corrected for extinction ratio	M	Yes [ ]
OR20	Total jitter measurement conditions at TP4	38.6.8	Measured without Bessel-Thomson filters	M	Yes [ ]
OR21	Coupled power ratio	38.6.10	Measured using TIA/EIA-526-14A [B15], meets values in Table 38–3 (for SX) or (for LX)	M	Yes [ ]
OR22	Compliance test signal at TP3	38.6.11	Meets requirements of Figure 38–4	M	Yes [ ]
OR23	Compliance test signal at TP3	38.6.11	Pattern specified in 36A.5	M	Yes [ ]
OR24	Compliance test signal at TP3	38.6.11	DJ eye closure no less than 65 ps	M	Yes [ ]
OR25	Compliance test signal at TP3	38.6.11	Vertical eye-closure penalty meets requirements of Table 38–4	SX:M	Yes [ ] N/A [ ]

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38.12.4.5 Optical measurement requirements *(continued)*

Item	Feature	Subclause	Value/Comment	Status	Support
OR26	Compliance test signal at TP3	38.6.11	Vertical eye-closure penalty meets requirements of Table 38–8	LX:M	Yes [ ] N/A [ ]
OR27	Compliance test signal at TP3	38.6.11	Bandwidth of photodetector >2.5 GHz, and couple through 4th order Bessel-Thomson filter	M	Yes [ ]
OR28	Receiver electrical cutoff frequency measurement procedure	38.6.12	As described in 38.6.12	M	Yes [ ]
OR29	Optical source used for cutoff frequency measurement	38.6.12	With the exception of extinction ratio, meets requirements of Clause 38	M	Yes [ ]
OR30	Compliance with IEC 60950-1991	38.7.1		M	Yes [ ]
OR31	Laser safety compliance	38.7.2	Hazard Level 1	M	Yes [ ]
OR32	Laser safety compliance test conditions	38.7.2	IEC 60825-1 and IEC 60825-2	M	Yes [ ]
OR33	Documentation explicitly defines requirements and usage restrictions on the host system necessary to meet after certifications	38.7.2		M	Yes [ ]
OR34	Sound installation practices	38.7.3		INS:M	Yes [ ] N/A [ ]
OR35	Compliance with all requirements over the life of the product	38.8		M	Yes [ ]
OR36	Compliance with applicable local and national codes for the limitation of electromagnetic interference	38.8.1		M	Yes [ ]

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38.12.4.6 Characteristics of the fiber optic cabling

Item	Feature	Subclause	Value/Comment	Status	Support
LI1	Fiber optic cabling	38.11	Meets specifications in Table 38–11	INS:M	Yes [ ] N/A [ ]
LI2	Return loss for multimode connections	38.11.2.2	> 20 dB	INS:M	Yes [ ] N/A [ ]
LI3	Return loss for single-mode connections	38.11.2.2	> 26 dB	INS:M	Yes [ ] N/A [ ]
LI4	MDI optical plug	38.11.3	Duplex SC meeting IEC 61754-4, IEC 61754-4:1997 [B39] Interface 4-2, and ISO/IEC 11801, maintains polarity and ensures orientation.	INS:M	Yes [ ]
LI5	MDI optical receptacle	38.11.3	Duplex SC meeting IEC 61754-4:1997 [B39] Interface 4-2, and ISO/IEC 11801, maintains polarity and ensures orientation.	M	Yes [ ]
LI6	Offset-launch mode-conditioning patch cord	38.11.4	Meet conditions of Table 38–13	OFP:M	Yes [ ] N/A [ ]
LI7	Single-mode ferrules in offset-launch mode-conditioning patch cords	38.11.4	IEC 61754-4:1997 [B39] grade 1 ferrule	OFP:M	Yes [ ] N/A [ ]
LI8	Single-mode fiber in offset-launch mode-conditioning patch cords	38.11.4	Per 38.11.1	OFP:M	Yes [ ] N/A [ ]
LI9	Multimode fiber in offset-launch mode-conditioning patch cords	38.11.4	Same type as used in LX cable plant	OFP:M	Yes [ ] N/A [ ]
LI10	Label on single-mode end of offset-launch mode-conditioning patch cords	38.11.4	Labeled “To Equipment”	OFP:M	Yes [ ] N/A [ ]
LI11	Label on multimode end of offset-launch mode-conditioning patch cords	38.11.4	Labeled “To Cable”	OFP:M	Yes [ ] N/A [ ]
LI12	Color identifier of single-mode fiber connector	38.11.4	Blue	OFP:M	Yes [ ] N/A [ ]
LI13	Color identifier of multimode fiber connector	38.11.4	Beige	OFP:M	Yes [ ] N/A [ ]

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39. Physical Medium Dependent (PMD) sublayer and baseband medium, type 1000BASE-CX (short-haul copper)

39.1 Overview

This clause specifies the 1000BASE-CX PMD (including MDI) and baseband medium for short-haul copper. In order to form a complete 1000BASE-CX Physical Layer it shall be integrated with the 1000BASE-X PCS of Clause 36 and the PMD of Clause 38, which are hereby incorporated by reference. As such, the 1000BASE-CX PMD shall comply with the PMD service interface specified in 38.1.1.

1000BASE-CX has a minimum operating range of 0.1 to 25 m. Jumper cables, described in 39.4, are used to interconnect 1000BASE-CX PMDs. These cables shall not be concatenated to achieve longer distances. A 1000BASE-CX jumper cable assembly consists of a continuous shielded balanced cable terminated at each end with a polarized shielded plug described in 39.5.1. The jumper cable assembly provides an output signal on contacts R+/R– meeting the requirements shown in Figure 39–5 when a transmit signal compliant with Figures 39–3 and 39–4 is connected to the T+/T– contacts at the near-end MDI connector.

The links described in this clause are applied only to homogenous ground applications such as between devices within a cabinet or rack, or between cabinets interconnected by a common ground return or ground plane. This restriction minimizes safety and interference concerns caused by any voltage differences that could otherwise exist between equipment grounds.

39.2 Functional specifications

The 1000BASE-CX PMD performs three functions, Transmit, Receive, and Signal Status according to the service interface definition in 38.1.

39.2.1 PMD transmit function

The PMD Transmit function shall convey the bits requested by the PMD service interface message PMD_UNITDATA.request(tx_bit) to the MDI according electrical specifications in 39.3.1. The higher output voltage of T+ minus T– (differential voltage) shall correspond to tx_bit = ONE.

39.2.2 PMD receive function

The PMD Receive function shall convey the bits received at the MDI in accordance with the electrical specifications of 39.3.2 to the PMD service interface using the message PMD_UNITDATA.indication(rx_bit). The higher output voltage of R+ minus R– (differential voltage) shall correspond to rx_bit = ONE.

39.2.3 PMD signal detect function

The PMD Signal Detect function shall report to the PMD service interface, using the message PMD_SIGNAL.indication(SIGNAL_DETECT), which is signaled continuously. PMD_SIGNAL.indication is intended to be an indicator of electrical signal presence.

The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 39–1. The PMD receiver is not required to verify whether a compliant 1000BASE-X signal is being received. This standard imposes no response time requirements on the generation of the SIGNAL_DETECT parameter.

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Table 39–1—SIGNAL_DETECT value definition

Receive Conditions	Signal Detect Value
V_{input}, Receiver < (receiver sensitivity + worst-case local system noise)[a]	FAIL
Minimum differential sensitivity ≤ V_{input}, Receiver ≤ Maximum differential input AND compliant 1000BASE-X signal input	OK
All other conditions	Unspecified

[a]Worst-case local system noise includes all receiver coupled noise sources (NEXT, power supply noise, and any reflected signals). Receive sensitivity is the actual sensitivity of the specific port (as opposed to the minimum differential sensitivity).

As an unavoidable consequence of the requirements for the setting of the SIGNAL_DETECT parameter, implementations must provide adequate margin between the input signal level at which the SIGNAL_DETECT parameter is set to OK, and the inherent noise level of the PMD due to cross talk, power supply noise, etc.

Various implementations of the Signal Detect function are permitted by this standard, including implementations which generate the SIGNAL_DETECT parameter values in response to the amplitude of the 8B/10B modulation of the electrical signal

39.3 PMD to MDI electrical specifications

All interface specifications are valid only at the point of entry and exit from the equipment. These points are identified as points TP2 and TP3 as shown in Figure 39–1. The specifications assume that all measurements are made after a mated connector pair, relative to the source or destination.

TP1 and TP4 are standardized reference points for use by implementers to certify component conformance. The electrical specifications of the PMD service interface (TP1 and TP4) are not system compliance points (these are not readily testable in a system implementation). It is expected that in many implementations TP1 and TP4 will be common between 1000BASE-SX (Clause 38), 1000BASE-LX (Clause 38), and 1000BASE-CX.

PMD specifications shall be measured using the measurement techniques defined in 39.6.

The reference points for all connections are those points TP2 and TP3 where the cabinet Faraday shield transitions between the cabinet and the jumper cable shield. If sections of transmission line exist within the Faraday shield, they are considered to be part of the associated transmit or receive network, and not part of the jumper cable assembly.

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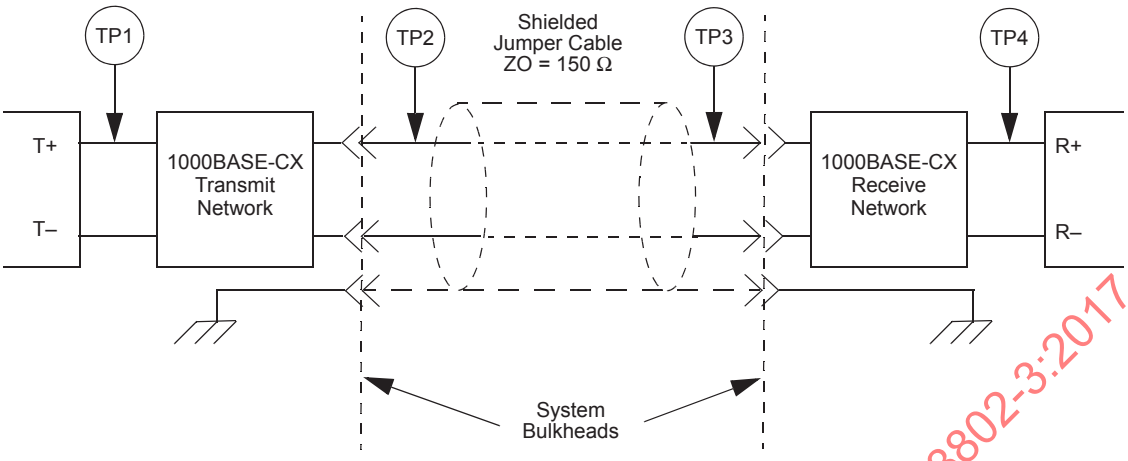

NOTE—Jumper cable assembly shielding is attached to the system chassis via the connector shroud.

Figure 39–1—1000BASE-CX link (half link is shown)

Schematics in the diagrams in this clause are for illustration only and do not represent the only feasible implementation.

39.3.1 Transmitter electrical specifications

The output driver is assumed to have output levels approximating those of Emitter Coupled Logic (ECL), as measured at TP1. The transmitter shall meet the specifications in Table 39–2.

Table 39–2—Transmitter characteristics at TP2

Description	Value	Unit
Type	(P)ECL	
Data rate	1000	Mb/s
Clock tolerance	±100	ppm
Nominal signaling speed	1250	MBd
Differential amplitude (p-p)		
Max (worst case p-p)	2000	mV
Min (opening)	1100	mV
Max (OFF)[a]	170	mV
Rise/Fall time (20-80%)		
maximum	327	ps
minimum	85	ps
Differential skew (max)	25	ps

[a]Examples of an OFF transmitter are no power supplied to the PMD and PMA transmit output being driven to a static state during loopback.

For all links, the output driver shall be AC-coupled to the jumper cable assembly through a transmission network, and have output levels, measured at the input to the jumper cable assembly (TP2), meeting the eye diagram requirements of Figure 39–3 and Figure 39–4, when terminated as shown in Figure 39–2. The symbols X1 and X2 in Figure 39–3 and Figure 39–4 are defined in Table 39–3.

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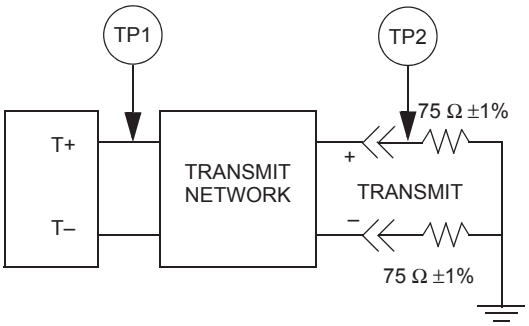

Figure 39–2—Balanced transmitter test load

The normalized amplitude limits in Figure 39–3 are set to allow signal overshoot of 10% and undershoot of 20%, relative to the amplitudes determined to be a logic 1 and 0. The absolute transmitter output timing and amplitude requirements are specified in Table 39–2, Table 39–3, and Figure 39–4. The normalized transmitter output timing and amplitude requirements are specified in Table 39–2, Table 39–3, and Figure 39–3. The transmit masks of Figure 39–3 and Figure 39–4 are not used for response time and jitter specifications.

NOTE 1—The relationship between Figure 39–3 and Figure 39–4 can best be explained by a counter example. If a transmitter outputs a nominal 600 mV-ppd logic one level with overshoot to 900 mV-ppd, it will pass the absolute mask of Figure 39–4 but will not pass the normalized mask of Figure 39–3. Normalized, this signal would have 50% overshoot. This exceeds the 10% overshoot limit defined by the normalized eye mask.

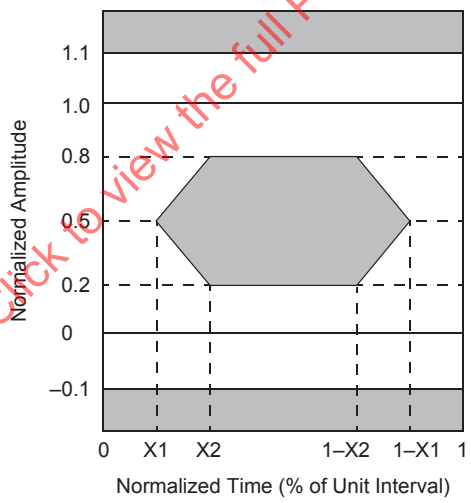

Figure 39–3—Normalized eye diagram mask at TP2

Table 39–3—Normalized time intervals for TP2

Symbol	Value	Units
X1	0.14	Unit Intervals (UI)
X2	0.34	Unit Intervals (UI)

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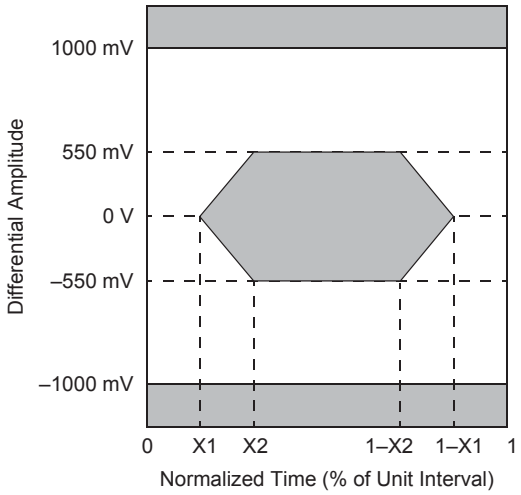

Figure 39–4—Absolute eye diagram mask at TP2

The recommended interface to electrical transmission media is via transformer or capacitive coupling.

NOTE 2—All specifications, unless specifically listed otherwise, are based on differential measurements.

NOTE 3—All times indicated for TDR measurements are recorded times. Recorded times are twice the transit time of the TDR signal.

NOTE 4—The transmit differential skew is the maximum allowed time difference (on both low-to-high and high-to low transitions) as measured at TP2, between the true and complement signals. This time difference is measured at the midway point on the signal swing of the true and complement signals. These are single-ended measurements.

NOTE 5—The transmitter amplitude maximum specification identifies the maximum p-p signal that can be delivered into a resistive load matching that shown in Figure 39–2.

NOTE 6—The transmitter amplitude minimum specification identifies the minimum allowed p-p eye amplitude opening that can be delivered into a resistive load matching that shown in Figure 39–2.

NOTE 7—The normalized 1 is that amplitude determined to be the average amplitude when driving a logic 1. The normalized 0 is that amplitude determined to be the average amplitude when driving a logic 0.

NOTE 8—Eye diagram assumes the presence of only high-frequency jitter components that are not tracked by the clock recovery circuit. For this standard the lower cutoff frequency for jitter is 637 kHz.

39.3.2 Receiver electrical specifications

The receiver shall be AC-coupled to the media through a receive network located between TP3 and TP4 as shown in Figure 39–1. The receiver shall meet the signal requirements listed in Table 39–4.

The minimum input amplitude to the receiver listed in Table 39–4 and Figure 39–5 is a worst case specification across all environmental conditions. Restricted environments may allow operation at lower minimum differential voltages, allowing significantly longer operating distances.

NOTE 1—All specifications, unless specifically listed otherwise, are based on differential measurements.

NOTE 2—The receiver minimum differential sensitivity identifies the minimum p-p eye amplitude at TP3 to meet the BER objective.

NOTE 3—Eye diagrams assume the presence of only high-frequency jitter components that are not tracked by the clock recovery circuit. For this standard the lower cutoff frequency for jitter is 637 kHz.

NOTE 4—All times indicated for TDR measurements are recorded times. Recorded times are twice the transit time of the TDR signal.

NOTE 5—Through_Connection impedance describes the impedance tolerance through a mated connector. This tolerance is greater than the termination or cable impedance due to limits in the technology of the connectors.

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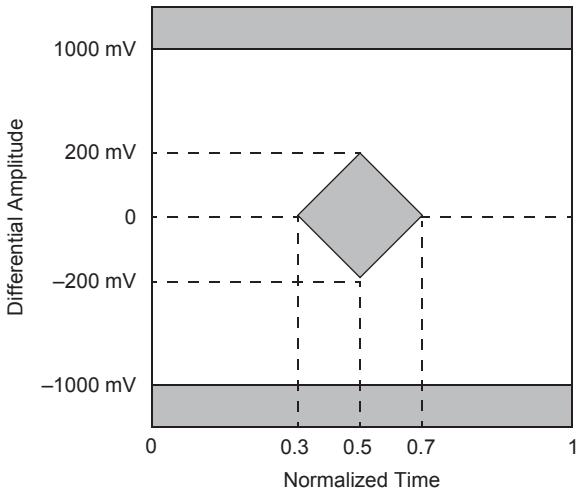

Figure 39–5—Eye diagram mask at point-TP3

Table 39–4—Receiver characteristics (TP3)

Description	Value	Units
Data rate	1000	Mb/s
Nominal signaling speed	1250	MBd
Tolerance	±100	ppm
Minimum differential sensitivity (peak-peak)	400	mV
Maximum differential input (peak-peak)	2000	mV
Input Impedance @ TP3		
TDR Rise Time	85	ps
Exception_window[a]	700	ps
Through_connection	150 ± 30	Ω
At Termination[b]	150 ± 10	Ω
Differential Skew	175	ps

[a]Within the Exception_window no single impedance excursion shall exceed the Through_Connection-impedance tolerance for a period of twice the TDR rise time specification.

[b]The input impedance at TP3, for the termination, shall be recorded 4.0 ns following the reference location determined by an open connector between TP3 and TP4.

39.3.3 Jitter specifications for 1000BASE-CX

The 1000BASE-CX PMD shall meet the total jitter specifications defined in Table 38–10. Normative values are highlighted **in bold.** All other values are informative. Compliance points are defined in 39.3.

Jitter shall be measured as defined in 38.6.8 with the exception that no measurement will require the use of an optical to electrical converter (O/E).

Deterministic jitter budgetary specifications are included here to assist implementers in specifying components. Measurements for DJ are described in 38.6.9 with the exception that no measurement will require the use of an O/E.

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Table 39–5—1000BASE-CX jitter budget

Compliance point	Total jitter[a]		Deterministic jitter	
	UI	ps	UI	ps
TP1	**0.240**	**192**	0.120	96
TP1 to TP2	0.090	72	0.020	16
TP2	**0.279**	**223**	0.140	112
TP2 to TP3	0.480	384	0.260	208
TP3	**0.660**	**528**	0.400	320
TP3 to TP4	0.050	40	0.050	40
TP4	**0.710**	**568**	0.450	360

[a]Total jitter is composed of both deterministic and random components. The allowed random jitter equals the allowed total jitter minus the actual deterministic jitter at that point.

39.4 Jumper cable assembly characteristics

A 1000BASE-CX compliant jumper cable assembly shall consist of a continuous shielded balanced cable terminated at each end with a polarized shielded plug as described in 39.5.1. The jumper cable assembly shall provide an output signal on contacts R+/R– meeting the requirements shown in Figure 39–5 when a transmit signal compliant with Figures 39–3 and 39–4 is connected to the T+/T– contacts at the near-end MDI connector. This jumper cable assembly shall have electrical and performance characteristics as described in Table 39–6. Jumper cable assembly specifications shall be measured using the measurement techniques defined in 39.6. The jumper cable assembly may have integrated compensation networks.

NOTE 1—Jumper cable assemblies that meet the requirements for ANSI X3.230-1994 [B21] (FC-PH) may not meet the requirements of this clause.

NOTE 2—Through_Connection impedance describes the impedance tolerance through a mated connector. This tolerance is greater than the termination or cable impedance due to limits in the technology of the connectors.

To produce jumper cable assemblies capable of delivering signals compliant with the requirements of 39.4, the assemblies should generally have characteristics equal to or better than those in Table 39–7.

39.4.1 Compensation networks

A jumper cable assembly may include an equalizer network to meet the specifications and signal quality requirements (e.g., receiver eye mask at TP3) of this clause. The equalizer shall need no adjustment. All jumper cable assemblies containing such circuits shall be marked with information identifying the specific designed operational characteristics of the jumper cable assembly.

39.4.2 Shielding

The jumper cable assembly shall provide class 2 or better shielding in accordance with IEC 61196-1.

39.5 MDI specification

This clause defines the Media Dependent Interface (MDI). The 1000BASE-CX PMD of 39.3 is coupled to the jumper cable assembly by the media dependent interface (MDI).

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Table 39–6—Jumper cable assembly characteristics (normative)

Description	Value	Unit
Differential skew (max)	150	ps
Link Impedance @ TP2/TP3[a] Through_connection Cable	 150 ± 30 150 ± 10	 W W
TDR rise time Exception_window[b]	85 700	ps ps
Round-trip delay (max)[c]	253 253	bit times ns

[a]The link impedance measurement identifies the impedance mismatches present in the jumper cable assembly when terminated in its characteristic impedance. This measurement includes mated connectors at both ends of the Jumper cable assembly (points TP2 and TP3). The link impedance for the jumper cable assembly, shall be recorded 4.0 ns following the reference location determined by an open connector at TP2 and TP3.

[b]Within the Exception_window no single impedance excursion shall exceed the Through_Connection-impedance tolerance for a period of twice the TDR rise time specification. The Exception_window (used with specific impedance measurements) identifies the maximum time period during which the measured impedance is allowed to exceed the listed impedance tolerance. The maximum excursion within the Exception_window at TP3 shall not exceed ±33% of the nominal cable impedance.

[c]Used in Clause 42. This delay is a budgetary requirement of the upper layers. It is easily met by the jumper cable delay characteristics in this clause.

Table 39–7—Jumper cable assembly characteristics (informative)

Description	Value	Unit
Attenuation (max.) at 625 MHz	8.8	dB
Minimum NEXT loss @ 85 ps Tr (max)	6 24.5	% dB

39.5.1 MDI connectors

Connectors meeting the requirements of 39.5.1.1 (Style-1) and 39.5.1.2 (Style-2) shall be used as the mechanical interface between the PMD of 39.3 and the jumper cable assembly of 39.4. The plug connector shall be used on the jumper cable assembly and the receptacle on the PHY. Style-1 or style-2 connectors may be used as the MDI interface. To limit possible cross-plugging with non-1000BASE-CX interfaces that make use of the Style-1 connector, it is recommended that the Style-2 connector be used as the MDI connector.

39.5.1.1 Style-1 connector specification

The style-1 balanced connector for balanced jumper cable assemblies shall be the 9-pin shielded D-subminiature connector, with the mechanical mating interface defined by IEC 60807-3, having pinouts matching those in Figure 39–6, and the signal quality and electrical requirements of this clause. The style-1 connector pin assignments are shown in Figure 39–6 and Table 39–8.

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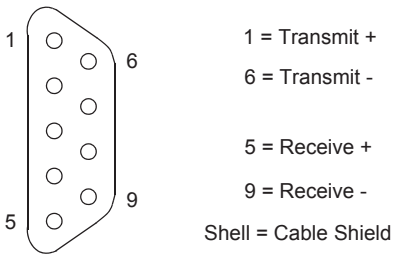

Figure 39–6—Style-1 balanced connector receptacle pin assignments

39.5.1.2 Style-2 connector specification

The style-2 balanced cable connector is the 8-pin shielded ANSI Fibre Channel style-2 connector with the mechanical mating interface defined by IEC 61076-3-103, having pinouts matching those shown in Figure 39–7, and conforming to the signal quality and electrical requirements of this clause.

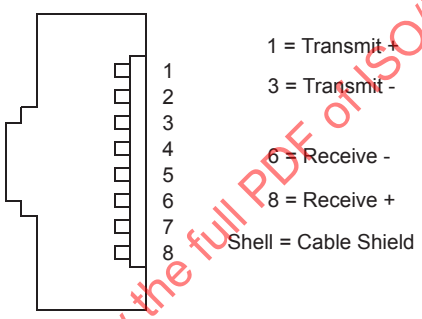

Figure 39–7—Style-2 balanced connector receptacle pin assignments

The style-1 or style-2 connector may be populated with optional contacts to support additional functions. The presence of such contacts in the connector assemblies does not imply support for these additional functions.

NOTE 1—Style-1 pins 2 and 8 (Style-2 pins 7 and 2) are reserved for applications that assign these pins to power and ground.

NOTE 2—Style-1 pin 3 (Style-2 pin 4) is reserved for applications that assign this pin to a Fault Detect function.

NOTE 3—Style-1 pin 7 (Style-2 pin 5) is reserved for applications that assign this pin to an Output Disable function.

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Table 39–8—MDI contact assignments

Contact		PMD MDI signal
Style-1	Style-2	
1	1	Transmit +
2	7	Reserved
3	4	Reserved
4		Mechanical key
5	8	Receive +
6	3	Transmit –
7	5	Reserved
8	2	Reserved
9	6	Receive –

39.5.1.3 Style-2 connector example drawing (informative)

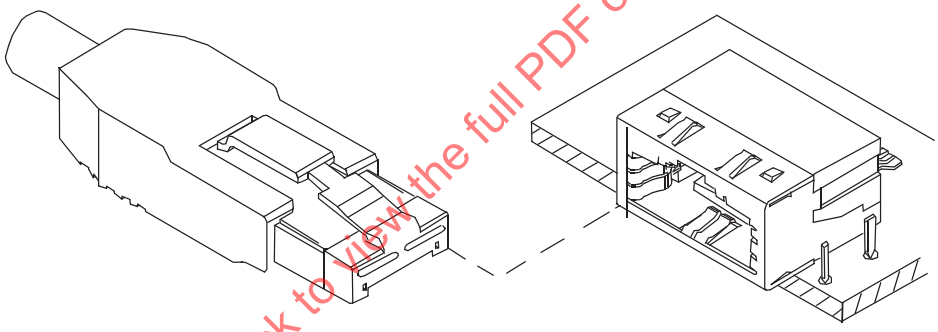

Figure 39–8—Style-2 connector, example drawing

39.5.2 Crossover function

The default jumper cable assembly shall be wired in a crossover fashion as shown in Figure 39–9, with each pair being attached to the transmitter contacts at one end and the receiver contacts at the other end.

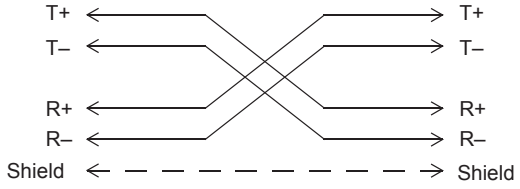

Figure 39–9—Balanced cable wiring

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39.6 Electrical measurement requirements

Electrical measurements shall be performed as described in this subclause.

39.6.1 Transmit rise/fall time

Rise time is a differential measurement across the T+ and T– outputs with a load present (including test equipment) equivalent to that shown in Figure 39–2. Both rising and falling edges are measured. The 100% and 0% levels are the normalized 1 and 0 levels present when sending an alternating K28.5 character stream.

Once the normalized amplitude is determined, the data pattern is changed to a continuous D21.5 character stream. The rise time specification is the time interval between the normalized 20% and 80% amplitude levels.

39.6.2 Transmit skew measurement

The transmitter skew is the time difference between the T+ and T– outputs measured at the normalized 50% crossover point with a load present (including test equipment) equivalent to that shown in Figure 39–2. This measurement is taken using two single ended probes. Skew in the test set-up must be calibrated out.

Normalized amplitudes can be determined using the method described in 39.6.1.

A continuous D21.5 or K28.7 data pattern is transmitted by the device under test. The data is averaged using an averaging scope. An easy method to view and measure the skew between these signals is to invert one.

39.6.3 Transmit eye (normalized and absolute)

This test is made as a differential measurement at the bulkhead connector. The scope trigger must either be a recovered clock as defined in 38.6.8 or a character clock internal to the equipment. The data pattern for this is the alternating K28.5.

If a character trigger is used, the overshoot/undershoot percentages must be measured at all ten bit positions. The load for this test is that shown in Figure 39–2.

39.6.4 Through_connection impedance

This is a differential TDR or equivalent measurement that must be made through a mated connector pair or pairs. Any lead-in trace or cable to the connector that is part of the test fixture should provide a reasonable impedance match so as to not effect the actual measurement. All TDR measurements must be filtered to the TDR rise time specification. Any test fixture used with these TDR tests must be calibrated to remove the effects of the test fixture, and verified to produce accurate results.

The impedance Through_connection interval starts at the first point where the measured impedance exceeds the limits for the termination and ends at the point that the impedance returns to within the termination impedance limits and remains there.

Within this Through_connection interval, an Exception_window exists where the impedance is allowed to exceed the Through_connection impedance limits up to a maximum deviation of ±33% of the nominal link impedance. The Exception_window begins at the point where the measured impedance first exceeds the impedance tolerance limits for Through_connection.

39.6.5 Jumper cable intra-pair differential skew

The jumper cable intra-pair differential skew measurement is conducted to determine the skew, or difference in velocity, of each wire in a cable pair when driven with a differential source. This measurement requires two

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mated connectors, one at the signal source and one at the opposite end of the cable. A pair of matched, complimentary signals (S+, S–) are driven into the T+ and T– contacts of the connector. These signals are time conditioned to start at the same point. This test shall be performed at both ends of the jumper cable assembly.

The jumper cable intra-pair skew is the time difference between the R+ and R– outputs of the excited pair within the jumper cable assembly measured at the normalized 50% crossover point with a load present (including test equipment) equivalent to that shown in Figure 39–2. This measurement is taken using two single ended probes. Skew in the test set-up must be calibrated out.

Normalized amplitudes can be determined using the method described in 39.6.1.

A continuous square wave is used for S+, S–. The data is averaged using an averaging scope. An easy method to view and measure the skew between these signals is to invert one. A differential TDR can provide a convenient method to time condition the input signals.

39.6.6 Receiver link signal

This differential measurement is made at the end of the jumper cable assembly, through mated connectors with a load present (including test equipment) equivalent to that shown in Figure 39–2. The signal is measured with an alternating K28.5 character stream and is tested to the mask requirements of Figure 39–5.

39.6.7 Near-End Cross Talk (NEXT)

NEXT Loss tests are conducted using a differential TDR (or equivalent) filtered to the rise time limit (near-end cross talk at a maximum T_r of 85 ps) in Table 39–6. The T+ and T– inputs of the jumper cable connector are excited to create a disturber pair while the R+ and R– contacts of the disturbed pair are measured within the same connector. The far-end R+/R– outputs of the disturber pair are terminated per Figure 39–2. The R+ and R– signals of the disturbed pair are terminated with a load (including test equipment) equivalent to that shown in Figure 39–2. The T+ and T– inputs of disturbed pair shall be terminated per Figure 39–2. This test shall be performed at both ends of the jumper cable assembly.

39.6.8 Differential time-domain reflectometry (TDR) measurement procedure

The differential TDR test setup measures the reflected waveform returned from a load when driven with a step input. It is obtained by driving the load under test with a step waveform using a driver with a specified source impedance and rise time. The reflected waveform is the difference between (a) the observed waveform at the device under test when driven with the specified test signal, and (b) the waveform that results when driving a standard test load with the same specified test signal. From this measured result we can infer the impedance of the device under test. The derivative of a time-domain reflectometry measurement is the time-domain equivalent of S_{11} parameter testing used in carrier-based systems.

For the measurement of 1000BASE-CX jumper cables, the following test conditions apply:

a) The driving waveform is sourced from a balanced, differential 150 Ω source with an 85 ps rise time (see 39.6.8.1).
b) The test setup is calibrated (see 39.6.8.2).

39.6.8.1 Driving waveform

If the natural differential output impedance of the driving waveform is not 75 Ω, it may be adjusted to within 75 Ω ± 5 Ω by an attenuating resistive pad. When the driving point resistance is 100 Ω (as would be the case with a differential signal source having two independent, antipodal, 50 Ω sources), a good pad design is shown in Figure 39–10, where R1 = 173.2 Ω and R2 = 43.3 Ω. All resistors are surface-mount packages

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soldered directly to the test fixture with no intervening leads or traces, and the whole structure is mounted on a solid ground plane (used in three places).

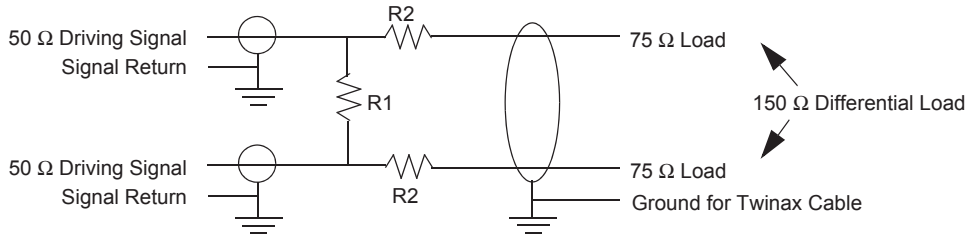

Figure 39–10—Differential TDR pad adapter

If the natural rise time of the driver is less than 85 ps, the resulting measured time-waveforms must be filtered to reduce the apparent rise time to 85 ps ± 10 ps.

39.6.8.2 Calibration of the test setup

Three measurements are made, with a short, and open, and a known test load. The value of the test resistance should be constant to within 1% over the frequency range dc to 6 GHz, and of known value. The value of the test resistance should be within the range 75 Ω ± 5 Ω.

The differential voltages measured across the device-under-test terminals in these three cases are called V_{short}, V_{open}, and V_{test}, respectively. From these three measurements we will compute three intermediate quantities:

$$A = (V_{open} - V_{short}) / 2$$

$$B = (V_{open} + V_{short}) / 2$$

$$Z_0 = Z_{test} \times (V_{open} - V_{test})/(V_{test} - V_{short})$$

The value of Z_0 is the actual driving point impedance of the tester. It must be within 75 Ω ± 5 Ω.

For any device under test, the conversion from measured voltage $V_{measured}$ to impedance is as follows:

Measured impedance = $Z_0 \times (1 + V')/(1 - V')$

where $V' = (V_{measured} - B)/A$.

39.7 Environmental specifications

All equipment subject to this clause shall conform to the requirements of 14.7 and applicable sections of ISO/IEC 11801:1995. References to the MAU or AUI should be replaced with PHY or DTE and AUI to jumper cable assembly, as appropriate. Subclause 14.7.2.4, *Telephony voltage*, should be ignored. Should a case occur where, through a cabling error, two transmitters or receivers are directly connected, no damage shall occur to any transmitter, receiver, or other link component in the system. The link shall be able to withstand such an invalid connection without component failure or degradation for an indefinite period of time.

Systems connected with 1000BASE-CX links shall meet the bonding requirements (common ground connection) of ISO/IEC 11801:1995, subclause 9.2, for shielded cable assemblies. Cable shield(s) shall be

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earthed (chassis ground) through the bulkhead connector shell(s) on both ends of the jumper cable assembly as shown in Figure 39–1.

39.8 Protocol implementation conformance statement (PICS) proforma for Clause 39, Physical Medium Dependent (PMD) sublayer and baseband medium, type 1000BASE-CX[7]

39.8.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 39, Physical Medium Dependent (PMD) sublayer and baseband medium, type 1000BASE-CX, shall complete the following protocol implementation conformance statement (PICS) proforma. A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

39.8.2 Identification

39.8.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

39.8.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 39, Physical Medium Dependent (PMD) sublayer and baseband medium, type 1000BASE-CX
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	No [ ] Yes [ ]

Date of Statement	

[7]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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39.8.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*INS	Installation / cable	39.4	Items marked with INS include installation practices and cable specifications not applicable to a PHY manufacturer	O	Yes [ ] No [ ]
*STY1	Style-1 MDI	39.5	Either the style-1 or the style-2 MDI must be provided	O/1	Yes [ ] No [ ]
*STY2	Style-2 MDI	39.5		O/1	Yes [ ] No [ ]
*TP1	Standardized reference point TP1 exposed and available for testing.	39.3	This point may be made available for use by implementers to certify component conformance.	O	Yes [ ] No [ ]
*TP4	Standardized reference point TP4 exposed and available for testing.	39.3	This point may be made available for use by implementers to certify component conformance.	O	Yes [ ] No [ ]

39.8.4 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and baseband medium, type 1000BASE-CX (short-haul copper)

39.8.4.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FN1	Integration with 1000BASE-X PCS and PMA	39.1		M	Yes [ ]
FN2	Complies with PMD service interface of 38.2	39.1		M	Yes [ ]
FN3	Jumper cables not concatenated	39.1		INS:M	Yes [ ] N/A [ ]
FN5	Transmit function	39.2.1	Convey bits requested by PMD_UNITDATA.request() to the MDI	M	Yes [ ]
FN6	Transmitter logical to electrical mapping	39.2.1;	Logical one equates to electrical high	M	Yes [ ]
FN7	Receive function	39.2.2	Convey bits received from the MDI to PMD_UNITDATA.indication()	M	Yes [ ]
FN8	Receiver logical to electrical mapping	39.2.2	Logical one equates to electrical high.	M	Yes [ ]
FN9	Signal detect function	39.2.3	Report to the PMD service interface the message PMD_SIGNAL.indication(SIGNAL_DETECT)	M	Yes [ ]
FN10	Signal detect behavior	39.2.3	Meets requirements of Table 39–1	M	Yes [ ]

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39.8.4.2 PMD to MDI electrical specifications

Item	Feature	Subclause	Value/Comment	Status	Support
PM1	Measurement requirements	39.3	Electrical measurements are made according to the tests specified in 39.6.	M	Yes [ ]
PM2	Transmitter characteristics	39.3.1	Transmitters meets requirements of Table 39–2	M	Yes [ ]
PM3	Transmitter coupling	39.3.1	AC-coupled	M	Yes [ ]
PM4	Transmitter eye diagram	39.3.1	Meets requirements of Figure 39–3 and Figure 39–4 when terminated as shown in Figure 39–2	M	Yes [ ]
PM5	Receiver coupling	39.3.2	AC-coupled	M	Yes [ ]
PM6	Receiver characteristics	39.3.2	Meet requirements of Table 39–4	M	Yes [ ]
PM7	Measurement conditions for input impedance at TP3	39.3.2	4 ns following reference location	M	Yes [ ]
PM8	Total jitter specification at TP1	39.3.3	Meets specification of bold entries in Table 38–10	TP1:M	Yes [ ] N/A [ ]
PM9	Total jitter specification at TP2	39.3.3	Meets specification of bold entries in Table 38–10	M	Yes [ ]
PM10	Total jitter specification at TP3	39.3.3	Meets specification of bold entries in Table 38–10	INS:M	Yes [ ] N/A [ ]
PM11	Total jitter specification at TP4	39.3.3	Meets specification of bold entries in Table 38–10	TP4:M	Yes [ ] N/A [ ]
PM12	Measurement conditions for jitter	39.3.3	Per 38.6.8 (with exceptions)	M	Yes [ ]

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39.8.4.3 Jumper cable assembly characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
LI1	Two polarized, shielded plug per 39.5.1 and shielded with electrical characteristics per Table 39–6	39.4	As defined in Table 39–6	INS:M	Yes [ ]
LI2	Delivers compliant signal when driven with worst case source signal	39.4	Transmit signal compliant with Figures 39–3 and 39–4, receive signal complaint with Figure 39–5, into a load compliant with Figure 39–2	INS:M	Yes [ ]
LI3	Measurement requirements	39.4	Electrical measurements are made according to the tests specified in 39.6	INS:M	Yes [ ]
LI4	Maximum excursion during Exception_window of cable impedance measurement	39.4	± 33% of nominal cable impedance	INS:M	Yes [ ]
LI5	Measurement conditions for link impedance	39.4	4 ns following the reference location between TP3 and TP4	INS:M	Yes [ ]
LI6	Equalizer needs no adjustment	39.4.1		INS:M	Yes [ ] N/A [ ]
LI7	Cables containing equalizers shall be marked	39.4.1		INS:M	Yes [ ] N/A [ ]
LI8	Cable shielding	39.4.2	Class 2 or better per IEC 61196-1	INS:M	Yes [ ]

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39.8.4.4 Other requirements

Item	Feature	Subclause	Value/Comment	Status	Support
OR1	Style-1 connector	39.5.1.1	9-pin shielded D-subminiature with the mechanical mating interface defined by IEC 60807-3.	STY1:M	Yes [ ] N/A [ ]
OR2	Style-2 connector	39.5.1.2	8-pin ANSI Fibre Channel style-2 connector with mechanical mating interface defined by IEC 61076-3-103.	STY2:M	Yes [ ] N/A [ ]
OR3	Default cable assembly wired in a crossover assembly	39.5.2		INS:M	Yes [ ]
OR4	Transmit rise/fall time measurement	39.6.1	Meet requirements of Table 39–2 with load equivalent to Figure 39–2	M	Yes [ ]
OR5	Transmit skew measurement	39.6.2	Meet requirements of Table 39–2 with load equivalent to Figure 39–2	M	Yes [ ]
OR6	Transmit eye measurement	39.6.3	Meet requirements of Figure 39–3 and Figure 39–4 with load equivalent to Figure 39–2	M	Yes [ ]
OR7	Through_connection impedance measurement	39.6.4	Meet requirements of Table 39–4 with load equivalent to Figure 39–2	M	Yes [ ]
OR8	Jumper cable assembly differential skew measurement	39.6.5	Meet requirements of Table 39–6 with load equivalent to Figure 39–2	M	Yes [ ]
OR9	Receiver link signal	39.6.6	Meet requirements of Figure 39–5 with load equivalent to Figure 39–2	M	Yes [ ]
OR10	NEXT Loss measurement	39.6.7	Meet requirements of Table 39–6 with load equivalent to Figure 39–2	M	Yes [ ]
OR11	Conformance to 14.7 and applicable sections of ISO/IEC 11801:1995.	39.7		M	Yes [ ]
OR12	Cabling errors shall cause no damage to transmitter, receiver, or other link components	39.7		M	Yes [ ]
OR13	Withstand invalid connection for indefinite period	39.7		M	Yes [ ]
OR14	System meets common ground requirements of ISO/IEC 11801	39.7	Per ISO/IEC 11801, subclause 9.2	INS:M	Yes [ ]
OR15	Cable shields earthed on both ends of cable	39.7		INS:M	Yes [ ]

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40. Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer and baseband medium, type 1000BASE-T

40.1 Overview

The 1000BASE-T PHY is one of the Gigabit Ethernet family of high-speed CSMA/CD network specifications. The 1000BASE-T Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) and baseband medium specifications are intended for users who want 1000 Mb/s performance over Category 5 balanced twisted-pair cabling systems. 1000BASE-T signaling requires four pairs of balanced cabling, as specified in ISO/IEC 11801:1995 (Class D) and ANSI/EIA/TIA-568-A-1995 (Category 5), and tested for the additional performance parameters specified in ANSI/EIA/TIA-568-B1 Annex D.

NOTE—ISO/IEC 11801:2002 provides a specification (Class D) for media that exceeds the minimum requirements of this standard.

This clause defines the type 1000BASE-T PCS, type 1000BASE-T PMA sublayer, and type 1000BASE-T Medium Dependent Interface (MDI). Together, the PCS and the PMA sublayer comprise a 1000BASE-T Physical Layer (PHY). Provided in this document are fully functional, electrical, and mechanical specifications for the type 1000BASE-T PCS, PMA, and MDI. This clause also specifies the baseband medium used with 1000BASE-T.

40.1.1 Objectives

The following are the objectives of 1000BASE-T:

a) Support the CSMA/CD MAC
b) Comply with the specifications for the GMII (Clause 35)
c) Support the 1000 Mb/s repeater (Clause 41)
d) Provide line transmission that supports full and half duplex operation
e) Meet or exceed FCC Class A/CISPR or better operation
f) Support operation over 100 meters of copper balanced cabling as defined in 40.7
g) Bit Error Ratio of less than or equal to 10^{-10}
h) Support Auto-Negotiation (Clause 28)

40.1.2 Relationship of 1000BASE-T to other standards

Relations between the 1000BASE-T PHY, the ISO Open Systems Interconnection (OSI) Reference Model, and the IEEE 802.3 CSMA/CD LAN Model are shown in Figure 40–1. The PHY sublayers (shown shaded) in Figure 40–1 connect one Clause 4 Media Access Control (MAC) layer to the medium.

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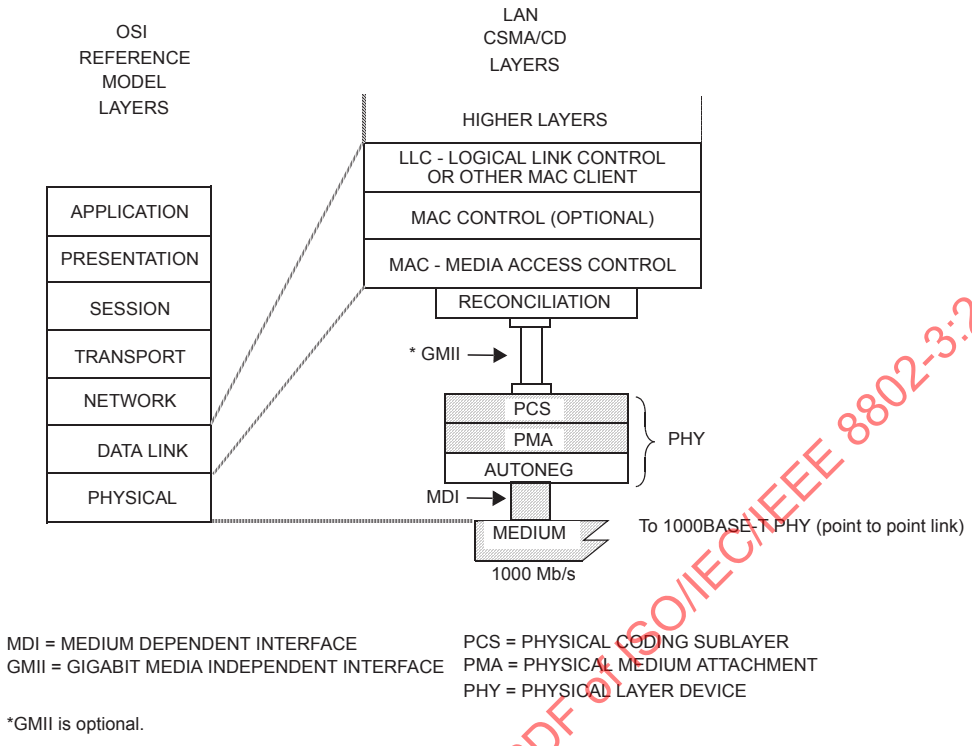

Figure 40–1—Type 1000BASE-T PHY relationship to the ISO Open Systems Interconnection (OSI) Reference Model and the IEEE 802.3 CSMA/CD LAN Model

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40.1.3 Operation of 1000BASE-T

The 1000BASE-T PHY employs full duplex baseband transmission over four pairs of Category 5 balanced cabling. The aggregate data rate of 1000 Mb/s is achieved by transmission at a data rate of 250 Mb/s over each wire pair, as shown in Figure 40–2. The use of hybrids and cancellers enables full duplex transmission by allowing symbols to be transmitted and received on the same wire pairs at the same time. Baseband signaling with a modulation rate of 125 MBd is used on each of the wire pairs. The transmitted symbols are selected from a four-dimensional 5-level symbol constellation. Each four-dimensional symbol can be viewed as a 4-tuple (A_n, B_n, C_n, D_n) of one-dimensional quinary symbols taken from the set {2, 1, 0, –1, –2}. 1000BASE-T uses a continuous signaling system; in the absence of data, Idle symbols are transmitted. Idle mode is a subset of code-groups in that each symbol is restricted to the set {2, 0, –2}to improve synchronization. Five-level Pulse Amplitude Modulation (PAM5) is employed for transmission over each wire pair. The modulation rate of 125 MBd matches the GMII clock rate of 125 MHz and results in a symbol period of 8 ns.

A 1000BASE-T PHY can be configured either as a MASTER PHY or as a SLAVE PHY. The MASTER-SLAVE relationship between two stations sharing a link segment is established during Auto-Negotiation (see Clause 28, 40.5, and Annex 28C). The MASTER PHY uses a local clock to determine the timing of transmitter operations. The SLAVE PHY recovers the clock from the received signal and uses it to determine the timing of transmitter operations, i.e., it performs loop timing, as illustrated in Figure 40–3. In a multiport to single-port connection, the multiport device is typically set to be MASTER and the single-port device is set to be SLAVE.

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The PCS and PMA subclauses of this document are summarized in 40.1.3.1 and 40.1.3.2. Figure 40–3 shows the functional block diagram.

A 1000BASE-T PHY with the optional Energy-Efficient Ethernet (EEE) capability may optionally enter the Low Power Idle (LPI) mode to conserve energy during periods of low link utilization. The “Assert LPI” request at the GMII is encoded in the transmitted symbols. Detection of LPI signaling in the received symbols is indicated as “Assert LPI” at the GMII. When LPI signaling is simultaneously transmitted and received, an energy-efficient 1000BASE-T PHY ceases transmission and deactivates transmit and receive functions to conserve energy. The PHY periodically transmits during this quiet period to allow the remote PHY to refresh its receiver state (e.g., timing recovery, adaptive filter coefficients) and thereby track long-term variation in the timing of the link or the underlying channel characteristics. If, during the quiet or refresh periods, normal interframe is asserted at the GMII, the PHY reactivates transmit and receive functions and initiates transmission. This transmission will be detected by the remote PHY, causing it to also exit the LPI mode.

The conditions for supporting the optional EEE capability are defined in 78.3.

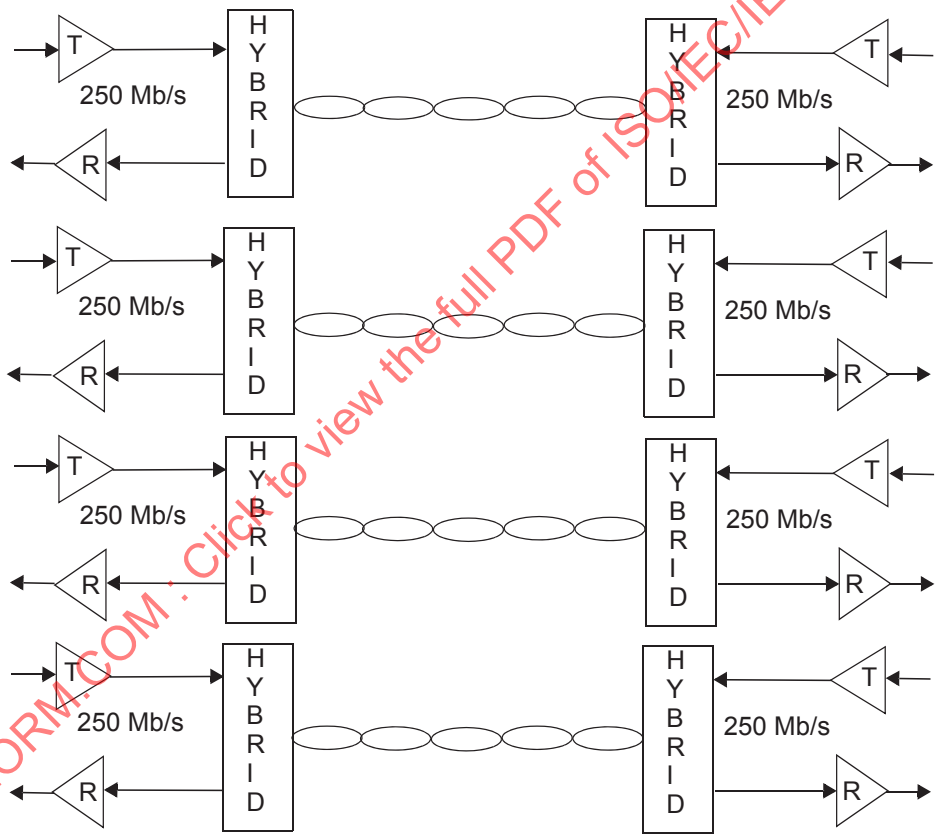

Figure 40–2—1000BASE-T topology

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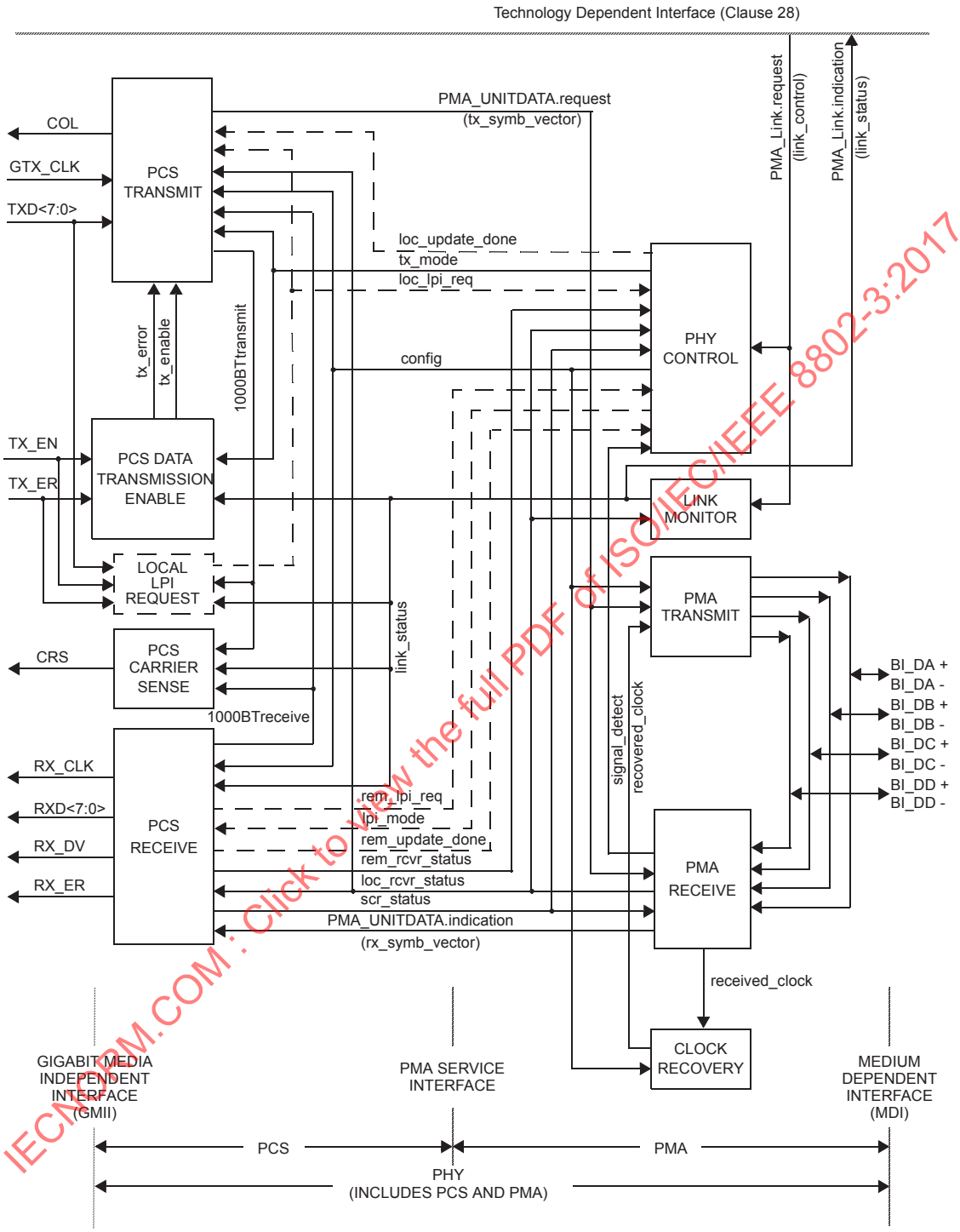

NOTE—The recovered_clock arc is shown to indicate delivery of the received clock signal back the PMA TRANSMIT for loop timing

NOTE—Signals and functions shown with dashed lines are only required for the EEE capability.

Figure 40–3—Functional block diagram

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40.1.3.1 Physical Coding Sublayer (PCS)

The 1000BASE-T PCS couples a Gigabit Media Independent Interface (GMII), as described in Clause 35, to a Physical Medium Attachment (PMA) sublayer.

The functions performed by the PCS comprise the generation of continuous code-groups to be transmitted over four channels and the processing of code-groups received from the remote PHY. The process of converting data bits to code-groups is called 4D-PAM5, which refers to the four-dimensional 5-level Pulse Amplitude Modulation coding technique used. Through this coding scheme, eight bits are converted to one transmission of four quinary symbols.

During the beginning of a frame's transmission, when TX_EN is asserted from the GMII, two code-groups representing the Start-of-Stream delimiter are transmitted followed by code-groups representing the octets coming from the GMII. Immediately following the data octets, the GMII sets TX_EN=FALSE, upon which the end of a frame is transmitted. The end of a frame consists of two convolutional state reset symbol periods and two End-of-Stream delimiter symbol periods. This is followed by an optional series of carrier extend symbol periods and, possibly, the start of a new frame during frame bursting. Otherwise, the end of a frame is followed by a series of symbols encoded in the idle mode. The nature of the encoding that follows the end of a frame is determined by the GMII signals TX_ER and TXD<7:0> as specified in Clause 35.

Between frames, a special subset of code-groups using only the symbols {2, 0, –2} is transmitted. This is called idle mode. Idle mode encoding takes into account the information of whether the local PHY is operating reliably or not (see 40.4.2.4) and allows this information to be conveyed to the remote station. During normal operation, idle mode is followed by a data mode that begins with a Start-of-Stream delimiter.

When the PHY supports the optional EEE capability, Idle mode encoding also conveys to the remote PHY information of whether the local PHY is requesting entry into the LPI mode or not. Such requests are a direct translation of "Assert LPI" at the GMII. In addition, Idle mode encoding conveys to the remote PHY whether the local PHY has completed the update of its receiver state or not, as indicated by the PMA PHY Control function.

Further patterns are used for signaling a transmit error and other control functions during transmission of a data stream.

The PCS Receive processes code-groups provided by the PMA. The PCS Receive detects the beginning and the end of frames of data and, during the reception of data, descrambles and decodes the received code-groups into octets RXD<7:0> that are passed to the GMII. The conversion of code-groups to octets uses an 8B1Q4 data decoding technique. PCS Receive also detects errors in the received sequences and signals them to the GMII. Furthermore, the PCS contains a PCS Carrier Sense function, a PCS Collision Presence function, and a management interface.

The PCS functions and state diagrams are specified in 40.3. The signals provided by the PCS at the GMII conform to the interface requirements of Clause 35. The PCS Service Interfaces to the GMII and the PMA are abstract message-passing interfaces specified in 40.2.

40.1.3.2 Physical Medium Attachment (PMA) sublayer

The PMA couples messages from the PMA service interface onto the balanced cabling physical medium and provides the link management and PHY Control functions. The PMA provides full duplex communications at 125 MBd over four pairs of balanced cabling up to 100 m in length.

The PMA Transmit function comprises four independent transmitters to generate five-level, pulse-amplitude modulated signals on each of the four pairs BI_DA, BI_DB, BI_DC, and BI_DD, as described in 40.4.3.1.

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The PMA Receive function comprises four independent receivers for five-level pulse-amplitude modulated signals on each of the four pairs BI_DA, BI_DB, BI_DC, and BI_DD, as described in 40.4.3.2. This signal encoding technique is referred to as 4D-PAM5. The receivers are responsible for acquiring clock and providing code-groups to the PCS as defined by the PMA_UNITDATA.indication message. The PMA also contains functions for Link Monitor.

The PMA PHY Control function generates signals that control the PCS and PMA sublayer operations. PHY Control begins following the completion of Auto-Negotiation and provides the start-up functions required for successful 1000BASE-T operation. It determines whether the PHY operates in a normal state, enabling data transmission over the link segment, or whether the PHY sends special code-groups that represent the idle mode. The latter occurs when either one or both of the PHYs that share a link segment are not operating reliably.

When the PHY supports the optional EEE capability, the PMA PHY Control function also coordinates transitions between the LPI mode and the normal operating mode.

PMA functions and state diagrams are specified in 40.4. PMA electrical specifications are given in 40.6.

40.1.4 Signaling

1000BASE-T signaling is performed by the PCS generating continuous code-group sequences that the PMA transmits over each wire pair. The signaling scheme achieves a number of objectives including

a) Forward Error Correction (FEC) coded symbol mapping for data.
b) Algorithmic mapping and inverse mapping from octet data to a quartet of quinary symbols and back.
c) Uncorrelated symbols in the transmitted symbol stream.
d) No correlation between symbol streams traveling both directions on any pair combination.
e) No correlation between symbol streams on pairs BI_DA, BI_DB, BI_DC, and BI_DD.
f) Idle mode uses a subset of code-groups in that each symbol is restricted to the set {2, 0, –2}to ease synchronization, start-up, and retraining.
g) Ability to rapidly or immediately determine if a symbol stream represents data or idle or carrier extension.
h) Robust delimiters for Start-of-Stream delimiter (SSD), End-of-Stream delimiter (ESD), and other control signals.
i) Ability to signal the status of the local receiver to the remote PHY to indicate that the local receiver is not operating reliably and requires retraining.
j) Optionally, ability to signal to the remote PHY a request to enter the LPI mode and to exit the LPI mode and return to normal operation.
k) Optionally, ability to signal to the remote PHY that the update of the local receiver state (e.g., timing recovery, adaptive filter coefficients) has completed.
l) Ability to automatically detect and correct for pair swapping and unexpected crossover connections.
m) Ability to automatically detect and correct for incorrect polarity in the connections.
n) Ability to automatically correct for differential delay variations across the wire-pairs.

The PHY may operate in three basic modes, normal mode, training mode, or an optional LPI mode. In normal mode, PCS generates code-groups that represent data, control, or idles for transmission by the PMA. In training mode, the PCS is directed to generate only idle code-groups for transmission by the PMA, which enable the receiver at the other end to train until it is ready to operate in normal mode. In LPI mode, the PCS is directed to generate only idle code-groups encoded with LPI request and update status indications, or zeros as dictated by the PMA PHY Control function. (See the PCS reference diagram in 40.2.)

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40.1.5 Inter-sublayer interfaces

All implementations of the balanced cabling link are compatible at the MDI. Designers are free to implement circuitry within the PCS and PMA in an application-dependent manner provided that the MDI and GMII (if the GMII is implemented) specifications are met. When the PHY is incorporated within the physical bounds of a single-port device or a multiport device, implementation of the GMII is optional. System operation from the perspective of signals at the MDI and management objects are identical whether the GMII is implemented or not.

40.1.6 Conventions in this clause

The body of this clause contains state diagrams, including definitions of variables, constants, and functions. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

The notation used in the state diagrams follows the conventions of 21.5.

The values of all components in test circuits shall be accurate to within ±1% unless otherwise stated.

Default initializations, unless specifically specified, are left to the implementer.

40.2 1000BASE-T Service Primitives and Interfaces

1000BASE-T transfers data and control information across the following four service interfaces:

a) Gigabit Media Independent Interface (GMII)
b) PMA Service Interface
c) Medium Dependent Interface (MDI)
d) Technology-Dependent Interface

The GMII is specified in Clause 35; the Technology-Dependent Interface is specified in Clause 28. The PMA Service Interface is defined in 40.2.2 and the MDI is defined in 40.8.

40.2.1 Technology-Dependent Interface

1000BASE-T uses the following service primitives to exchange status indications and control signals across the Technology-Dependent Interface as specified in Clause 28:

PMA_LINK.request (link_control)

PMA_LINK.indication (link_status)

40.2.1.1 PMA_LINK.request

This primitive allows the Auto-Negotiation algorithm to enable and disable operation of the PMA as specified in 28.2.6.2.

40.2.1.1.1 Semantics of the primitive

PMA_LINK.request (link_control)

The link_control parameter can take on one of three values: SCAN_FOR_CARRIER, DISABLE, or ENABLE.

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SCAN_FOR_CARRIER	Used by the Auto-Negotiation algorithm prior to receiving any fast link pulses. During this mode the PMA reports link_status=FAIL.PHY processes are disabled.
DISABLE	Set by the Auto-Negotiation algorithm in the event fast link pulses are detected. PHY processes are disabled. This allows the Auto-Negotiation algorithm to determine how to configure the link.
ENABLE	Used by Auto-Negotiation to turn control over to the PHY for data processing functions.

40.2.1.1.2 When generated

Auto-Negotiation generates this primitive to indicate a change in link_control as described in Clause 28.

40.2.1.1.3 Effect of receipt

This primitive affects operation of the PMA Link Monitor function as defined in 40.4.2.5.

40.2.1.2 PMA_LINK.indication

This primitive is generated by the PMA to indicate the status of the underlying medium as specified in 28.2.6.1. This primitive informs the PCS, PMA PHY Control function, and the Auto-Negotiation algorithm about the status of the underlying link.

40.2.1.2.1 Semantics of the primitive

PMA_LINK.indication (link_status)

The link_status parameter can take on one of three values: FAIL, READY, or OK.

FAIL	No valid link established.
READY	The Link Monitor function indicates that a 1000BASE-T link is intact and ready to be established.
OK	The Link Monitor function indicates that a valid 1000BASE-T link is established. Reliable reception of signals transmitted from the remote PHY is possible.

40.2.1.2.2 When generated

The PMA generates this primitive continuously to indicate the value of link_status in compliance with the state diagram given in Figure 40–17.

40.2.1.2.3 Effect of receipt

The effect of receipt of this primitive is specified in 40.3.3.1.

40.2.2 PMA Service Interface

1000BASE-T uses the following service primitives to exchange symbol vectors, status indications, and control signals across the service interfaces:

PMA_TXMODE.indication (tx_mode)

PMA_CONFIG.indication (config)

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PMA_UNITDATA.request (tx_symb_vector)

PMA_UNITDATA.indication (rx_symb_vector)

PMA_SCRSTATUS.request (scr_status)

PMA_RXSTATUS.indication (loc_rcvr_status)

PMA_REMRXSTATUS.request (rem_rcvr_status)

PMA_LPIMODE.indication(lpi_mode)

PMA_LPIREQ.request(loc_lpi_req)

PMA_REMLPIREQ.request(rem_lpi_req)

PMA_UPDATE.indication(loc_update_done)

PMA_REMUPDATE.request(rem_update_done)

The use of these primitives is illustrated in Figure 40–4.

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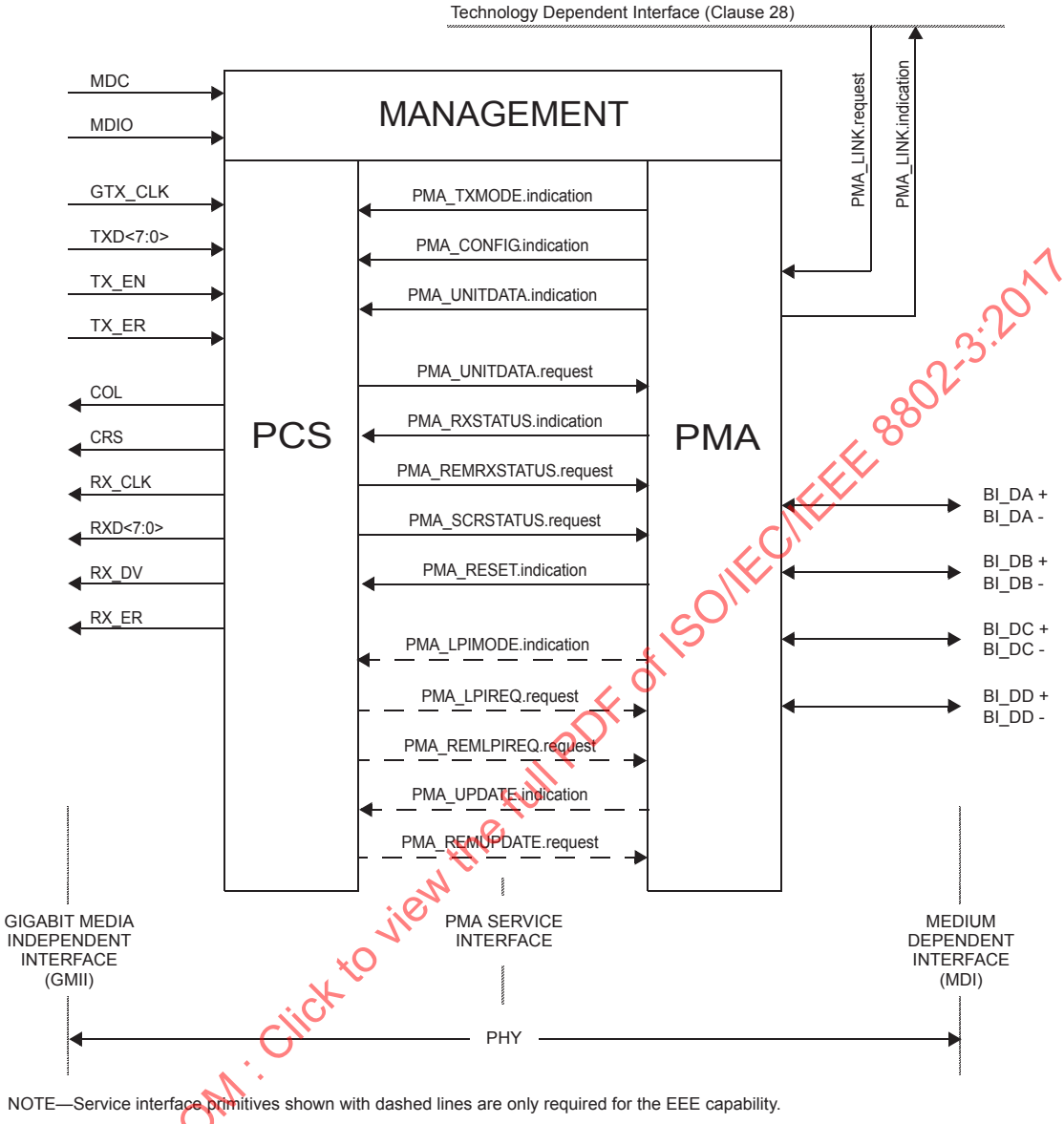

NOTE—Service interface primitives shown with dashed lines are only required for the EEE capability.

Figure 40–4—1000BASE-T service interfaces

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40.2.3 PMA_TXMODE.indication

The transmitter in a 1000BASE-T link normally sends over the four pairs, code-groups that can represent a GMII data stream, control information, or idles.

40.2.3.1 Semantics of the primitive

PMA_TXMODE.indication (tx_mode)

PMA_TXMODE.indication specifies to PCS Transmit via the parameter tx_mode what sequence of code-groups the PCS should be transmitting. The parameter tx_mode can take on one of the following three values of the form:

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SEND_N This value is continuously asserted when transmission of sequences of code-groups representing a GMII data stream (data mode), control mode or idle mode is to take place.

SEND_I This value is continuously asserted in case transmission of sequences of code-groups representing the idle mode is to take place.

SEND_Z This value is continuously asserted in case transmission of zeros is required.

40.2.3.2 When generated

The PMA PHY Control function generates PMA_TXMODE.indication messages continuously.

40.2.3.3 Effect of receipt

Upon receipt of this primitive, the PCS performs its Transmit function as described in 40.3.1.3.

40.2.4 PMA_CONFIG.indication

Each PHY in a 1000BASE-T link is capable of operating as a MASTER PHY and as a SLAVE PHY. MASTER-SLAVE configuration is determined during Auto-Negotiation (40.5). The result of this negotiation is provided to the PMA.

40.2.4.1 Semantics of the primitive

PMA_CONFIG.indication (config)

PMA_CONFIG.indication specifies to PCS and PMA Transmit via the parameter config whether the PHY must operate as a MASTER PHY or as a SLAVE PHY. The parameter config can take on one of the following two values of the form:

MASTER This value is continuously asserted when the PHY must operate as a MASTER PHY.

SLAVE This value is continuously asserted when the PHY must operate as a SLAVE PHY.

40.2.4.2 When generated

PMA generates PMA_CONFIG.indication messages continuously.

40.2.4.3 Effect of receipt

PCS and PMA Clock Recovery perform their functions in MASTER or SLAVE configuration according to the value assumed by the parameter config.

40.2.5 PMA_UNITDATA.request

This primitive defines the transfer of code-groups in the form of the tx_symb_vector parameter from the PCS to the PMA. The code-groups are obtained in the PCS Transmit function using the encoding rules defined in 40.3.1.3 to represent GMII data streams, an idle mode, or other sequences.

40.2.5.1 Semantics of the primitive

PMA_UNITDATA.request (tx_symb_vector)

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During transmission, the PMA_UNITDATA.request simultaneously conveys to the PMA via the parameter tx_symb_vector the value of the symbols to be sent over each of the four transmit pairs BI_DA, BI_DB, BI_DC, and BI_DD. The tx_symb_vector parameter takes on the form:

SYMB_4D A vector of four quinary symbols, one for each of the four transmit pairs BI_DA, BI_DB, BI_DC, and BI_DD. Each quinary symbol may take on one of the values –2, –1, 0, +1, or +2.

The quinary symbols that are elements of tx_symb_vector are called, according to the pair on which each will be transmitted, tx_symb_vector[BI_DA], tx_symb_vector[BI_DB], tx_symb_vector[BI_DC], and tx_symb_vector[BI_DD].

40.2.5.2 When generated

The PCS generates PMA_UNITDATA.request (SYMB_4D) synchronously with every transmit clock cycle.

40.2.5.3 Effect of receipt

Upon receipt of this primitive the PMA transmits on the MDI the signals corresponding to the indicated quinary symbols. The parameter tx_symb_vector is also used by the PMA Receive function to process the signals received on pairs BI_DA, BI_DB, BI_DC, and BI_DD.

40.2.6 PMA_UNITDATA.indication

This primitive defines the transfer of code-groups in the form of the rx_symb_vector parameter from the PMA to the PCS.

40.2.6.1 Semantics of the primitive

PMA_UNITDATA.indication (rx_symb_vector)

During reception the PMA_UNITDATA.indication simultaneously conveys to the PCS via the parameter rx_symb_vector the values of the symbols detected on each of the four receive pairs BI_DA, BI_DB, BI_DC, and BI_DD. The rx_symbol_vector parameter takes on the form:

SYMB_4DA vector of four quinary symbols, one for each of the four receive pairs BI_DA, BI_DB, BI_DC, and BI_DD. Each quinary symbol may take on one of the values –2, –1, 0, +1, or +2.

The quinary symbols that are elements of rx_symb_vector are called, according to the pair upon which each symbol was received, rx_symbol_vector[BI_DA], rx_symbol_vector[BI_DB], rx_symbol_vector[BI_DC], and rx_symb_vector[BI_DD].

40.2.6.2 When generated

The PMA generates PMA_UNITDATA.indication (SYMB_4D) messages synchronously with signals received at the MDI. The nominal rate of the PMA_UNITDATA.indication primitive is 125 MHz, as governed by the recovered clock.

40.2.6.3 Effect of receipt

The effect of receipt of this primitive is unspecified.

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40.2.7 PMA_SCRSTATUS.request

This primitive is generated by PCS Receive to communicate the status of the descrambler for the local PHY. The parameter scr_status conveys to the PMA Receive function the information that the descrambler has achieved synchronization.

40.2.7.1 Semantics of the primitive

PMA_SCRSTATUS.request (scr_status)

The scr_status parameter can take on one of two values of the form:

OK The descrambler has achieved synchronization.
NOT_OK The descrambler is not synchronized.

40.2.7.2 When generated

PCS Receive generates PMA_SCRSTATUS.request messages continuously.

40.2.7.3 Effect of receipt

The effect of receipt of this primitive is specified in 40.4.2.3, 40.4.2.4, and 40.4.6.1.

40.2.8 PMA_RXSTATUS.indication

This primitive is generated by PMA Receive to indicate the status of the receive link at the local PHY. The parameter loc_rcvr_status conveys to the PCS Transmit, PCS Receive, PMA PHY Control function, and Link Monitor the information on whether the status of the overall receive link is satisfactory or not. Note that loc_rcvr_status is used by the PCS Receive decoding functions. The criterion for setting the parameter loc_rcvr_status is left to the implementer. It can be based, for example, on observing the mean-square error at the decision point of the receiver and detecting errors during reception of symbol streams that represent the idle mode.

40.2.8.1 Semantics of the primitive

PMA_RXSTATUS.indication (loc_rcvr_status)

The loc_rcvr_status parameter can take on one of two values of the form:

OK This value is asserted and remains true during reliable operation of the receive link for the local PHY.
NOT_OK This value is asserted whenever operation of the link for the local PHY is unreliable.

40.2.8.2 When generated

PMA Receive generates PMA_RXSTATUS.indication messages continuously on the basis of signals received at the MDI.

40.2.8.3 Effect of receipt

The effect of receipt of this primitive is specified in Figure 40–16a and in subclauses 40.2 and 40.4.6.2.

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40.2.9 PMA_REMRXSTATUS.request

This primitive is generated by PCS Receive to indicate the status of the receive link at the remote PHY as communicated by the remote PHY via its encoding of its loc_rcvr_status parameter. The parameter rem_rcvr_status conveys to the PMA PHY Control function the information on whether reliable operation of the remote PHY is detected or not. The criterion for setting the parameter rem_rcvr_status is left to the implementer. It can be based, for example, on asserting rem_rcvr_status is NOT_OK until loc_rcvr_status is OK and then asserting the detected value of rem_rcvr_status after proper PCS receive decoding is achieved.

40.2.9.1 Semantics of the primitive

PMA_REMRXSTATUS.request (rem_rcvr_status)

The rem_rcvr_status parameter can take on one of two values of the form:

OK The receive link for the remote PHY is operating reliably.
NOT_OKReliable operation of the receive link for the remote PHY is not detected.

40.2.9.2 When generated

The PCS generates PMA_REMRXSTATUS.request messages continuously on the basis on signals received at the MDI.

40.2.9.3 Effect of receipt

The effect of receipt of this primitive is specified in Figure 40–16a.

40.2.10 PMA_RESET.indication

This primitive is used to pass the PMA Reset function to the PCS (pcs_reset=ON) when reset is enabled.

The PMA_RESET.indication primitive can take on one of two values:

TRUE Reset is enabled.
FALSE Reset is not enabled.

40.2.10.1 When generated

The PMA Reset function is executed as described in 40.4.2.1.

40.2.10.2 Effect of receipt

The effect of receipt of this primitive is specified in 40.4.2.1.

40.2.11 PMA_LPIMODE.indication

This primitive is generated by the PMA to indicate that the PHY has entered the LPI mode of operation.

40.2.11.1 Semantics of the primitive

PMA_LPIMODE.indication(lpi_mode)

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PMA_LPIMODE.indication specifies to the PCS Receive function, via the parameter lpi_mode, whether or not the PHY has entered LPI mode. The parameter lpi_mode can take on one of the following values of the form:

ON	This value is asserted with the PHY is operating in LPI mode.
OFF	This value is asserted during normal operation.

40.2.11.2 When generated

The PMA PHY Control function generates PMA_LPIMODE.indication messages continuously.

40.2.11.3 Effect of receipt

Upon receipt of this primitive, the PCS performs its Receive function as described in 40.3.1.4.

40.2.12 PMA_LPIREQ.request

This primitive is generated by the PCS to indicate a request to enter the LPI mode.

40.2.12.1 Semantics of the primitive

PMA_LPIREQ.request (loc_lpi_req)

PMA_LPIREQ.request specifies to the PMA PHY Control, via the parameter loc_lpi_req, whether or not the PHY is requested to enter the LPI mode. The parameter loc_lpi_req can take on one of the following values of the form:

TRUE	This value is continuously asserted when “Assert LPI” is present on the GMII. Note that “Assert LPI” at the GMII implies that no frame transmission is in progress hence 1000BT transmit (see 40.3.3.1) will be set to FALSE by the PCS Transmit state diagram.
FALSE	This value is continuously asserted when “Assert LPI” is not present at the GMII.

40.2.12.2 When generated

The PCS Local LPI Request function generates PMA_LPIREQ.request messages continuously.

40.2.12.3 Effect of receipt

Upon receipt of this primitive, the PMA performs its PHY Control function as described in 40.4.2.4.

40.2.13 PMA_REMLPIREQ.request

This primitive is generated by the PCS to indicate a request to enter LPI mode as communicated by the remote PHY via its encoding of its loc_lpi_req parameter.

40.2.13.1 Semantics of the primitive

PMA_REMLPIREQ.request (rem_lpi_req)

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PMA_REMLPIREQ.request specifies to the PMA PHY Control, via the parameter rem_lpi_req, whether or not the remote PHY is requesting entry into the LPI mode. The parameter rem_lpi_req can take on one of the following values of the form:

TRUE	This value is continuously asserted when LPI is encoded in the received symbols.
FALSE	This value is continuously asserted when LPI is not encoded in the received symbols.

40.2.13.2 When generated

The PCS Receive function generates PMA_REMLPIREQ.request messages continuously on the basis of the signals received at the MDI.

40.2.13.3 Effect of receipt

Upon receipt of this primitive, the PMA performs its PHY Control function as described in 40.4.2.4.

40.2.14 PMA_UPDATE.indication

This primitive is generated by the PMA to indicate that the PHY has completed the update of its receiver state (e.g., timing recovery, adaptive filter coefficients).

40.2.14.1 Semantics of the primitive

PMA_UPDATE.indication(loc_update_done)

PMA_UPDATE.indication specifies to the PCS Transmit functions, via the parameter loc_update_done, whether or not the PHY has completed the update of its receiver state. The parameter loc_update_done can take on one of the following values of the form:

TRUE	This value is asserted when the PHY has completed the current update.
FALSE	This value is asserted when the PHY is ready for the next update or when the current update is still in progress.

40.2.14.2 When generated

The PMA PHY Control function generates PMA_UPDATE.indication messages continuously.

40.2.14.3 Effect of receipt

Upon receipt of this primitive, the PCS performs its Transmit function as described in 40.3.1.3 and 40.3.1.4.

40.2.15 PMA_REMUPDATE.request

This primitive is generated by the PCS to indicate that the remote PHY has completed the update of its receiver state (e.g., timing recovery, adaptive filter coefficients).

40.2.15.1 Semantics of the primitive

PMA_REMUPDATE.request(rem_update_done)

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PMA_REMUPDATE.indication specifies to the PMA PHY Control function, via the parameter rem_update_done, whether or not the remote PHY has completed the update of its receiver state. The parameter rem_update_done can take on one of the following values of the form:

TRUE	This value is asserted when the remote PHY has completed the current update.
FALSE	This value is asserted to when the remote PHY is ready for the next update or when the current update is still in progress.

40.2.15.2 When generated

The PCS Receive function generates PMA_REMUDPATE.request messages continuously.

40.2.15.3 Effect of receipt

Upon receipt of this primitive, the PMA performs its PHY Control function as described in 40.4.2.4.

40.3 Physical Coding Sublayer (PCS)

The PCS comprises one PCS Reset function and four simultaneous and asynchronous operating functions. The PCS operating functions are: PCS Transmit Enable, PCS Transmit, PCS Receive, and PCS Carrier Sense. All operating functions start immediately after the successful completion of the PCS Reset function.

The PCS reference diagram, Figure 40–5, shows how the four operating functions relate to the messages of the PCS-PMA interface. Connections from the management interface (signals MDC and MDIO) to other layers are pervasive, and are not shown in Figure 40–5. Management is specified in Clause 30. See also Figure 40–7, which defines the structure of frames passed from PCS to PMA.

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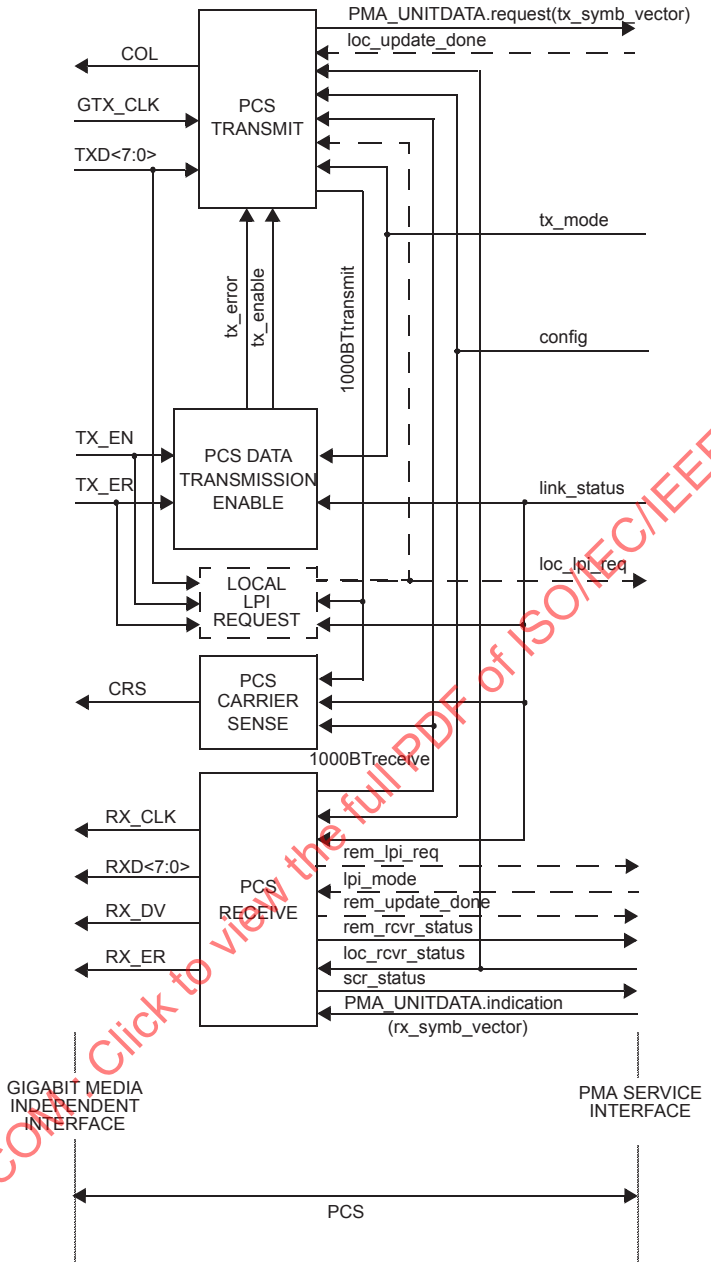

NOTE—Signals and functions shown with dashed lines are only required for the EEE capability.

Figure 40–5—PCS reference diagram

40.3.1 PCS functions

40.3.1.1 PCS Reset function

PCS Reset initializes all PCS functions. The PCS Reset function shall be executed whenever one of the following conditions occur:

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a) Power on (see 36.2.5.1.3).

b) The receipt of a request for reset from the management entity.

PCS Reset sets pcs_reset=ON while any of the above reset conditions hold true. All state diagrams take the open-ended pcs_reset branch upon execution of PCS Reset. The reference diagrams do not explicitly show the PCS Reset function.

40.3.1.2 PCS Data Transmission Enable

The PCS Data Transmission Enabling process generates the signals tx_enable and tx_error, which PCS Transmit uses for data and carrier extension encoding. The process uses logical operations on tx_mode, TX_ER, TX_EN, and TXD<7:0>. The PCS shall implement the Data Transmission Enabling process as depicted in Figure 40–8 including compliance with the associated state variables as specified in 40.3.3.

40.3.1.3 PCS Transmit function

The PCS Transmit function shall conform to the PCS Transmit state diagram in Figure 40–10.

The PCS Transmit function generates the GMII signal COL based on whether a reception is occurring simultaneously with transmission. The PCS Transmit function is not required to generate the GMII signal COL in a 1000BASE-T PHY that does not support half duplex operation.

In each symbol period, PCS Transmit generates a code-group (A_n, B_n, C_n, D_n) that is transferred to the PMA via the PMA_UNITDATA.request primitive. The PMA transmits symbols A_n, B_n, C_n, D_n over wire-pairs BI_DA, BI_DB, BI_DC, and BI_DD respectively. The integer, n, is a time index that is introduced to establish a temporal relationship between different symbol periods. A symbol period, T, is nominally equal to 8 ns. In normal mode of operation, between streams of data indicated by the parameter tx_enable, PCS Transmit generates sequences of vectors using the encoding rules defined for the idle mode. Upon assertion of tx_enable, PCS Transmit passes a SSD of two consecutive vectors of four quinary symbols to the PMA, replacing the first two preamble octets. Following the SSD, each TXD<7:0> octet is encoded using an 4D-PAM5 technique into a vector of four quinary symbols until tx_enable is de-asserted. If TX_ER is asserted while tx_enable is also asserted, then PCS Transmit passes to the PMA vectors indicating a transmit error. Note that if the signal TX_ER is asserted while SSD is being sent, the transmission of the error condition is delayed until transmission of SSD has been completed. Following the de-assertion of tx_enable, a Convolutional State Reset (CSReset) of two consecutive code-groups, followed by an ESD of two consecutive code-groups, is generated, after which the transmission of idle or control mode is resumed.

If a PMA_TXMODE.indication message has the value SEND_Z, PCS Transmit passes a vector of zeros at each symbol period to the PMA via the PMA_UNITDATA.request primitive.

If a PMA_TXMODE.indication message has the value SEND_I, PCS Transmit generates sequences of code-groups according to the encoding rule in training mode. Special code-groups that use only the values {+2, 0, −2} are transmitted in this case. Training mode encoding also takes into account the value of the parameter loc_rcvr_status. By this mechanism, a PHY indicates the status of its own receiver to the link partner during idle transmission.

When the PHY supports the optional EEE capability, the LPI mode encoding also takes into account the value of the parameter loc_lpi_req. By this mechanism, the PHY indicates whether it requests to operate in LPI mode or return to the normal mode of operation. In addition, LPI mode encoding takes into account the value of loc_update_done. By this mechanism, the PHY indicates whether it has completed the update of its receiver state (e.g., timing recovery, adaptive filter coefficients) or not, as indicated by the PMA PHY Control function.

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In the normal mode of operation, the PMA_TXMODE.indication message has the value SEND_N, and the PCS Transmit function uses an 8B1Q4 coding technique to generate at each symbol period code-groups that represent data, control or idle based on the code-groups defined in Table 40–1 and Table 40–2. During transmission of data, the TXD<7:0> bits are scrambled by the PCS using a side-stream scrambler, then encoded into a code-group of quinary symbols and transferred to the PMA. During data encoding, PCS Transmit utilizes a three-state convolutional encoder.

The transition from idle or carrier extension to data is signalled by inserting a SSD, and the end of transmission of data is signalled by an ESD. Further code-groups are reserved for signaling the assertion of TX_ER within a stream of data, carrier extension, CSReset, and other control functions. During idle and carrier extension encoding, special code-groups with symbol values restricted to the set {2, 0, –2} are used. These code-groups are also generated using the transmit side-stream scrambler. However, the encoding rules for the idle, SSD, and carrier extend code-groups are different from the encoding rules for data, CSReset, CSExtend, and ESD code-groups. During idle, SSD, and carrier extension, the PCS Transmit function reverses the sign of the transmitted symbols. This allows, at the receiver, sequences of code-groups that represent data, CSReset, CSExtend, and ESD to be easily distinguished from sequences of code-groups that represent SSD, carrier extension, and idle.

PCS encoding involves the generation of the four-bit words $Sx_n[3:0]$, $Sy_n[3:0]$, and $Sg_n[3:0]$ from which the quinary symbols (A_n, B_n, C_n, D_n) are obtained. The four-bit words $Sx_n[3:0]$, $Sy_n[3:0]$, and $Sg_n[3:0]$ are determined (as explained in 40.3.1.3.2) from sequences of pseudorandom binary symbols derived from the transmit side-stream scrambler.

40.3.1.3.1 Side-stream scrambler polynomials

The PCS Transmit function employs side-stream scrambling. If the parameter config provided to the PCS by the PMA PHY Control function via the PMA_CONFIG.indication message assumes the value MASTER, PCS Transmit shall employ

$$g_M(x) = 1 + x^{13} + x^{33}$$

as transmitter side-stream scrambler generator polynomial. If the PMA_CONFIG.indication message assumes the value of SLAVE, PCS Transmit shall employ

$$g_S(x) = 1 + x^{20} + x^{33}$$

as transmitter side-stream scrambler generator polynomial. An implementation of master and slave PHY side-stream scramblers by linear-feedback shift registers is shown in Figure 40–6. The bits stored in the shift register delay line at time n are denoted by $Scr_n[32:0]$. At each symbol period, the shift register is advanced by one bit, and one new bit represented by $Scr_n[0]$ is generated. The transmitter side-stream scrambler is reset upon execution of the PCS Reset function. If PCS Reset is executed, all bits of the 33-bit vector representing the side-stream scrambler state are arbitrarily set. The initialization of the scrambler state is left to the implementer. In no case shall the scrambler state be initialized to all zeros.

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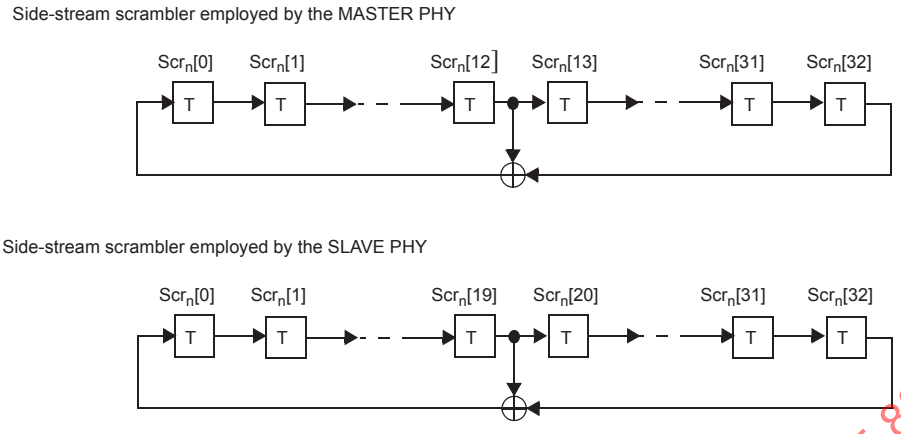

Figure 40–6—A realization of side-stream scramblers by linear feedback shift registers

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40.3.1.3.2 Generation of bits $Sx_n[3:0]$, $Sy_n[3:0]$, and $Sg_n[3:0]$

PCS Transmit encoding rules are based on the generation, at time n, of the twelve bits $Sx_n[3:0]$, $Sy_n[3:0]$, and $Sg_n[3:0]$. The eight bits, $Sx_n[3:0]$ and $Sy_n[3:0]$, are used to generate the scrambler octet $Sc_n[7:0]$ for decorrelating the GMII data word TXD<7:0> during data transmission and for generating the idle and training symbols. The four bits, $Sg_n[3:0]$, are used to randomize the signs of the quinary symbols (A_n, B_n, C_n, D_n) so that each symbol stream has no dc bias. These twelve bits are generated in a systematic fashion using three bits, X_n, Y_n, and $Scr_n[0]$, and an auxiliary generating polynomial, g(x). The two bits, X_n and Y_n, are mutually uncorrelated and also uncorrelated with the bit $Scr_n[0]$. For both master and slave PHYs, they are obtained by the same linear combinations of bits stored in the transmit scrambler shift register delay line. These two bits are derived from elements of the same maximum-length shift register sequence of length $2^{33} - 1$ as $Scr_n[0]$, but shifted in time. The associated delays are all large and different so that there is no short-term correlation among the bits $Scr_n[0]$, X_n, and Y_n. The bits X_n and Y_n are generated as follows:

$X_n = Scr_n[4] \wedge Scr_n[6]$

$Y_n = Scr_n[1] \wedge Scr_n[5]$

where ^ denotes the XOR logic operator. From the three bits X_n, Y_n, and $Scr_n[0]$, further mutually uncorrelated bit streams are obtained systematically using the generating polynomial

$g(x) = x^3 \wedge x^8$

The four bits $Sy_n[3:0]$ are generated using the bit $Scr_n[0]$ and g(x) as in the following equations:

$Sy_n[0] = Scr_n[0]$

$Sy_n[1] = g(Scr_n[0]) = Scr_n[3] \wedge Scr_n[8]$

$Sy_n[2] = g^2(Scr_n[0]) = Scr_n[6] \wedge Scr_n[16]$

$Sy_n[3] = g^3(Scr_n[0]) = Scr_n[9] \wedge Scr_n[14] \wedge Scr_n[19] \wedge Scr_n[24]$

The four bits $Sx_n[3:0]$ are generated using the bit X_n and g(x) as in the following equations:

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$Sx_n[0] = X_n = Scr_n[4] \wedge Scr_n[6]$

$Sx_n[1] = g(X_n) = Scr_n[7] \wedge Scr_n[9] \wedge Scr_n[12] \wedge Scr_n[14]$

$Sx_n[2] = g^2(X_n) = Scr_n[10] \wedge Scr_n[12] \wedge Scr_n[20] \wedge Scr_n[22]$

$Sx_n[3] = g^3(X_n) = Scr_n[13] \wedge Scr_n[15] \wedge Scr_n[18] \wedge Scr_n[20] \wedge Scr_n[23] \wedge Scr_n[25] \wedge Scr_n[28] \wedge Scr_n[30]$

The four bits $Sg_n[3:0]$ are generated using the bit Y_n and g(x) as in the following equations:

$Sg_n[0] = Y_n = Scr_n[1] \wedge Scr_n[5]$

$Sg_n[1] = g(Y_n) = Scr_n[4] \wedge Scr_n[8] \wedge Scr_n[9] \wedge Scr_n[13]$

$Sg_n[2] = g^2(Y_n) = Scr_n[7] \wedge Scr_n[11] \wedge Scr_n[17] \wedge Scr_n[21]$

$Sg_n[3] = g^3(Y_n) = Scr_n[10] \wedge Scr_n[14] \wedge Scr_n[15] \wedge Scr_n[19] \wedge Scr_n[20] \wedge Scr_n[24] \wedge Scr_n[25] \wedge Scr_n[29]$

By construction, the twelve bits $Sx_n[3:0]$, $Sy_n[3:0]$, and $Sg_n[3:0]$ are derived from elements of the same maximum-length shift register sequence of length $2^{33}–1$ as $Scr_n[0]$, but shifted in time by varying delays. The associated delays are all large and different so that there is no apparent correlation among the bits.

40.3.1.3.3 Generation of bits $Sc_n[7:0]$

The bits $Sc_n[7:0]$ are used to scramble the GMII data octet TXD[7:0] and for control, idle, and training mode quartet generation. The definition of these bits is dependent upon the bits $Sx_n[3:0]$ and $Sy_n[3:0]$ that are specified in 40.3.1.3.2, the variable tx_mode that is obtained through the PMA Service Interface, the variable tx_enable_n that is defined in Figure 40–8, and the time index n.

The four bits $Sc_n[7:4]$ are defined as

$$Sc_n[7:4] = \begin{cases} Sx_n[3:0] & \text{if } (tx_enable_{n-2} = 1) \\ [0\ 0\ 0\ 0] & \text{else} \end{cases}$$

The bits $Sc_n[3:1]$ are defined as

$$Sc_n[3:1] = \begin{cases} [0\ 0\ 0] & \text{if (tx_mode = SEND_Z)} \\ Sy_n[3:1] & \text{else if } (n\text{-}n_0) = 0 \text{ (mod 2)} \\ (Sy_{n-1}[3:1] \wedge [1\ 1\ 1]) & \text{else} \end{cases}$$

where n_0 denotes the time index of the last transmitter side-stream scrambler reset.

The bit $Sc_n[0]$ is defined as

$$Sc_n[0] = \begin{cases} 0 & \text{if } (tx_mode = \text{SEND_Z}) \\ Sy_n[0] & \text{else} \end{cases}$$

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40.3.1.3.4 Generation of bits $Sd_n[8:0]$

The PCS Transmit function generates a nine-bit word $Sd_n[8:0]$ from Sc_n that represents either a convolutionally encoded stream of data, control, or idle mode code-groups. The convolutional encoder uses a three-bit word $cs_n[2:0]$, which is defined as

$$cs_n[1] = \begin{cases} Sd_n[6] \wedge cs_{n-1}[0] & \text{if } (tx_enable_{n-2} = 1) \\ 0 & \text{else} \end{cases}$$

$$cs_n[2] = \begin{cases} Sd_n[7] \wedge cs_{n-1}[1] & \text{if } (tx_enable_{n-2} = 1) \\ 0 & \text{else} \end{cases}$$

$$cs_n[0] = cs_{n-1}[2]$$

from which $Sd_n[8]$ is obtained as

$$Sd_n[8] = cs_n[0]$$

The convolutional encoder bits are non-zero only during the transmission of data. Upon the completion of a frame, the convolutional encoder bits are reset using the bit $csreset_n$. The bit $csreset_n$ is defined as

$$csreset_n = (tx_enable_{n-2}) \text{ and } (\text{not } tx_enable_n)$$

The bits $Sd_n[7:6]$ are derived from the bits $Sc_n[7:6]$, the GMII data bits $TXD_n[7:6]$, and from the convolutional encoder bits as

$$Sd_n[7] = \begin{cases} Sc_n[7] \wedge TXD_n[7] & \text{if } (csreset_n = 0 \text{ and } tx_enable_{n-2} = 1) \\ cs_{n-1}[1] & \text{else if } (csreset_n = 1) \\ Sc_n[7] & \text{else} \end{cases}$$

$$Sd_n[6] = \begin{cases} Sc_n[6] \wedge TXD_n[6] & \text{if } (csreset_n = 0 \text{ and } tx_enable_{n-2} = 1) \\ cs_{n-1}[0] & \text{else if } (csreset_n = 1) \\ Sc_n[6] & \text{else} \end{cases}$$

The bits $Sd_n[5:4]$ are derived from the bits $Sc_n[5:4]$ and the GMII data bits $TXD_n[5:4]$ as

$$Sd_n[5:4] = \begin{cases} Sc_n[5:4] \wedge TXD_n[5:4] & \text{if } (tx_enable_{n-2} = 1) \\ Sc_n[5:4] & \text{else} \end{cases}$$

The bit $Sd_n[3]$ is used to scramble the GMII data bit $TXD_n[3]$ during data mode and to encode loc_lpi_req otherwise. It is defined as

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$$Sd_n[3] = \begin{cases} Sc_n[3] \wedge TXD_n[3] & \text{if } (tx_enable_{n-2} = 1) \\ Sc_n[3] \wedge 1 & \text{else if } ((loc_lpi_req = \text{TRUE}) \text{ and } (tx_mode \neq \text{SEND_Z})) \\ Sc_n[3] & \text{else} \end{cases}$$

The bit $Sd_n[2]$ is used to scramble the GMII data bit $TXD_n[2]$ during data mode and to encode loc_rcvr_status otherwise. It is defined as

$$Sd_n[2] = \begin{cases} Sc_n[2] \wedge TXD_n[2] & \text{if } (tx_enable_{n-2} = 1) \\ Sc_n[2] \wedge 1 & \text{else if } ((loc_rcvr_status = \text{OK}) \text{ and } (tx_mode \neq \text{SEND_Z})) \\ Sc_n[2] & \text{else} \end{cases}$$

The bits $Sd_n[1:0]$ are used to transmit carrier extension information during tx_mode=SEND_N and are thus dependent upon the bits $cext_n$ and $cext_err_n$. In addition, bit $Sd_n[1]$ is used to encode loc_update_done. These bits are dependent on the variable tx_error_n, which is defined in Figure 40–8. These bits are defined as

$$cext_n = \begin{cases} tx_error_n & \text{if } ((tx_enable_n = 0) \text{ and } (TXD_n[7:0] = 0x0F)) \\ 0 & \text{else} \end{cases}$$

$$cext_err_n = \begin{cases} tx_error_n & \text{if } ((tx_enable_n = 0) \text{ and } (TXD_n[7:0] \neq 0x0F) \text{ and } (loc_lpi_req = FALSE)) \\ 0 & \text{else} \end{cases}$$

$$Sd_n[1] = \begin{cases} Sc_n[1] \wedge TXD_n[1] & \text{if } (tx_enable_{n-2} = 1) \\ Sc_n[1] \wedge 1 & \text{else if } ((loc_update_done = \text{TRUE}) \text{ and } (tx_mode \neq \text{SEND_Z})) \\ Sc_n[1] \wedge cext_err_n & \text{else} \end{cases}$$

$$Sd_n[0] = \begin{cases} Sc_n[0] \wedge TXD_n[0] & \text{if } (tx_enable_{n-2} = 1) \\ Sc_n[0] \wedge cext_n & \text{else} \end{cases}$$

40.3.1.3.5 Generation of quinary symbols TA_n, TB_n, TC_n, TD_n

The nine-bit word $Sd_n[8:0]$ is mapped to a quartet of quinary symbols (TA_n, TB_n, TC_n, TD_n) according to Table 40–1 and Table 40–2 shown as $Sd_n[6:8] + Sd_n[5:0]$.

Encoding of error indication:

If tx_error_n=1 when the condition (tx_enable_n * tx_enable_{n-2}) = 1, error indication is signaled by means of symbol substitution. In this condition, the values of $Sd_n[5:0]$ are ignored during mapping and the symbols corresponding to the row denoted as “xmt_err” in Table 40–1 and Table 40–2 shall be used.

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Encoding of Convolutional Encoder Reset:

If tx_error_n=0 when the variable $csreset_n$ = 1, the convolutional encoder reset condition is normal. This condition is indicated by means of symbol substitution, where the values of $Sd_n[5:0]$ are ignored during mapping and the symbols corresponding to the row denoted as "CSReset" in Table 40–1 and Table 40–2 shall be used.

Encoding of Carrier Extension during Convolutional Encoder Reset:

If tx_error_n=1 when the variable $csreset_n$ = 1, the convolutional encoder reset condition indicates carrier extension. In this condition, the values of $Sd_n[5:0]$ are ignored during mapping and the symbols corresponding to the row denoted as "CSExtend" in Table 40–1 and Table 40–2 shall be used when TXD_n = 0x'0F, and the row denoted as "CSExtend_Err" in Table 40–1 and Table 40–2 shall be used when TXD_n ≠ 0x'0F. The latter condition denotes carrier extension with error. In case carrier extension with error is indicated during the first octet of CSReset, the error condition shall be encoded during the second octet of CSReset, and during the subsequent two octets of the End-of-Stream delimiter as well. Thus, the error condition is assumed to persist during the symbol substitutions at the End-of-Stream.

Encoding of Start-of-Stream delimiter:

The Start-of-Stream delimiter (SSD) is related to the condition SSD_n, which is defined as $(tx_enable_n) * (!tx_enable_{n-2}) = 1$, where "*" and "!" denote the logic AND and NOT operators, respectively. For the generation of SSD, the first two octets of the preamble in a data stream are mapped to the symbols corresponding to the rows denoted as SSD1 and SSD2 respectively in Table 40–1. The symbols corresponding to the SSD1 row shall be used when the condition $(tx_enable_n) * (!tx_enable_{n-1}) = 1$. The symbols corresponding to the SSD2 row shall be used when the condition $(tx_enable_{n-1}) * (!tx_enable_{n-2}) = 1$.

Encoding of End-of-Stream delimiter:

The definition of an End-of-Stream delimiter (ESD) is related to the condition ESD_n, which is defined as $(!tx_enable_{n-2}) * (tn_enable_{n-4}) = 1$. This occurs during the third and fourth symbol periods after transmission of the last octet of a data stream.

If carrier extend error is indicated during ESD, the symbols corresponding to the ESD_Ext_Err row shall be used. The two conditions upon which this may occur are

$(tx_error_n) * (tx_error_{n-1}) * (tx_error_{n-2}) * (TXD_n \neq 0x0F) = 1$, and
$(tx_error_n) * (tx_error_{n-1}) * (tx_error_{n-2}) * (tx_error_{n-3}) * (TXD_n \neq 0x0F) = 1$.

The symbols corresponding to the ESD1 row in Table 40–1 shall be used when the condition $(!tx_enable_{n-2}) * (tx_enable_{n-3}) = 1$, in the absence of carrier extend error indication at time n.

The symbols corresponding to the ESD2_Ext_0 row in Table 40–1 shall be used when the condition $(!tx_enable_{n-3}) * (tx_enable_{n-4}) * (!tx_error_n) * (!tx_error_{n-1}) = 1$.

The symbols corresponding to the ESD2_Ext_1 row in Table 40–1 shall be used when the condition $(!tx_enable_{n-3}) * (tx_enable_{n-4}) * (!tx_error_n) * (tx_error_{n-1}) * (tx_error_{n-2}) * (tx_error_{n-3}) = 1$.

The symbols corresponding to the ESD2_Ext_2 row in Table 40–1 shall be used when the condition $(!tx_enable_{n-3}) * (tx_enable_{n-4}) * (tx_error_n) * (tx_error_{n-1}) * (tx_error_{n-2}) * (tx_error_{n-3}) * (TXD_n = 0x0F) = 1$, in the absence of carrier extend error indication.

NOTE—The ASCII for Table 40–1 and Table 40–2 is available at http://standards.ieee.org/downloads/802.3/.[8]

[8]*Copyright release for symbol codes:* Users of this standard may freely reproduce the symbol codes in this subclause so it can be used for its intended purpose.

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Table 40–1—Bit-to-symbol mapping (even subsets)

		$Sd_n[6:8] = [000]$	$Sd_n[6:8] = [010]$	$Sd_n[6:8] = [100]$	$Sd_n[6:8] = [110]$
Condition	**$Sd_n[5:0]$**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**
Normal	000000	0, 0, 0, 0	0, 0,+1,+1	0,+1,+1, 0	0,+1, 0,+1
Normal	000001	–2, 0, 0, 0	–2, 0,+1,+1	–2,+1,+1, 0	–2,+1, 0,+1
Normal	000010	0,–2, 0, 0	0,–2,+1,+1	0,–1,+1, 0	0,–1, 0,+1
Normal	000011	–2,–2, 0, 0	–2,–2,+1,+1	–2,–1,+1, 0	–2,–1, 0,+1
Normal	000100	0, 0,–2, 0	0, 0,–1,+1	0,+1,–1, 0	0,+1,–2,+1
Normal	000101	–2, 0,–2, 0	–2, 0,–1,+1	–2,+1,–1, 0	–2,+1,–2,+1
Normal	000110	0,–2,–2, 0	0,–2,–1,+1	0,–1,–1, 0	0,–1,–2,+1
Normal	000111	–2,–2,–2, 0	–2,–2,–1,+1	–2,–1,–1, 0	–2,–1,–2,+1
Normal	001000	0, 0, 0,–2	0, 0,+1,–1	0,+1,+1,–2	0,+1, 0,–1
Normal	001001	–2, 0, 0,–2	–2, 0,+1,–1	–2,+1,+1,–2	–2,+1, 0,–1
Normal	001010	0,–2, 0,–2	0,–2,+1,–1	0,–1,+1,–2	0,–1, 0,–1
Normal	001011	–2,–2, 0,–2	–2,–2,+1,–1	–2,–1,+1,–2	–2,–1, 0,–1
Normal	001100	0, 0,–2,–2	0, 0,–1,–1	0,+1,–1,–2	0,+1,–2,–1
Normal	001101	–2, 0,–2,–2	–2, 0,–1,–1	–2,+1,–1,–2	–2,+1,–2,–1
Normal	001110	0,–2,–2,–2	0,–2,–1,–1	0,–1,–1,–2	0,–1,–2,–1
Normal	001111	–2,–2,–2,–2	–2,–2,–1,–1	–2,–1,–1,–2	–2,–1,–2,–1
Normal	010000	+1,+1,+1,+1	+1,+1, 0, 0	+1, 0, 0,+1	+1, 0,+1, 0
Normal	010001	–1,+1,+1,+1	–1,+1, 0, 0	–1, 0, 0,+1	–1, 0,+1, 0
Normal	010010	+1,–1,+1,+1	+1,–1, 0, 0	+1,–2, 0,+1	+1,–2,+1, 0
Normal	010011	–1,–1,+1,+1	–1,–1, 0, 0	–1,–2, 0,+1	–1,–2,+1, 0
Normal	010100	+1,+1,–1,+1	+1,+1,–2, 0	+1, 0,–2,+1	+1, 0,–1, 0
Normal	010101	–1,+1,–1,+1	–1,+1,–2, 0	–1, 0,–2,+1	–1, 0,–1, 0
Normal	010110	+1,–1,–1,+1	+1,–1,–2, 0	+1,–2,–2,+1	+1,–2,–1, 0
Normal	010111	–1,–1,–1,+1	–1,–1,–2, 0	–1,–2,–2,+1	–1,–2,–1, 0
Normal	011000	+1,+1,+1,–1	+1,+1, 0,–2	+1, 0, 0,–1	+1, 0,+1,–2
Normal	011001	–1,+1,+1,–1	–1,+1, 0,–2	–1, 0, 0,–1	–1, 0,+1,–2
Normal	011010	+1,–1,+1,–1	+1,–1, 0,–2	+1,–2, 0,–1	+1,–2,+1,–2
Normal	011011	–1,–1,+1,–1	–1,–1, 0,–2	–1,–2, 0,–1	–1,–2,+1,–2
Normal	011100	+1,+1,–1,–1	+1,+1,–2,–2	+1, 0,–2,–1	+1, 0,–1,–2
Normal	011101	–1,+1,–1,–1	–1,+1,–2,–2	–1, 0,–2,–1	–1, 0,–1,–2
Normal	011110	+1,–1,–1,–1	+1,–1,–2,–2	+1,–2,–2,–1	+1,–2,–1,–2

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Table 40–1—Bit-to-symbol mapping (even subsets) *(continued)*

		$Sd_n[6:8] = [000]$	$Sd_n[6:8] = [010]$	$Sd_n[6:8] = [100]$	$Sd_n[6:8] = [110]$
Condition	**$Sd_n[5:0]$**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**
Normal	011111	–1,–1,–1,–1	–1,–1,–2,–2	–1,–2,–2,–1	–1,–2,–1,–2
Normal	100000	+2, 0, 0, 0	+2, 0,+1,+1	+2,+1,+1, 0	+2,+1, 0,+1
Normal	100001	+2,–2, 0, 0	+2,–2,+1,+1	+2,–1,+1, 0	+2,–1, 0,+1
Normal	100010	+2, 0,–2, 0	+2, 0,–1,+1	+2,+1,–1, 0	+2,+1,–2,+1
Normal	100011	+2,–2,–2, 0	+2,–2,–1,+1	+2,–1,–1, 0	+2,–1,–2,+1
Normal	100100	+2, 0, 0,–2	+2, 0,+1,–1	+2,+1,+1,–2	+2,+1, 0,–1
Normal	100101	+2,–2, 0,–2	+2,–2,+1,–1	+2,–1,+1,–2	+2,–1, 0,–1
Normal	100110	+2, 0,–2,–2	+2, 0,–1,–1	+2,+1,–1,–2	+2,+1,–2,–1
Normal	100111	+2,–2,–2,–2	+2,–2,–1,–1	+2,–1,–1,–2	+2,–1,–2,–1
Normal	101000	0, 0,+2, 0	+1,+1,+2, 0	+1, 0,+2,+1	0,+1,+2,+1
Normal	101001	–2, 0,+2, 0	–1,+1,+2, 0	–1, 0,+2,+1	–2,+1,+2,+1
Normal	101010	0,–2,+2, 0	+1,–1,+2, 0	+1,–2,+2,+1	0,–1,+2,+1
Normal	101011	–2,–2,+2, 0	–1,–1,+2, 0	–1,–2,+2,+1	–2,–1,+2,+1
Normal	101100	0, 0,+2,–2	+1,+1,+2,–2	+1, 0,+2,–1	0,+1,+2,–1
Normal	101101	–2, 0,+2,–2	–1,+1,+2,–2	–1, 0,+2,–1	–2,+1,+2,–1
Normal	101110	0,–2,+2,–2	+1,–1,+2,–2	+1,–2,+2,–1	0,–1,+2,–1
Normal	101111	–2,–2,+2,–2	–1,–1,+2,–2	–1,–2,+2,–1	–2,–1,+2,–1
Normal	110000	0,+2, 0, 0	0,+2,+1,+1	+1,+2, 0,+1	+1,+2,+1, 0
Normal	110001	–2,+2, 0, 0	–2,+2,+1,+1	–1,+2, 0,+1	–1,+2,+1, 0
Normal	110010	0,+2,–2, 0	0,+2,–1,+1	+1,+2,–2,+1	+1,+2,–1, 0
Normal	110011	–2,+2,–2, 0	–2,+2,–1,+1	–1,+2,–2,+1	–1,+2,–1, 0
Normal	110100	0,+2, 0,–2	0,+2,+1,–1	+1,+2, 0,–1	+1,+2,+1,–2
Normal	110101	–2,+2, 0,–2	–2,+2,+1,–1	–1,+2, 0,–1	–1,+2,+1,–2
Normal	110110	0,+2,–2,–2	0,+2,–1,–1	+1,+2,–2,–1	+1,+2,–1,–2
Normal	110111	–2,+2,–2,–2	–2,+2,–1,–1	–1,+2,–2,–1	–1,+2,–1,–2
Normal	111000	0, 0, 0,+2	+1,+1, 0,+2	0,+1,+1,+2	+1, 0,+1,+2
Normal	111001	–2, 0, 0,+2	–1,+1, 0,+2	–2,+1,+1,+2	–1, 0,+1,+2
Normal	111010	0,–2, 0,+2	+1,–1, 0,+2	0,–1,+1,+2	+1,–2,+1,+2
Normal	111011	–2,–2, 0,+2	–1,–1, 0,+2	–2,–1,+1,+2	–1,–2,+1,+2
Normal	111100	0, 0,–2,+2	+1,+1,–2,+2	0,+1,–1,+2	+1, 0,–1,+2
Normal	111101	–2, 0,–2,+2	–1,+1,–2,+2	–2,+1,–1,+2	–1, 0,–1,+2
Normal	111110	0,–2,–2,+2	+1,–1,–2,+2	0,–1,–1,+2	+1,–2,–1,+2

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Table 40–1—Bit-to-symbol mapping (even subsets) *(continued)*

		$Sd_n[6:8] = [000]$	$Sd_n[6:8] = [010]$	$Sd_n[6:8] = [100]$	$Sd_n[6:8] = [110]$
Condition	**$Sd_n[5:0]$**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**
Normal	111111	–2,–2,–2,+2	–1,–1,–2,+2	–2,–1,–1,+2	–1,–2,–1,+2
xmt_err	XXXXXX	0,+2,+2,0	+1,+1,+2,+2	+2,+1,+1,+2	+2,+1,+2,+1
CSExtend_Err	XXXXXX	–2,+2,+2,–2	–1,–1,+2,+2	+2,–1,–1,+2	+2,–1,+2,–1
CSExtend	XXXXXX	+2, 0, 0,+2	+2,+2,+1,+1	+1,+2,+2,+1	+1,+2,+1,+2
CSReset	XXXXXX	+2,–2,–2,+2	+2,+2,–1,–1	–1,+2,+2,–1	–1,+2,–1,+2
SSD1	XXXXXX	+2,+2,+2,+2	—	—	—
SSD2	XXXXXX	+2,+2,+2,–2	—	—	—
ESD1	XXXXXX	+2,+2,+2,+2	—	—	—
ESD2_Ext_0	XXXXXX	+2,+2,+2,–2	—	—	—
ESD2_Ext_1	XXXXXX	+2,+2, –2,+2	—	—	—
ESD2_Ext_2	XXXXXX	+2,–2,+2,+2	—	—	—
ESD_Ext_Err	XXXXXX	–2,+2,+2,+2	—	—	—
Idle/Carrier Extension	000000	0, 0, 0, 0	—	—	—
Idle/Carrier Extension	000001	–2, 0, 0, 0	—	—	—
Idle/Carrier Extension	000010	0,–2, 0, 0	—	—	—
Idle/Carrier Extension	000011	–2,–2, 0, 0	—	—	—
Idle/Carrier Extension	000100	0, 0,–2, 0	—	—	—
Idle/Carrier Extension	000101	–2, 0,–2, 0	—	—	—
Idle/Carrier Extension	000110	0,–2,–2, 0	—	—	—
Idle/Carrier Extension	000111	–2,–2,–2, 0	—	—	—
Idle/Carrier Extension	001000	0, 0, 0,–2	—	—	—
Idle/Carrier Extension	001001	–2, 0, 0,–2	—	—	—
Idle/Carrier Extension	001010	0,–2, 0,–2	—	—	—
Idle/Carrier Extension	001011	–2,–2, 0,–2	—	—	—
Idle/Carrier Extension	001100	0, 0,–2,–2	—	—	—

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Table 40–1—Bit-to-symbol mapping (even subsets) *(continued)*

		$Sd_n[6:8] = [000]$	$Sd_n[6:8] = [010]$	$Sd_n[6:8] = [100]$	$Sd_n[6:8] = [110]$
Condition	**$Sd_n[5:0]$**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**
Idle/Carrier Extension	001101	–2, 0,–2,–2	—	—	—
Idle/Carrier Extension	001110	0,–2,–2,–2	—	—	—
Idle/Carrier Extension	001111	–2,–2,–2,–2	—	—	—

Table 40–2—Bit-to-symbol mapping (odd subsets)

		$Sd_n[6:8] = [001]$	$Sd_n[6:8] = [011]$	$Sd_n[6:8] = [101]$	$Sd_n[6:8] = [111]$
Condition	**$Sd_n[5:0]$**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**
Normal	000000	0, 0, 0,+1	0, 0,+1, 0	0,+1,+1,+1	0,+1, 0, 0
Normal	000001	–2, 0, 0,+1	–2, 0,+1, 0	–2,+1,+1,+1	–2,+1, 0, 0
Normal	000010	0,–2, 0,+1	0,–2,+1, 0	0,–1,+1,+1	0,–1, 0, 0
Normal	000011	–2,–2, 0,+1	–2,–2,+1, 0	–2,–1,+1,+1	–2,–1, 0, 0
Normal	000100	0, 0,–2,+1	0, 0,–1, 0	0,+1,–1,+1	0,+1,–2, 0
Normal	000101	–2, 0,–2,+1	–2, 0,–1, 0	–2,+1,–1,+1	–2,+1,–2, 0
Normal	000110	0,–2,–2,+1	0,–2,–1, 0	0,–1,–1,+1	0,–1,–2, 0
Normal	000111	–2,–2,–2,+1	–2,–2,–1, 0	–2,–1,–1,+1	–2,–1,–2, 0
Normal	001000	0, 0, 0,–1	0, 0,+1,–2	0,+1,+1,–1	0,+1, 0,–2
Normal	001001	–2, 0, 0,–1	–2, 0,+1,–2	–2,+1,+1,–1	–2,+1, 0,–2
Normal	001010	0,–2, 0,–1	0,–2,+1,–2	0,–1,+1,–1	0,–1, 0,–2
Normal	001011	–2,–2, 0,–1	–2,–2,+1,–2	–2,–1,+1,–1	–2,–1, 0,–2
Normal	001100	0, 0,–2,–1	0, 0,–1,–2	0,+1,–1,–1	0,+1,–2,–2
Normal	001101	–2, 0,–2,–1	–2, 0,–1,–2	–2,+1,–1,–1	–2,+1,–2,–2
Normal	001110	0,–2,–2,–1	0,–2,–1,–2	0,–1,–1,–1	0,–1,–2,–2
Normal	001111	–2,–2,–2,–1	–2,–2,–1,–2	–2,–1,–1,–1	–2,–1,–2,–2
Normal	010000	+1,+1,+1, 0	+1,+1, 0,+1	+1, 0, 0, 0	+1, 0,+1,+1
Normal	010001	–1,+1,+1, 0	–1,+1, 0,+1	–1, 0, 0, 0	–1, 0,+1,+1
Normal	010010	+1,–1,+1, 0	+1,–1, 0,+1	+1,–2, 0, 0	+1,–2,+1,+1
Normal	010011	–1,–1,+1, 0	–1,–1, 0,+1	–1,–2, 0, 0	–1,–2,+1,+1
Normal	010100	+1,+1,–1, 0	+1,+1,–2,+1	+1, 0,–2, 0	+1, 0,–1,+1
Normal	010101	–1,+1,–1, 0	–1,+1,–2,+1	–1, 0,–2, 0	–1, 0,–1,+1

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Table 40–2—Bit-to-symbol mapping (odd subsets) *(continued)*

		$Sd_n[6:8] = [001]$	$Sd_n[6:8] = [011]$	$Sd_n[6:8] = [101]$	$Sd_n[6:8] = [111]$
Condition	**$Sd_n[5:0]$**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**
Normal	010110	+1,–1,–1, 0	+1,–1,–2,+1	+1,–2,–2, 0	+1,–2,–1,+1
Normal	010111	–1,–1,–1, 0	–1,–1,–2,+1	–1,–2,–2, 0	–1,–2,–1,+1
Normal	011000	+1,+1,+1,–2	+1,+1, 0,–1	+1, 0, 0,–2	+1, 0,+1,–1
Normal	011001	–1,+1,+1,–2	–1,+1, 0,–1	–1, 0, 0,–2	–1, 0,+1,–1
Normal	011010	+1,–1,+1,–2	+1,–1, 0,–1	+1,–2, 0,–2	+1,–2,+1,–1
Normal	011011	–1,–1,+1,–2	–1,–1, 0,–1	–1,–2, 0,–2	–1,–2,+1,–1
Normal	011100	+1,+1,–1,–2	+1,+1,–2,–1	+1, 0,–2,–2	+1, 0,–1,–1
Normal	011101	–1,+1,–1,–2	–1,+1,–2,–1	–1, 0,–2,–2	–1, 0,–1,–1
Normal	011110	+1,–1,–1,–2	+1,–1,–2,–1	+1,–2,–2,–2	+1,–2,–1,–1
Normal	011111	–1,–1,–1,–2	–1,–1,–2,–1	–1,–2,–2,–2	–1,–2,–1,–1
Normal	100000	+2, 0, 0,+1	+2, 0,+1, 0	+2,+1,+1,+1	+2,+1, 0, 0
Normal	100001	+2,–2, 0,+1	+2,–2,+1, 0	+2,–1,+1,+1	+2,–1, 0, 0
Normal	100010	+2, 0,–2,+1	+2, 0,–1, 0	+2,+1,–1,+1	+2,+1,–2, 0
Normal	100011	+2,–2,–2,+1	+2,–2,–1, 0	+2,–1,–1,+1	+2,–1,–2, 0
Normal	100100	+2, 0, 0,–1	+2, 0,+1,–2	+2,+1,+1,–1	+2,+1, 0,–2
Normal	100101	+2,–2, 0,–1	+2,–2,+1,–2	+2,–1,+1,–1	+2,–1, 0,–2
Normal	100110	+2, 0,–2,–1	+2, 0,–1,–2	+2,+1,–1,–1	+2,+1,–2,–2
Normal	100111	+2,–2,–2,–1	+2,–2,–1,–2	+2,–1,–1,–1	+2,–1,–2,–2
Normal	101000	0, 0,+2,+1	+1,+1,+2,+1	+1, 0,+2, 0	0,+1,+2, 0
Normal	101001	–2, 0,+2,+1	–1,+1,+2,+1	–1, 0,+2, 0	–2,+1,+2, 0
Normal	101010	0,–2,+2,+1	+1,–1,+2,+1	+1,–2,+2, 0	0,–1,+2, 0
Normal	101011	–2,–2,+2,+1	–1,–1,+2,+1	–1,–2,+2, 0	–2,–1,+2, 0
Normal	101100	0, 0,+2,–1	+1,+1,+2,–1	+1, 0,+2,–2	0,+1,+2,–2
Normal	101101	–2, 0,+2,–1	–1,+1,+2,–1	–1, 0,+2,–2	–2,+1,+2,–2
Normal	101110	0,–2,+2,–1	+1,–1,+2,–1	+1,–2,+2,–2	0,–1,+2,–2
Normal	101111	–2,–2,+2,–1	–1,–1,+2,–1	–1,–2,+2,–2	–2,–1,+2,–2
Normal	110000	0,+2, 0,+1	0,+2,+1, 0	+1,+2, 0, 0	+1,+2,+1,+1
Normal	110001	–2,+2, 0,+1	–2,+2,+1, 0	–1,+2, 0, 0	–1,+2,+1,+1
Normal	110010	0,+2,–2,+1	0,+2,–1, 0	+1,+2,–2, 0	+1,+2,–1,+1
Normal	110011	–2,+2,–2,+1	–2,+2,–1, 0	–1,+2,–2, 0	–1,+2,–1,+1
Normal	110100	0,+2, 0,–1	0,+2,+1,–2	+1,+2, 0,–2	+1,+2,+1,–1

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Table 40–2—Bit-to-symbol mapping (odd subsets) *(continued)*

		$Sd_n[6:8] = [001]$	$Sd_n[6:8] = [011]$	$Sd_n[6:8] = [101]$	$Sd_n[6:8] = [111]$
Condition	**$Sd_n[5:0]$**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**	**TA_n,TB_n,TC_n,TD_n**
Normal	110101	–2,+2, 0,–1	–2,+2,+1,–2	–1,+2, 0,–2	–1,+2,+1,–1
Normal	110110	0,+2,–2,–1	0,+2,–1,–2	+1,+2,–2,–2	+1,+2,–1,–1
Normal	110111	–2,+2,–2,–1	–2,+2,–1,–2	–1,+2,–2,–2	–1,+2,–1,–1
Normal	111000	+1,+1,+1,+2	0, 0,+1,+2	+1, 0, 0,+2	0,+1, 0,+2
Normal	111001	–1,+1,+1,+2	–2, 0,+1,+2	–1, 0, 0,+2	–2,+1, 0,+2
Normal	111010	+1,–1,+1,+2	0,–2,+1,+2	+1,–2, 0,+2	0,–1, 0,+2
Normal	111011	–1,–1,+1,+2	–2,–2,+1,+2	–1,–2, 0,+2	–2,–1, 0,+2
Normal	111100	+1,+1,–1,+2	0, 0,–1,+2	+1, 0,–2,+2	0,+1,–2,+2
Normal	111101	–1,+1,–1,+2	–2, 0,–1,+2	–1, 0,–2,+2	–2,+1,–2,+2
Normal	111110	+1,–1,–1,+2	0,–2,–1,+2	+1,–2,–2,+2	0,–1,–2,+2
Normal	111111	–1,–1,–1,+2	–2,–2,–1,+2	–1,–2,–2,+2	–2,–1,–2,+2
xmt_err	XXXXXX	+2,+2, 0,+1	0,+2,+1,+2	+1,+2,+2, 0	+2,+1,+2, 0
CSExtend_Err	XXXXXX	+2,+2, –2,–1	–2,+2,–1,+2	–1,+2,+2,–2	+2,–1,+2,–2
CSExtend	XXXXXX	+2, 0,+2,+1	+2, 0,+1,+2	+1, 0,+2,+2	+2,+1, 0,+2
CSReset	XXXXXX	+2,–2,+2,–1	+2,–2,–1,+2	–1,–2,+2,+2	+2,–1,–2,+2

40.3.1.3.6 Generation of A_n, B_n, C_n, D_n

The four bits $Sg_n[3:0]$ are used to randomize the signs of the quinary symbols (A_n, B_n, C_n, D_n) so that each symbol stream has no dc bias. The bits are used to generate binary symbols (SnA_n, SnB_n, SnC_n, SnD_n) that, when multiplied by the quinary symbols (TA_n, TB_n, TC_n, TD_n), result in (A_n, B_n, C_n, D_n).

PCS Transmit ensures a distinction between code-groups transmitted during idle mode plus SSD and those transmitted during other symbol periods. This distinction is accomplished by reversing the mapping of the sign bits when the condition (tx_enable_{n-2} + tx_enable_{n-4}) = 1. This sign reversal is controlled by the variable $Srev_n$ defined as

$$Srev_n = tx_enable_{n-2} + tx_enable_{n-4}$$

The binary symbols SnA_n, SnB_n, SnC_n, and SnD_n are defined using $Sg_n[3:0]$ as

$$SnA_n = \begin{cases} +1 \text{ if } [(Sg_n[0] \wedge Srev_n) = 0] \\ -1 \text{ else} \end{cases}$$

$$SnB_n = \begin{cases} +1 \text{ if } [(Sg_n[1] \wedge Srev_n) = 0] \\ -1 \text{ else} \end{cases}$$

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$$SnC_n = \begin{cases} +1 \text{ if } [(Sg_n[2] \wedge Srev_n) = 0] \\ -1 \text{ else} \end{cases}$$

$$SnD_n = \begin{cases} +1 \text{ if } [(Sg_n[3] \wedge Srev_n) = 0] \\ -1 \text{ else} \end{cases}$$

The quinary symbols (A_n, B_n, C_n, D_n) are generated as the product of (SnA_n, SnB_n, SnC_n, SnD_n) and (TA_n, TB_n, TC_n, TD_n) respectively.

$$A_n = TA_n \times SnA_n$$

$$B_n = TB_n \times SnB_n$$

$$C_n = TC_n \times SnC_n$$

$$D_n = TD_n \times SnD_n$$

40.3.1.4 PCS Receive function

The PCS Receive function shall conform to the PCS Receive state diagram in Figure 40–11a including compliance with the associated state variables as specified in 40.3.3.

The PCS Receive function accepts received code-groups provided by the PMA Receive function via the parameter rx_symb_vector. To achieve correct operation, PCS Receive uses the knowledge of the encoding rules that are employed in the idle mode. PCS Receive generates the sequence of vectors of four quinary symbols (RA_n, RB_n, RC_n, RD_n) and indicates the reliable acquisition of the descrambler state by setting the parameter scr_status to OK. The sequence (RA_n, RB_n, RC_n, RD_n) is processed to generate the signals RXD<7:0>, RX_DV, and RX_ER, which are presented to the GMII. PCS Receive detects the transmission of a stream of data from the remote station and conveys this information to the PCS Carrier Sense and PCS Transmit functions via the parameter 1000BTreceive.

When the PHY supports the optional EEE capability, the PCS Receive uses the knowledge of the encoding rules that are employed in the idle mode to derive the values of the variables rem_lpi_req and rem_update_done.

40.3.1.4.1 Decoding of code-groups

When the PMA indicates that correct receiver operation has been achieved by setting the loc_rcvr_status parameter to the value OK, the PCS Receive continuously checks that the received sequence satisfies the encoding rule used in idle mode. When a violation is detected, PCS Receive assigns the value TRUE to the parameter 1000BTreceive and, by examining the last two received vectors (RA_{n-1}, RB_{n-1}, RC_{n-1}, RD_{n-1}) and (RA_n, RB_n, RC_n, RD_n), determines whether the violation is due to reception of SSD or to a receiver error.

Upon detection of SSD, PCS Receive also assigns the value TRUE to the parameter 1000BTreceive that is provided to the PCS Carrier Sense and Collision Presence functions. During the two symbol periods corresponding to SSD, PCS Receive replaces SSD by preamble bits. Upon the detection of SSD, the signal RX_DV is asserted and each received vector is decoded into a data octet RXD<7:0> until ESD is detected.

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Upon detection of a receiver error, the signal RX_ER is asserted and the parameter rxerror_status assumes the value ERROR. De-assertion of RX_ER and transition to the IDLE state (rxerror_status=NO_ERROR) takes place upon detection of four consecutive vectors satisfying the encoding rule used in idle mode.

During reception of a stream of data, PCS Receive checks that the symbols RA_n, RB_n, RC_n, RD_n follow the encoding rule defined in 40.3.1.3.5 for ESD whenever they assume values ± 2. PCS Receive processes two consecutive vectors at each time n to detect ESD. Upon detection of ESD, PCS Receive de-asserts the signal RX_DV on the GMII. If the last symbol period of ESD indicates that a carrier extension is present, PCS Receive will assert the RX_ER signal on the GMII. If no extension is indicated in the ESD2 quartet, PCS Receive assigns the value FALSE to the parameter receiving. If an extension is present, the transition to the IDLE state occurs after detection of a valid idle symbol period and the parameter receiving remains TRUE until check_idle is TRUE. If a violation of the encoding rules is detected, PCS Receive asserts the signal RX_ER for at least one symbol period.

A premature stream termination is caused by the detection of invalid symbols during the reception of a data stream. Then, PCS Receive waits for the reception of four consecutive vectors satisfying the encoding rule used in idle mode prior to de-asserting the error indication. Note that RX_DV remains asserted during the symbol periods corresponding to the first three idle vectors, while RX_ER=TRUE is signaled on the GMII. The signal RX_ER is also asserted in the LINK FAILED state, which ensures that RX_ER remains asserted for at least one symbol period.

40.3.1.4.2 Receiver descrambler polynomials

The PHY shall descramble the data stream and return the proper sequence of code-groups to the decoding process for generation of RXD<7:0> to the GMII. For side-stream descrambling, the MASTER PHY shall employ the receiver descrambler generator polynomial $g_M(x) = 1 + x^{20} + x^{33}$ and the SLAVE PHY shall employ the receiver descrambler generator polynomial $g_S(x) = 1 + x^{13} + x^{33}$.

40.3.1.5 PCS Carrier Sense function

The PCS Carrier Sense function generates the GMII signal CRS, which the MAC uses for deferral in half duplex mode. The PCS shall conform to the Carrier Sense state diagram as depicted in Figure 40–12 including compliance with the associated state variables as specified in 40.3.3. The PCS Carrier Sense function is not required in a 1000BASE-T PHY that does not support half duplex operation.

40.3.1.6 PCS Local LPI Request function

The PCS Local LPI Request function generates the signal loc_lpi_req, which indicates to the PMA PHY Control function whether or not the local PHY is requested to enter the LPI mode. When the PHY supports the optional EEE capability, the PCS shall conform to the Local LPI Request state diagram as depicted in Figure 40–9 including compliance with the associated state variables as specified in 40.3.3.

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40.3.2 Stream structure

The tx_symb_vector and rx-symb_vector structure is shown in Figure 40–7.

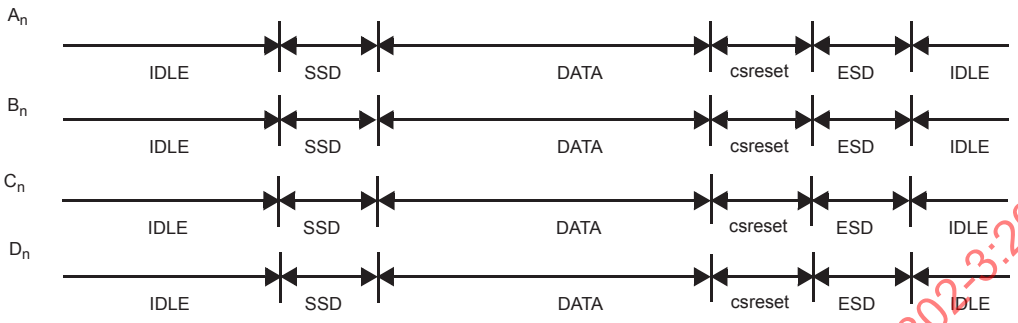

Figure 40–7—The tx_symb_vector and rx-symb_vector structure

40.3.3 State variables

40.3.3.1 Variables

CEXT
: A sequence of vectors of four quinary symbols corresponding to the code-group generated in idle mode to denote carrier extension, as specified in 40.3.1.3.

CEXT_Err
: A sequence of vectors of four quinary symbols corresponding to the code-group generated in idle mode to denote carrier extension with error indication, as specified in 40.3.1.3.

COL
: The COL signal of the GMII as specified in 35.2.2.12.

config
: The config parameter set by PMA and passed to the PCS via the PMA_CONFIG.indication primitive.
Values: MASTER, SLAVE.

CRS
: The CRS signal of the GMII as specified in 35.2.2.11.

CSExtend
: A vector of four quinary symbols corresponding to the code-group indicating convolutional encoder reset condition during carrier extension, as specified in 40.3.1.3.

CSExtend_Err
: A vector of four quinary symbols corresponding to the code-group indicating convolutional encoder reset condition during carrier extension with error indication, as specified in 40.3.1.3.

CSReset
: A vector of four quinary symbols corresponding to the code-group indicating convolutional encoder reset condition in the absence of carrier extension, as specified in 40.3.1.3.

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DATA
: A vector of four quinary symbols corresponding to the code-group indicating valid data, as specified in 40.3.1.3.

ESD1
: A vector of four quinary symbols corresponding to the first code-group of End-of-Stream delimiter, as specified in 40.3.1.3.

ESD2_Ext_0
: A vector of four quinary symbols corresponding to the second code-group of End-of-Stream delimiter in the absence of carrier extension over the two ESD symbol periods, as specified in 40.3.1.3.

ESD2_Ext_1
: A vector of four quinary symbols corresponding to the second code-group of End-of-Stream delimiter when carrier extension is indicated during the first symbol period of the End-of-Stream delimiter, but not during the second symbol period, as specified in 40.3.1.3.

ESD2_Ext_2
: A vector of four quinary symbols corresponding to the second code-group of End-of-Stream delimiter when carrier extension is indicated during the two symbol periods of the End-of-Stream delimiter, as specified in 40.3.1.3.

ESD_Ext_Err
: A vector of four quinary symbols corresponding to either the first or second code-group of End-of-Stream delimiter when carrier extension with error is indicated during the End-of-Stream delimiter, as specified in 40.3.1.3.

IDLE
: A sequence of vectors of four quinary symbols representing the special code-group generated in idle mode in the absence of carrier extension or carrier extension with error indication, as specified in 40.3.1.3.

link_status
: The link_status parameter set by PMA Link Monitor and passed to the PCS via the PMA_LINK.indication primitive.
Values: OK or FAIL

loc_rcvr_status
: The loc_rcvr_status parameter set by the PMA Receive function and passed to the PCS via the PMA_RXSTATUS.indication primitive.
Values: OK or NOT_OK

pcs_reset
: The pcs_reset parameter set by the PCS Reset function.
Values: ON or OFF

(RA_n, RB_n, RC_n, RD_n)
: The vector of the four correctly aligned most recently received quinary symbols generated by PCS Receive at time n.

1000BTreceive
: The receiving parameter generated by the PCS Receive function.
Values: TRUE or FALSE

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rem_rcvr_status
The rem_rcvr_status parameter generated by PCS Receive.
Values: OK or NOT_OK

repeater_mode
See 36.2.5.1.3

Rx_n
Alias for rx_symb_vector (a vector RA_n, RB_n, RC_n, RD_n) at time n.

rxerror_status
The rxerror_status parameter set by the PCS Receive function.
Values: ERROR or NO_ERROR

RX_DV
The RX_DV signal of the GMII as specified in 35.2.2.7.

RX_ER
The RX_ER signal of the GMII as specified in 35.2.2.9.

rx_symb_vector
A vector of four quinary symbols received by the PMA and passed to the PCS via the PMA_UNITDATA.indication primitive.
Value: SYMB_4D

RXD[7:0]
The RXD<7:0> signal of the GMII as specified in 35.2.2.8.

SSD1
A vector of four quinary symbols corresponding to the first code-group of the Start-of-Stream delimiter, as specified in 40.3.1.3.5.

SSD2
A vector of four quinary symbols corresponding to the second code-group of the Start-of-Stream delimiter, as specified in 40.3.1.3.5.

1000BTtransmit
A Boolean used by the PCS Transmit Process to indicate whether a frame transmission is in progress. Also used by the Carrier Sense and Local LPI Request processes.
Values: TRUE: The PCS is transmitting a stream
FALSE: The PCS is not transmitting a stream

TXD[7:0]
The TXD<7:0> signal of the GMII as specified in 35.2.2.4.

tx_enable
The tx_enable parameter generated by PCS Transmit as specified in Figure 40–8.
Values: TRUE or FALSE

tx_error
The tx_error parameter generated by PCS Transmit as specified in Figure 40–8.
Values: TRUE or FALSE

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TX_EN
: The TX_EN signal of the GMII as specified in 35.2.2.3.

TX_ER
: The TX_ER signal of the GMII as specified in 35.2.2.5.

tx_mode
: The tx_mode parameter set by the PMA PHY Control function and passed to the PCS via the PMA_TXMODE.indication primitive.
Values: SEND_Z, SEND_N, or SEND_I

Tx_n
: Alias for tx_symb_vector at time n.

tx_symb_vector
: A vector of four quinary symbols generated by the PCS Transmit function and passed to the PMA via the PMA_UNITDATA.request primitive.
Value: SYMB_4D

xmt_err
: A vector of four quinary symbols corresponding to a transmit error indication during normal data transmission or reception, as specified in 40.3.1.3.

The following state variables are only required for the optional EEE capability:

loc_lpi_req
: The loc_lpi_req variable is set by the PCS Local LPI Request function and indicates whether or not the local PHY is requested to enter the LPI mode. It is passed to the PMA PHY Control function via the PMA_LPIREQ.request primitive. In the absence of the optional EEE capability, the PHY shall operate as if the value of this variable is FALSE.
Values: TRUE or FALSE

lpi_mode
: The lpi_mode variable is generated by the PMA PHY Control function and indicates whether or not the local PHY has entered LPI mode. It is passed to the PCS Receive function via the PMA_LPIMODE.indication primitive. In the absence of the optional EEE capability, the PHY operates as if the value of this variable is OFF.
Values: ON or OFF

rem_lpi_req
: The rem_lpi_req variable is generated by the PCS Receive function and indicates whether or not the remote PHY is requesting entry into LPI mode. It is passed to the PMA PHY Control function via the PMA_REMLPIREQ.request primitive. In the absence of the optional EEE capability, the PHY shall operate as if the value of this variable is FALSE.
Values: TRUE or FALSE

40.3.3.2 Functions

check_end
: A function used by the PCS Receive process to detect the reception of valid ESD symbols. The check_end function operates on the next two rx_symb_vectors, (Rx_{n+1}) and (Rx_{n+2}), available via PMA_UNITDATA.indication, and returns a Boolean value indicating whether these two consecutive vecctors contain symbols corresponding to a legal ESD encoding or not, as specified in 40.3.1.3.

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check_idle
: A function used by the PCS Receive process to detect the reception of valid idle code-groups after an error condition during the process. The check_idle function operates on the current rx_symb_vector and the next three rx_symb_vectors available via PMA_UNITDATA.indication and
returns a Boolean value indicating whether the four consecutive vectors contain symbols corresponding to the idle mode encoding or not, as specified in 40.3.1.3.

DECODE
: In the PCS Receive process, this function takes as its argument the value of rx_symb_vector and returns the corresponding GMII RXD<7:0> octet. DECODE follows the rules outlined in 40.2.6.1.

ENCODE
: In the PCS Transmit process, this function takes as its argument GMII TXD <7:0> and returns the corresponding tx_symb_vector. ENCODE follows the rules outlined in 40.2.5.1.

40.3.3.3 Timer

symb_timer
: Continuous timer:The condition symb_timer_done becomes true upon timer expiration.

  Restart time: Immediately after expiration; timer restart resets the condition symb_timer_done.

  Duration: 8 ns nominal. (See clock tolerance in 40.6.1.2.6.)

  Symb-timer shall be generated synchronously with TX_TCLK. In the PCS Transmit state diagram, the message PMA_UNITDATA.request is issued concurrently with symb_timer_done.

40.3.3.4 Messages

PMA_UNITDATA.indication (rx_symb_vector)
: A signal sent by PMA Receive indicating that a vector of four quinary symbols is available in rx_symb_vector. (See 40.2.6.)

PMA_UNITDATA.request (tx_symb_vector)
: A signal sent to PMA Transmit indicating that a vector of four quinary symbols is available in tx_symb_vector. (See 40.2.5.)

PUDI
: Alias for PMA_UNITDATA.indication (rx_symb_vector).

PUDR
: Alias for PMA_UNITDATA.request (tx_symb_vector).

STD
: Alias for symb_timer_done.

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40.3.4 State diagrams

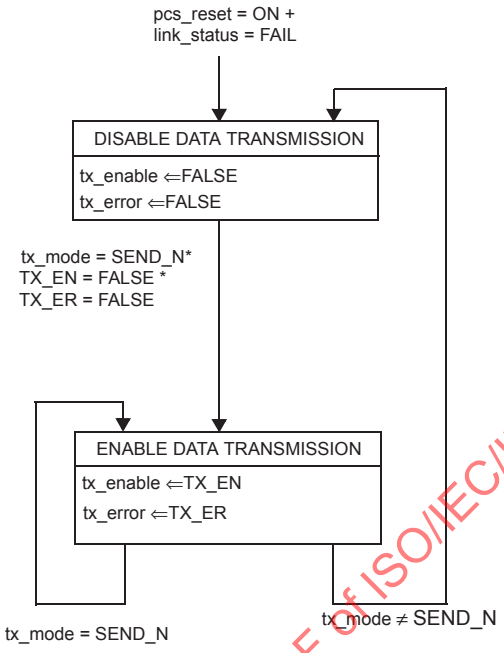

Figure 40–8—PCS Data Transmission Enabling state diagram

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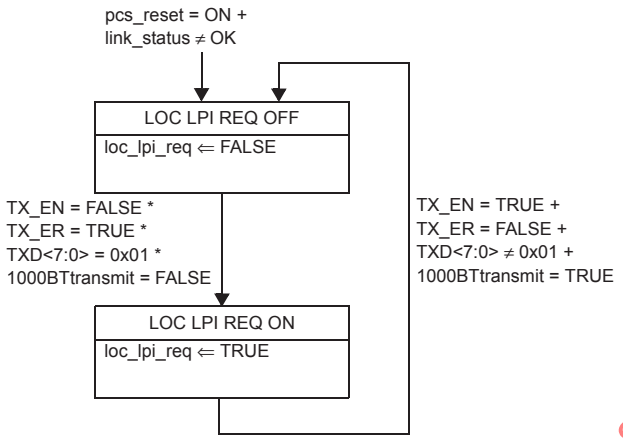

Figure 40–9—PCS Local LPI Request state diagram (optional)

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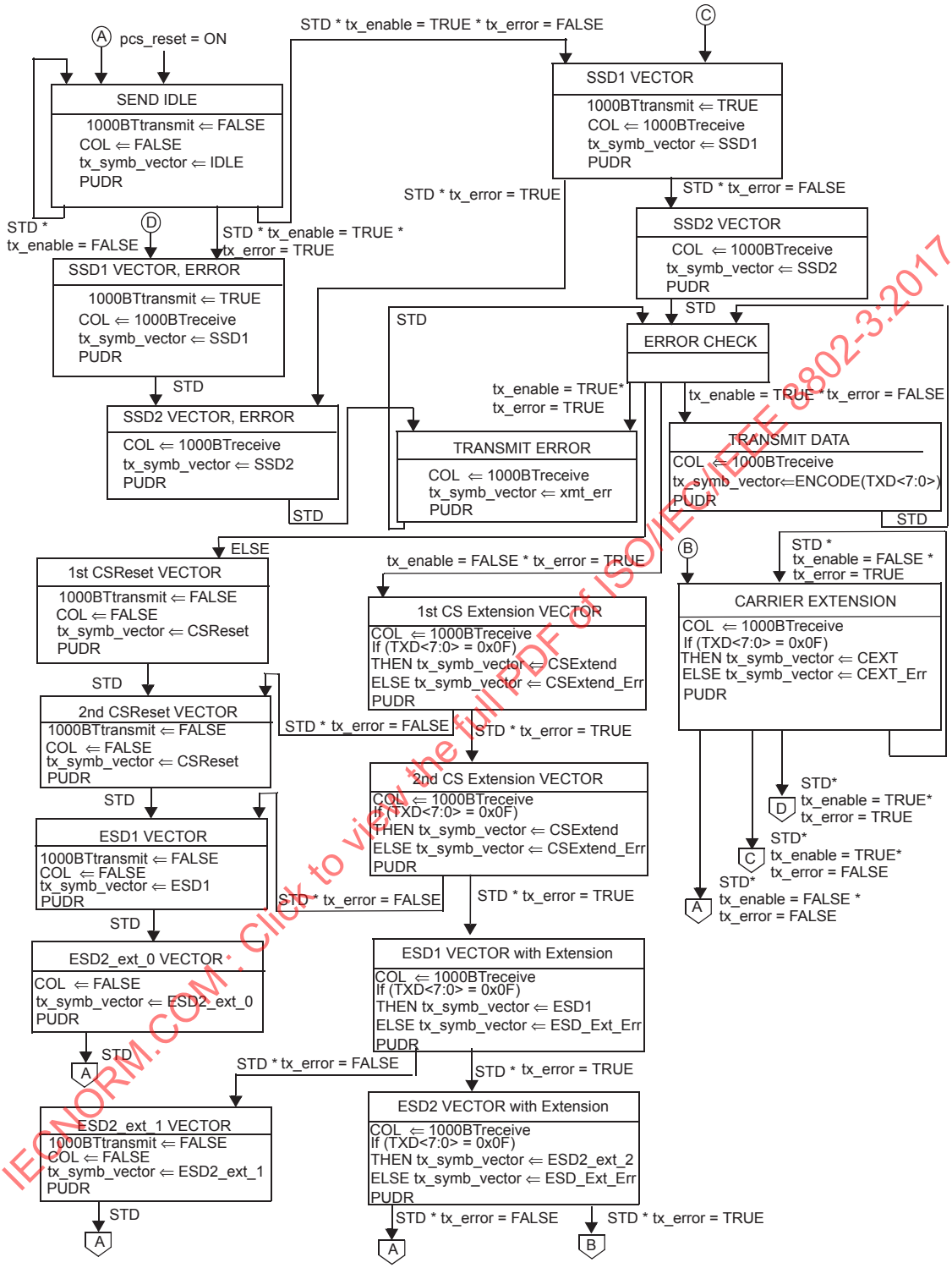

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Figure 40–10—PCS Transmit state diagram

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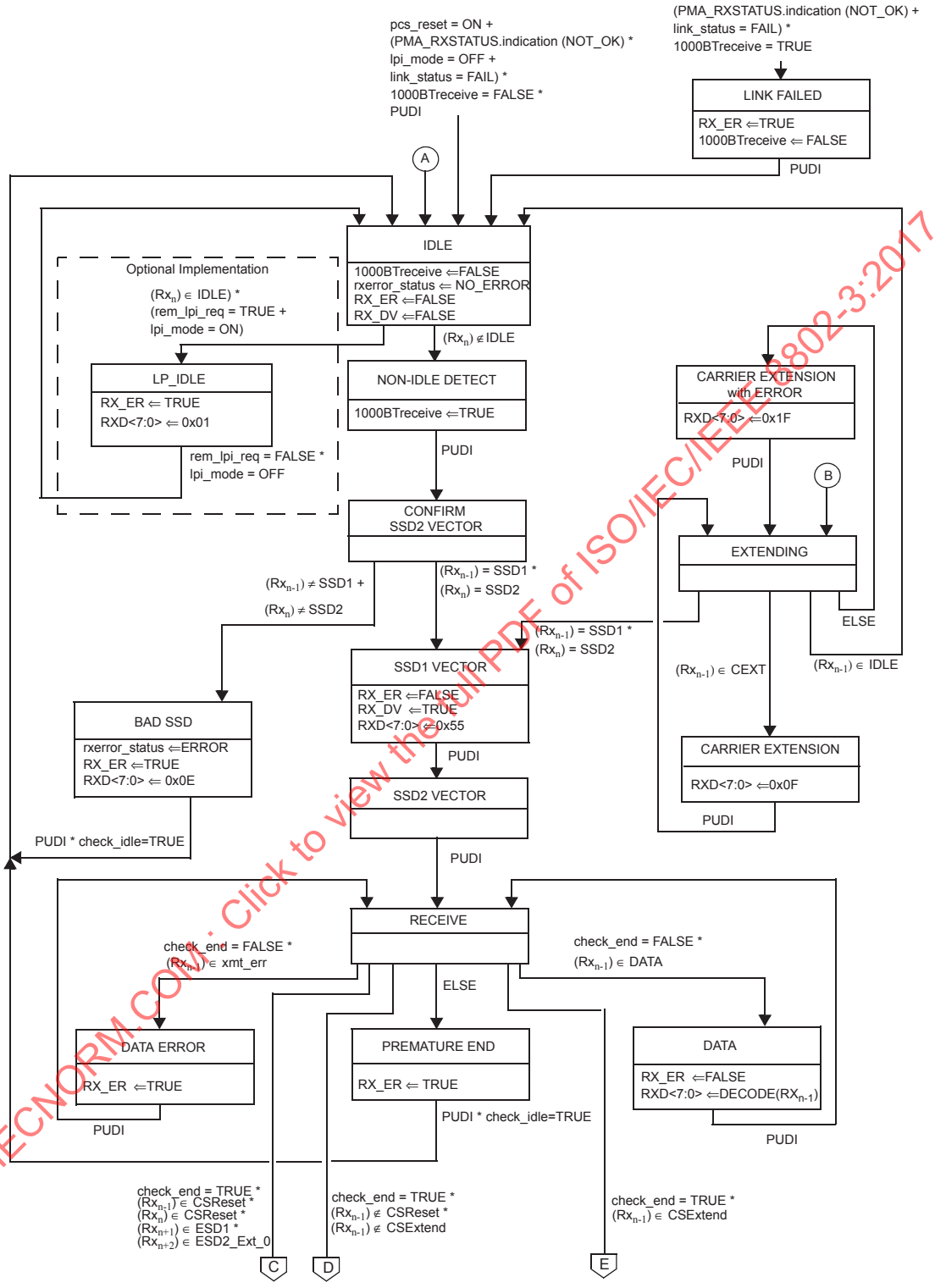

Figure 40–11a—PCS Receive state diagram, part a

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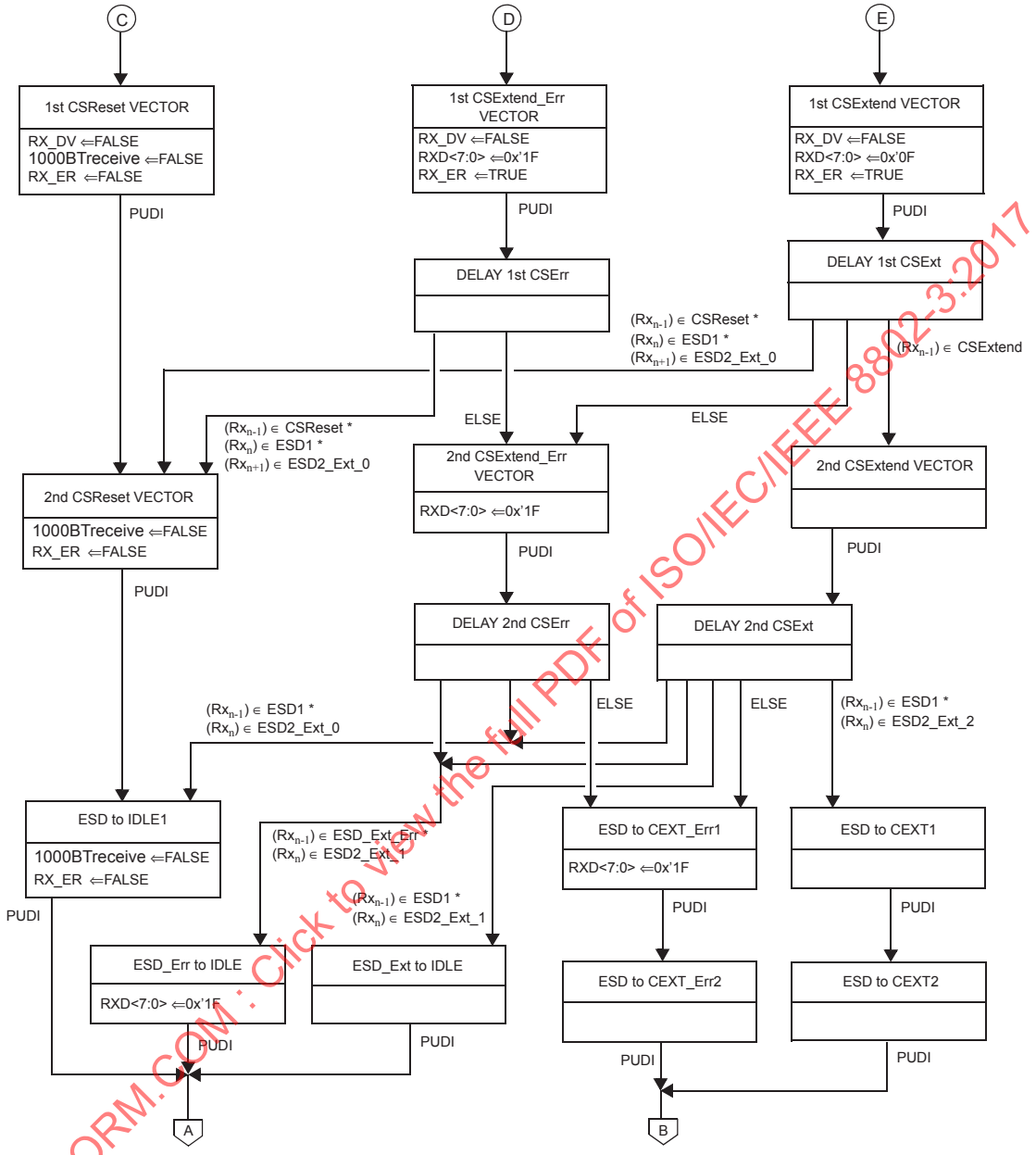

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Figure 40–11b—PCS Receive state diagram, part b

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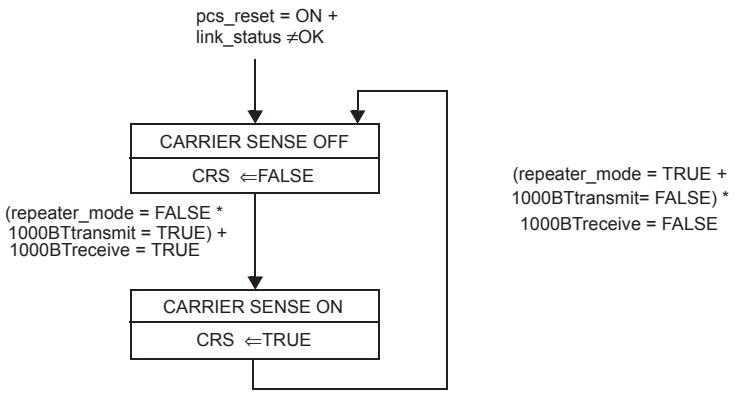

Figure 40–12—PCS Carrier Sense state diagram

40.3.4.1 Supplement to state diagram

Figure 40–13 reiterates the information shown in Figure 40–10 in timing diagram format. It is informative only. Time proceeds from left to right in the figure.

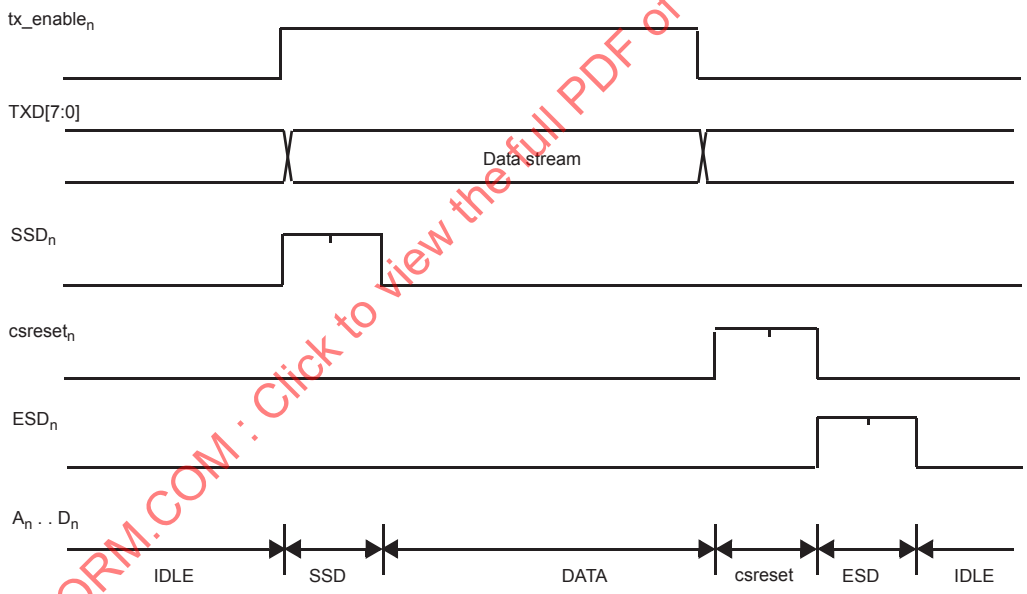

Figure 40–13—PCS sublayer to PMA timing

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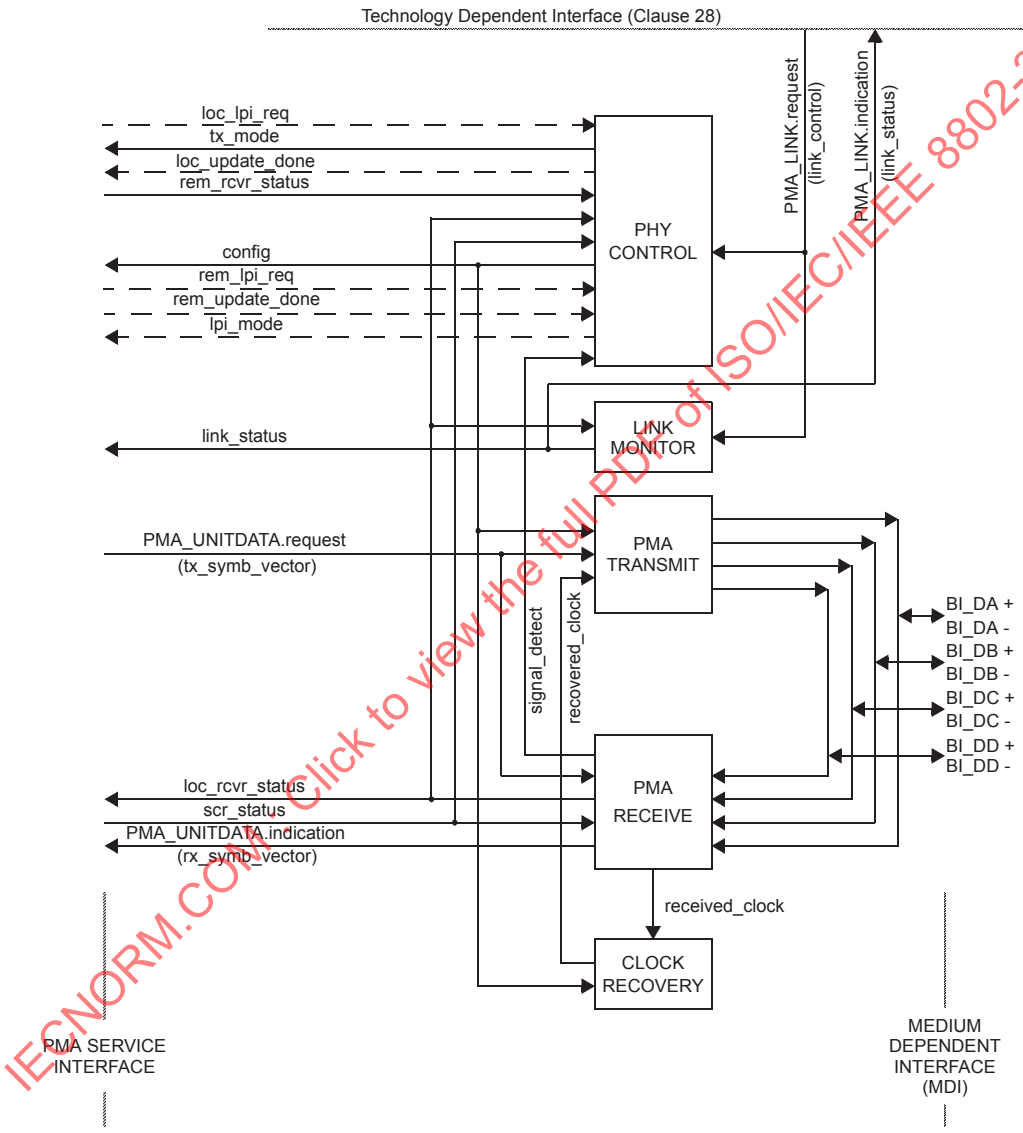
40.4 Physical Medium Attachment (PMA) sublayer

40.4.1 PMA functional specifications

The PMA couples messages from a PMA service interface specified in 40.2.2 to the 1000BASE-T baseband medium, specified in 40.7.

The interface between PMA and the baseband medium is the Medium Dependent Interface (MDI), which is specified in 40.8.



NOTE 1—The recovered_clock arc is shown to indicate delivery of the received clock signal back the PMA TRANSMIT for loop timing.

NOTE 2—Signals and functions shown with dashed lines are only required for the EEE capability.

Figure 40–14—PMA reference diagram

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40.4.2 PMA functions

The PMA sublayer comprises one PMA Reset function and five simultaneous and asynchronous operating functions. The PMA operating functions are PHY Control, PMA Transmit, PMA Receive, Link Monitor, and Clock Recovery. All operating functions are started immediately after the successful completion of the PMA Reset function.

The PMA reference diagram, Figure 40–14, shows how the operating functions relate to the messages of the PMA Service interface and the signals of the MDI. Connections from the management interface, comprising the signals MDC and MDIO, to other layers are pervasive and are not shown in Figure 40–14. The management interface and its functions are specified in Clause 22.

40.4.2.1 PMA Reset function

The PMA Reset function shall be executed whenever one of the two following conditions occur:

a) Power on (see 36.2.5.1.3)
b) The receipt of a request for reset from the management entity

PMA Reset sets pcs_reset=ON while any of the above reset conditions hold true. All state diagrams take the open-ended pma_reset branch upon execution of PMA Reset. The reference diagrams do not explicitly show the PMA Reset function.

40.4.2.2 PMA Transmit function

The PMA Transmit function comprises four synchronous transmitters to generate four 5-level pulse-amplitude modulated signals on each of the four pairs BI_DA, BI_DB, BI_DC, and BI_DD. PMA Transmit shall continuously transmit onto the MDI pulses modulated by the quinary symbols given by tx_symb_vector[BI_DA], tx_symb_vector[BI_DB], tx_symb_vector[BI_DC] and tx_symb_vector[BI_DD], respectively. The four transmitters shall be driven by the same transmit clock, TX_TCLK. The signals generated by PMA Transmit shall follow the mathematical description given in 40.4.3.1, and shall comply with the electrical specifications given in 40.6.

When the PMA_CONFIG.indication parameter config is MASTER, the PMA Transmit function shall source TX_TCLK from a local clock source while meeting the transmit jitter requirements of 40.6.1.2.5. When the PMA_CONFIG.indication parameter config is SLAVE, the PMA Transmit function shall source TX_TCLK from the recovered clock of 40.4.2.6 while meeting the jitter requirements of 40.6.1.2.5.

40.4.2.3 PMA Receive function

The PMA Receive function comprises four independent receivers for quinary pulse-amplitude modulated signals on each of the four pairs BI_DA, BI_DB, BI_DC, and BI_DD. PMA Receive contains the circuits necessary to both detect quinary symbol sequences from the signals received at the MDI over receive pairs BI_DA, BI_DB, BI_DC, and BI_DD and to present these sequences to the PCS Receive function. The signals received at the MDI are described mathematically in 40.4.3.2. The PMA shall translate the signals received on pairs BI_DA, BI_DB, BI_DC, and BI_DB into the PMA_UNITDATA.indication parameter rx_symb_vector with a symbol error ratio of less than 10^{-10} over a channel meeting the requirements of 40.7.

To achieve the indicated performance, it is highly recommended that PMA Receive include the functions of signal equalization, echo and crosstalk cancellation, and sequence estimation. The sequence of code-groups assigned to tx_symb_vector is needed to perform echo and self near-end crosstalk cancellation.

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The PMA Receive function uses the scr_status parameter and the state of the equalization, cancellation, and estimation functions to determine the quality of the receiver performance, and generates the loc_rcvr_status variable accordingly. The precise algorithm for generation of loc_rcvr_status is implementation dependent.

40.4.2.4 PHY Control function

PHY Control generates the control actions that are needed to bring the PHY into a mode of operation during which frames can be exchanged with the link partner. PHY Control shall comply with the state diagram description given in Figure 40–16a and Figure 40–16b.

During Auto-Negotiation PHY Control is in the DISABLE 1000BASE-T TRANSMITTER state and the transmitters are disabled. When the Auto-Negotiation process asserts link_control=ENABLE, PHY Control enters the SLAVE SILENT state. Upon entering this state, the maxwait timer is started and PHY Control forces transmission of zeros by setting tx_mode=SEND_Z. The transition out of the SLAVE SILENT state depends on whether the PHY is operating in MASTER or SLAVE mode. In MASTER mode, PHY Control transitions immediately to the TRAINING state. In SLAVE mode, PHY Control transitions to the TRAINING state only after the SLAVE PHY converges its decision feedback equalizer (DFE), acquires timing, and acquires its descrambler state, and sets scr_status=OK**.**

For the SLAVE PHY, the final convergence of the adaptive filter parameters is completed in the TRAINING state. The MASTER PHY performs all its receiver convergence functions in the TRAINING state. Upon entering the TRAINING state, the minwait_timer is started and PHY Control forces transmission into the idle mode by asserting tx_mode=SEND_I. After the PHY completes successful training and establishes proper receiver operations, PCS Transmit conveys this information to the link partner via transmission of the parameter loc_rcvr_status. (See Sd_n[2] in 40.3.1.3.4.) The link partner's value for loc_rcvr_status is stored in the local device parameter rem_rcvr status. When the minwait_timer expires and the condition loc_rcvr_status=OK is satisfied, PHY Control transitions into either the SEND IDLE OR DATA state if rem_rcvr_status=OK or the SEND IDLE state if rem_rcvr_status=NOT_OK. On entry into either the SEND IDLE or SEND IDLE OR DATA states, the maxwait_timer is stopped and the minwait_timer is started.

The normal mode of operation corresponds to the SEND IDLE OR DATA state, where PHY Control asserts tx_mode=SEND_N and transmission of data over the link can take place. In this state, when no frames have to be sent, idle transmission takes place.

If unsatisfactory receiver operation is detected in the SEND IDLE OR DATA or SEND IDLE states (loc_rcvr_status=NOT_OK) and the minwait_timer has expired, transmission of the current frame is completed and PHY Control enters the SLAVE SILENT state. In the SEND IDLE OR DATA state, whenever a PHY that operates reliably detects unsatisfactory operation of the remote PHY (rem_rcvr_status=NOT_OK) and the minwait_timer has expired, it enters the SEND IDLE state where tx_mode=SEND_I is asserted and idle transmission takes place. In this state, encoding is performed with the parameter loc_rcvr_status=OK. As soon as the remote PHY signals satisfactory receiver operation (rem_rcvr_status=OK) and the minwait_timer has expired, the SEND IDLE OR DATA state is entered.

When the PHY supports the optional EEE capability, PHY Control will transition to the LPI mode in response to concurrent requests for LPI mode from the local PHY (loc_lpi_req = TRUE) and remote PHY (rem_lpi_req = TRUE).

Upon activation of the LPI mode, the PHY Control asserts tx_mode = SEND_I for a period of time defined by lpi_update_timer, which allows the remote PHY to prepare for cessation of transmission. When lpi_update_timer expires, PHY Control transitions to the POST_UPDATE state, signals to the remote PHY that is has completed the update by setting loc_update_done = TRUE, and starts the lpi_postupdate_timer. When lpi_postupdate_timer expires, PHY Control transitions to the WAIT_QUIET state. If there is a request to wake (loc_lpi_req = FALSE or rem_lpi_req = FALSE) while in the POST_UPDATE state, PHY Control

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will wait for confirmation that the remote PHY has completed the update (rem_update_done = TRUE) and is prepared for cessation of transmission before proceeding to the WAIT_QUIET state.

Upon entry into the WAIT_QUIET state, PHY Control asserts tx_mode = SEND_Z and transmission ceases. During the WAIT_QUIET and QUIET states, the PHY may deactivate transmit and receive functions in order to conserve energy. However, in the WAIT_QUIET state, the PHY shall be capable of correctly decoding rem_lpi_req. The PHY will remain in the QUIET state no longer than the time implied by lpi_quiet_timer.

When lpi_quiet_timer expires, the PHY initiates a wake sequence. The wake sequence begins with a transition to the WAKE state where the PHY will transmit (tx_mode = SEND_I) for the period lpi_waketx_timer and simultaneously start a parallel timer, lpi_wakemz_timer. Since it is likely that transmit circuits were deactivated while in the QUIET state, this transmission is not expected to be compliant 1000BASE-T signaling, but rather of sufficient quality and duration to be detected by the remote PHY receiver and initiate the wake sequence in the remote PHY.

Upon expiration of lpi_waketx_timer, the PHY will enter the WAKE_SILENT state and cease transmission (tx_mode = SEND_Z). The PHY will remain in the WAKE_SILENT state until lpi_wakemz_timer has expired, at which point it is assumed that the transmitter circuits have stabilized and compliant 1000BASE-T signaling can be transmitted. At this point the MASTER transitions to the WAKE_TRAINING state and transmits to the SLAVE PHY.

The remaining wake sequence is essentially an accelerated training mode sequence leading to entry into the UPDATE state.

Once scrambler synchronization is achieved, the incoming value of rem_lpi_req can be determined. If the LPI mode is no longer requested by either the local or remote PHY, then both PHYs return to the SEND IDLE OR DATA state and the normal mode of operation (tx_mode = SEND_N). If both PHYs continue to request the LPI mode, then both PHYs remain in the UPDATE state and continue to transmit for a time defined by lpi_update_timer. This time is intended to allow the remote PHY to refresh its receiver state (e.g., timing recovery, adaptive filter coefficients) and thereby track long-term variation in the timing of the link or the underlying channel characteristics. If lpi_update_timer expires and both PHYs continue to request the LPI mode, then the PHY transitions to the POST_UPDATE state.

PHY Control may force the transmit scrambler state to be initialized to an arbitrary value by requesting the execution of the PCS Reset function defined in 40.3.1.1.

40.4.2.5 Link Monitor function

Link Monitor determines the status of the underlying receive channel and communicates it via the variable link_status. Failure of the underlying receive channel typically causes the PMA's clients to suspend normal operation.

The Link Monitor function shall comply with the state diagram of Figure 40–17.

Upon power on, reset, or release from power down, the Auto-Negotiation algorithm sets link_control=SCAN_FOR_CARRIER and, during this period, sends fast link pulses to signal its presence to a remote station. If the presence of a remote station is sensed through reception of fast link pulses, the Auto-Negotiation algorithm sets link_control=DISABLE and exchanges Auto-Negotiation information with the remote station. During this period, link_status=FAIL is asserted. If the presence of a remote 1000BASE-T station is established, the Auto-Negotiation algorithm permits full operation by setting link_control=ENABLE. As soon as reliable transmission is achieved, the variable link_status=OK is asserted, upon which further PHY operations can take place.

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40.4.2.6 Clock Recovery function

The Clock Recovery function couples to all four receive pairs. It may provide independent clock phases for sampling the signals on each of the four pairs.

The Clock Recovery function shall provide clocks suitable for signal sampling on each line so that the symbol error ratio indicated in 40.4.2.3 is achieved. The received clock signal must be stable and ready for use when training has been completed (loc_rcvr_status=OK). The received clock signal is supplied to the PMA Transmit function by received_clock.

40.4.3 MDI

Communication through the MDI is summarized in 40.4.3.1 and 40.4.3.2.

40.4.3.1 MDI signals transmitted by the PHY

The quinary symbols to be transmitted by the PMA on the four pairs BI_DA, BI_DB, BI_DC, and BI_DD are denoted by tx_symb_vector[BI_DA], tx_symb_vector[BI_DB], tx_symb_vector[BI_DC], and tx_symb_vector[BI_DD], respectively. The modulation scheme used over each pair is 5-level Pulse Amplitude Modulation. PMA Transmit generates a pulse-amplitude modulated signal on each pair in the following form:

$$s(t) = \sum_k a_k h_1(t - kT)$$

In the above equation, a_k represents the quinary symbol from the set {2, 1, 0, –1, –2} to be transmitted at time kT, and $h_1(t)$ denotes the system symbol response at the MDI. This symbol response shall comply with the electrical specifications given in 40.6.

40.4.3.2 Signals received at the MDI

Signals received at the MDI can be expressed for each pair as pulse-amplitude modulated signals that are corrupted by noise as follows:

$$r(t) = \sum_k a_k h_2(t - kT) + w(t)$$

In this equation, $h_2(t)$ denotes the impulse response of the overall channel between the transmit symbol source and the receive MDI and $w(t)$ is a term that represents the contribution of various noise sources. The four signals received on pairs BI_DA, BI_DB, BI_DC, and BI_DD shall be processed within the PMA Receive function to yield the quinary received symbols rx_symb_vector[BI_DA], rx_symb_vector[BI_DB], rx_symb_vector[BI_DC], and rx_symb_vector[BI_DD].

40.4.4 Automatic MDI/MDI-X Configuration

Automatic MDI/MDI-X Configuration is intended to eliminate the need for crossover cables between similar devices. Implementation of an automatic MDI/MDI-X configuration is optional for 1000BASE-T devices. If an automatic configuration method is used, it shall comply with the following specifications. The assignment of pin-outs for a 1000BASE-T crossover function cable is shown in Table 40–12 in 40.8.

40.4.4.1 Description of Automatic MDI/MDI-X state diagram

The Automatic MDI/MDI-X state diagram facilitates switching the BI_DA(C)+ and BI_DA(C)– with the BI_DB(D)+ and BI_DB(D)– signals respectively prior to the auto-negotiation mode of operation so that FLPs can be transmitted and received in compliance with Clause 28 Auto-Negotiation specifications. The

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correct polarization of the crossover circuit is determined by an algorithm that controls the switching function. This algorithm uses an 11-bit linear feedback shift register (LFSR) to create a pseudo-random sequence that each end of the link uses to determine its proposed configuration. Upon making the selection to either MDI or MDI-X, the node waits for a specified amount of time while evaluating its receive channel to determine whether the other end of the link is sending link pulses or PHY-dependent data. If link pulses or PHY-dependent data are detected, it remains in that configuration. If link pulses or PHY-dependent data are not detected, it increments its LFSR and makes a decision to switch based on the value of the next bit. The state diagram does not move from one state to another while link pulses are being transmitted.

40.4.4.2 Pseudo-random sequence generator

One possible implementation of the pseudo-random sequence generator using a linear-feedback shift register is shown in Figure 40–15. The bits stored in the shift register delay line at time n are denoted by S[10:0]. At each sample period, the shift register is advanced by one bit and one new bit represented by S[0] is generated. Switch control is determined by S[10].

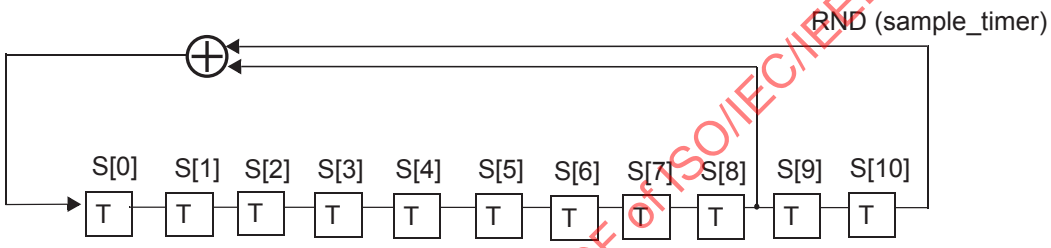

Figure 40–15—Automatic MDI/MDI-X linear-feedback shift register

40.4.5 State variables

40.4.5.1 State diagram variables

config
: The PMA shall generate this variable continuously and pass it to the PCS via the PMA_CONFIG.indication primitive.
Values: MASTER or SLAVE

link_control
: This variable is defined in 28.2.6.2.

Link_Det
: This variable indicates linkpulse = true or link_status = READY or OK has occurred at the receiver since the last time sample_timer has been started.
Values: TRUE: linkpulse = true or link_status = READY or OK has occurred since the last time sample_timer has been started.
FALSE: otherwise

linkpulse
: This variable is defined in 28.2.6.3.

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link_status
: This variable is defined in 28.2.6.1.

loc_rcvr_status
: Variable set by the PMA Receive function to indicate correct or incorrect operation of the receive link for the local PHY.

Values: OK: The receive link for the local PHY is operating reliably.
NOT_OK: Operation of the receive link for the local PHY is unreliable.

MDI_Status
: This variable defines the condition of the Automatic MDI/MDI-X physical connection.

Values: MDI: The BI_DA, BI_DB, BI_DC, and BI_DD pairs follow the connections as described in the MDI column of Table 40–12.

MDI-X: The BI_DA, BI_DB, BI_DC, and BI_DD pairs follow the connections as described in the MDI-X column of Table 40–12.

pma_reset
: Allows reset of all PMA functions.

Values: ON or OFF

Set by: PMA Reset

rem_rcvr_status
: Variable set by the PCS Receive function to indicate whether correct operation of the receive link for the remote PHY is detected or not.

Values: OK: The receive link for the remote PHY is operating reliably.

NOT_OK: Reliable operation of the receive link for the remote PHY is not detected.

RND (sample_timer)
: This variable is defined as bit S[10] of the LSFR described in 40.4.4.2

scr_status
: The scr_status parameter as communicated by the PMA_SCRSTATUS.request primitive.

Values: OK: The descrambler has achieved synchronization.

NOT_OK: The descrambler is not synchronized. Note that when the PHY supports the optional EEE capability and signal_detect is FALSE, scr_status is set to NOT_OK.

T_Pulse
: This variable indicates that a linkpulse is being transmitted to the MDI.

Values: TRUE: Pulse being transmitted to the MDI

FALSE: Otherwise

tx_enable
: The tx_enable parameter generated by PCS Transmit as specified in Figure 40–8.

Values: TRUE or FALSE as per 40.3.3.1.

tx_mode
: PCS Transmit sends code-groups according to the value assumed by this variable.

Values: SEND_N: This value is continuously asserted when transmission of sequences of code-groups representing a GMII data stream, control information, or idle mode is to take place.

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SEND_I: This value is continuously asserted when transmission of sequences of code-groups representing the idle mode is to take place.

SEND_Z: This value is asserted when transmission of zero code-groups is to take place.

The following state variables are only required for the optional EEE capability:

loc_lpi_req

The loc_lpi_req variable is set by the PCS Local LPI Request function and indicates whether or not the local PHY is requested to enter the LPI mode. It is passed to the PMA PHY Control function via the PMA_LPIREQ.request primitive. In the absence of the optional EEE capability, the PHY operates as if the value of this variable is FALSE.

Values: TRUE: "Assert LPI" is present at the GMII.
FALSE: "Assert LPI" is not present at the GMII.

loc_udpate_done

The loc_update_done variable is generated by the PMA PHY Control function and indicates whether or not the local PHY has completed the update of its receiver state. It is passed to the PCS Transmit function via the PMA_UPDATE.indication primitive. In the absence of the optional EEE capability, the PHY shall operate as if the value of this variable is FALSE.

Values: TRUE: The PHY has completed the current update.
FALSE: The PHY is ready for the next update or the current update is still in progress.

lpi_mode

The lpi_mode variable is generated by the PMA PHY Control function and indicates whether or not the local PHY has entered the LPI mode. It is passed to the PCS Receive function via the PMA_LPIMODE.indication primitive. In the absence of the optional EEE capability, the PHY shall operate as if the value of this variable is OFF.

Values: ON: The PHY is operating in LPI mode.
OFF: The PHY is in normal operation.

rem_lpi_req

The rem_lpi_req variable is generated by the PCS Receive function and indicates whether or not the remote PHY is requesting entry into LPI mode. It is passed to the PMA PHY Control function via the PMA_REMLPIREQ.request primitive. In the absence of the optional EEE capability, the PHY operates as if the value of this variable is FALSE.

Values: TRUE: LPI is encoded in the received symbols.
FALSE: LPI is not encoded in the received symbols.

rem_update_done

The rem_update_done variable is generated by the PCS Receive function and indicates whether or not the remote PHY has completed the update of its receiver state. It is passed to the PMA PHY Control function via the PMA_REMUPDATE.request primitive. In the absence of the optional EEE capability, the PHY shall operate as if the value of this variable is FALSE.

Values: TRUE: The remote PHY has completed the current update.
FALSE: The remote PHY is ready for the next update or the current update is still in progress.

signal_detect

The signal_detect variable is set by the PMA Receive function and indicates the presence of a signal at the MDI, as defined in 40.6.1.3.5.

Values: TRUE: There is a signal present at the MDI.
FALSE: There is no signal present at the MDI.

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40.4.5.2 Timers

All timers operate in the manner described in 14.2.3.2 with the following addition. A timer is reset and stops counting upon entering a state where “stop timer” is asserted.

A_timer
: An asynchronous (to the Auto-Crossover state diagram) free-running timer that provides for a relatively arbitrary reset of the state diagram to its initial state. This timer is used to reduce the probability of a lock-up condition where both nodes have the same identical seed initialization at the same point in time.

  Values: The condition A_timer_done becomes true upon timer expiration.

  Duration: This timer shall have a period of 1.3 s ± 25%.

  Initialization of A_timer is implementation specific.

maxwait_timer
: A timer used to limit the amount of time during which a receiver dwells in the SLAVE SILENT and TRAINING states. The timer shall expire 750 ms ± 10 ms if config = MASTER or 350 ms ± 5 ms if config = SLAVE. This timer is used jointly in the PHY Control and Link Monitor state diagrams. The maxwait_timer is tested by the Link Monitor to force link_status to be set to FAIL if the timer expires and loc_rcvr_status is NOT_OK. See Figure 40–16a.

minwait_timer
: A timer used to determine the minimum amount of time the PHY Control stays in the TRAINING, SEND IDLE, or DATA states. The timer shall expire 1 µs ± 0.1µs after being started.

sample_timer
: This timer provides a long enough sampling window to ensure detection of Link Pulses or link_status, if they exist at the receiver.

  Values: The condition sample_timer_done becomes true upon timer expiration.

  Duration: This timer shall have a period of 62 ms ± 2 ms.

stabilize_timer
: A timer used to control the minimum time that loc_rcvr_status must be OK before a transition to Link Up can occur. The timer shall expire 1 µs ± 0.1 µs after being started.

The following timers are only required for the optional EEE capability:

lpi_link_fail_timer
: This timer defines the maximum time the PHY allows between entry into the WAKE state and subsequent entry into the UPDATE or SEND IDLE OR DATA states before forcing the link to restart.

  Values: The condition lpi_link_fail_timer_done becomes true upon timer expiration.
  Duration: This timer shall have a period between 90 µs and 110 µs.

lpi_postupdate_timer
: This timer defines the maximum time the PHY dwells in the POST_UPDATE state before proceeding to the WAIT_QUIET state.

  Values: The condition lpi_postupdate_timer_done becomes true upon timer expiration.
  Duration: This timer shall have a period between 2.0 µs and 3.2 µs.

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lpi_quiet_timer
: This timer defines the maximum time the PHY remains quiet before initiating transmission to refresh the remote PHY.

  Values: The condition lpi_quiet_timer_done becomes true upon timer expiration.
  Duration: This timer shall have a period between 20 ms and 24 ms.

lpi_waitwq_timer
: This timer defines the maximum time the PHY dwells in the WAIT_QUIET state before forcing the link to restart.

  Values: The condition lpi_waitwq_timer_done becomes true upon timer expiration.
  Duration: This timer shall have a period between 10 µs and 12 µs.

lpi_wake_timer
: This timer defines the expected time for the PHY to transition from the LPI mode to normal operation.

  Values: The condition lpi_wake_timer_done becomes true upon timer expiration. For each transition of lpi_wake_timer_done from false to true, the wake error counter (see 40.5.1.1) shall be incremented.
  Duration: This timer shall have a period that does not exceed 16.5 µs.

lpi_waketx_timer
: This timer defines the time the PHY transmits to ensure detection by the remote PHY receiver and trigger an exit from the low power state.

  Values: The condition lpi_waketx_timer_done becomes true upon timer expiration.
  Duration: This timer shall have a period between 1.2 µs and 1.4 µs.

lpi_wakemz_timer
: This timer defines the time allowed for the PHY transmitter to achieve compliant operation following activation.

  Values: The condition lpi_wakemz_timer_done becomes true upon timer expiration.
  Duration: This timer shall have a period between 4.25 µs and 5.00 µs.

lpi_update_timer
: This timer defines the time the PHY transmits to facilitate a refresh of the remote PHY receiver.

  Values: The condition lpi_update_timer_done becomes true upon timer expiration.
  Duration: For a PHY configured as the MASTER, this timer shall have a period between 0.23 ms and 0.25 ms. For a PHY configured as the SLAVE, this timer shall have a period between 0.18 ms and 0.20 ms.

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40.4.6 State Diagrams

40.4.6.1 PHY Control state diagram

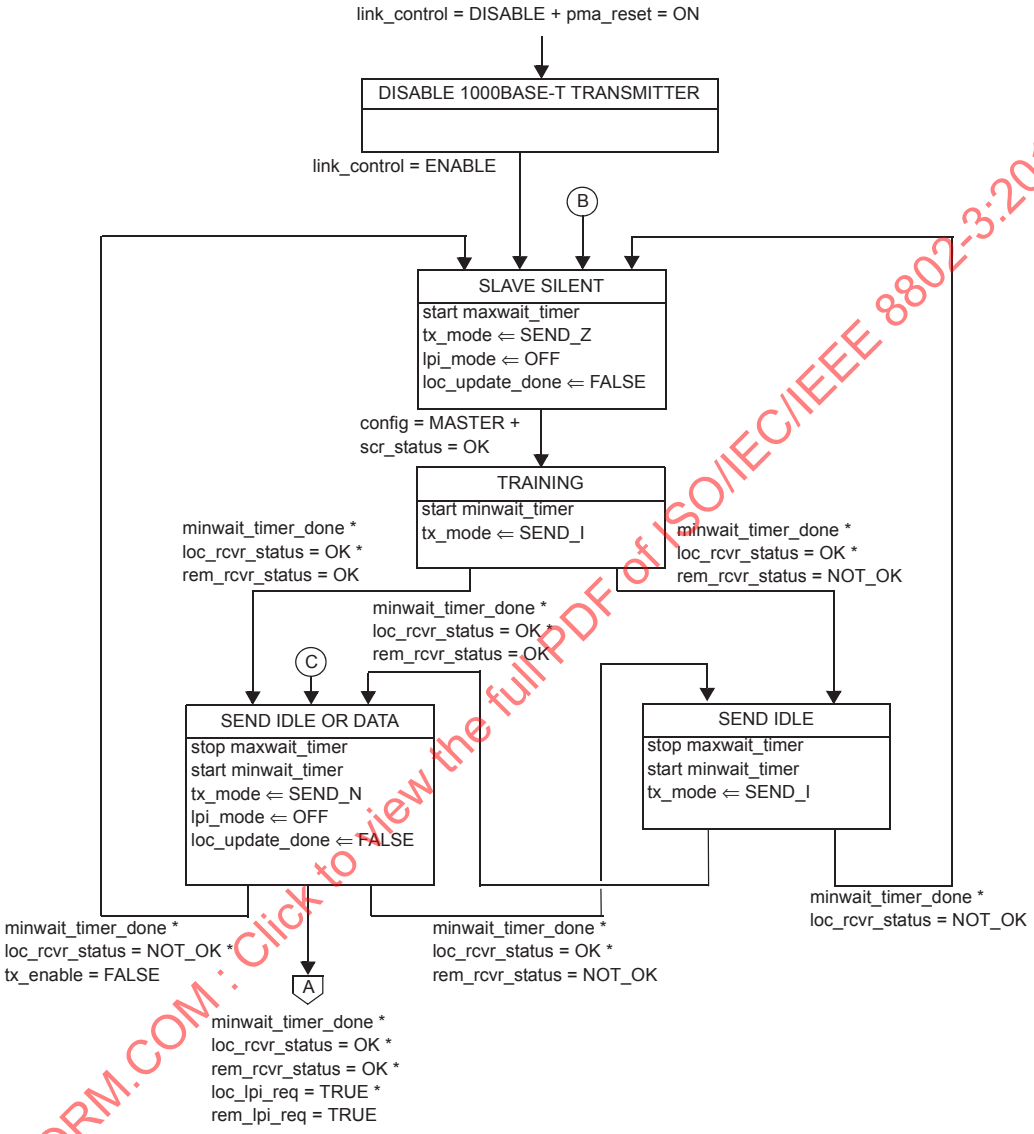

Figure 40–16a—PHY Control state diagram, part a

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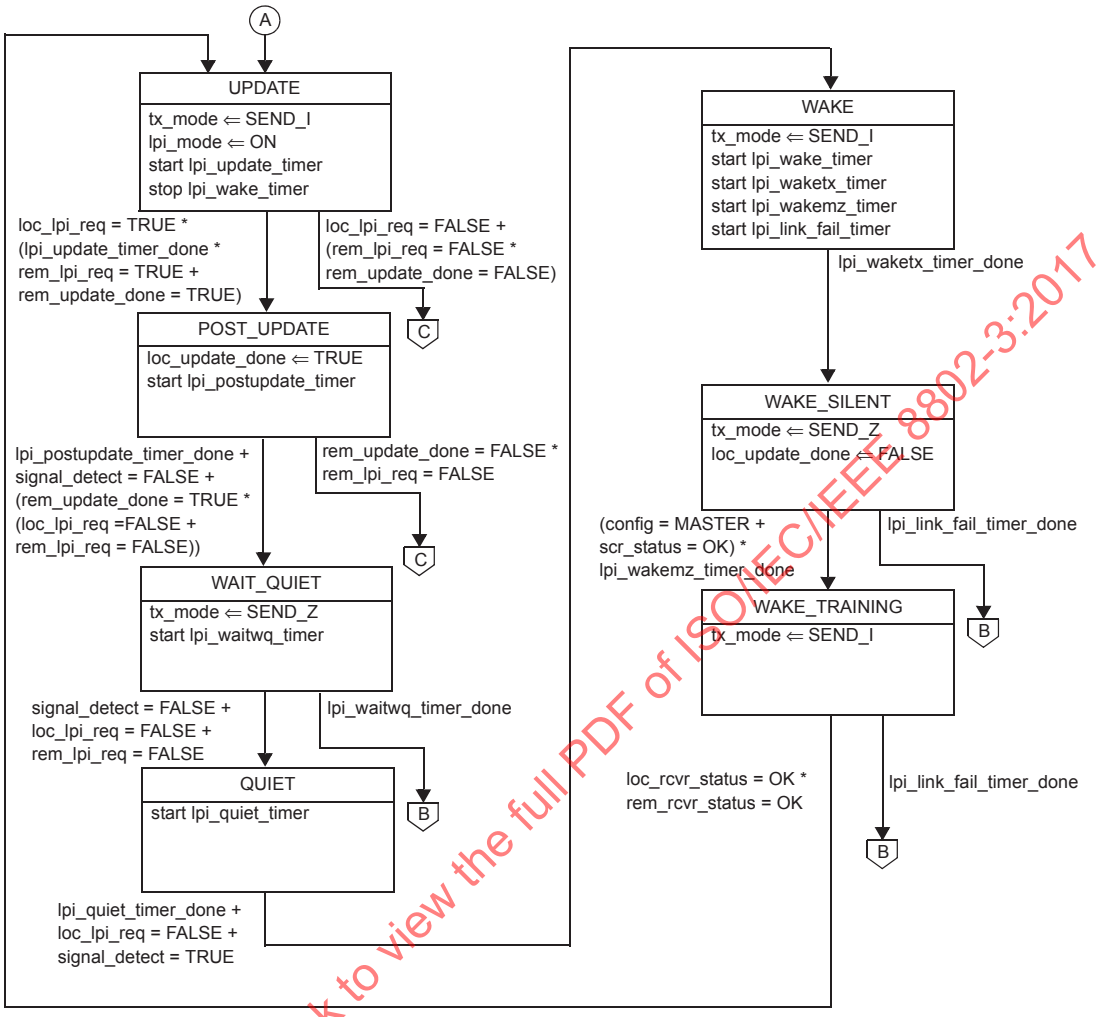

Figure 40–16b—PHY Control state diagram, part b (optional)

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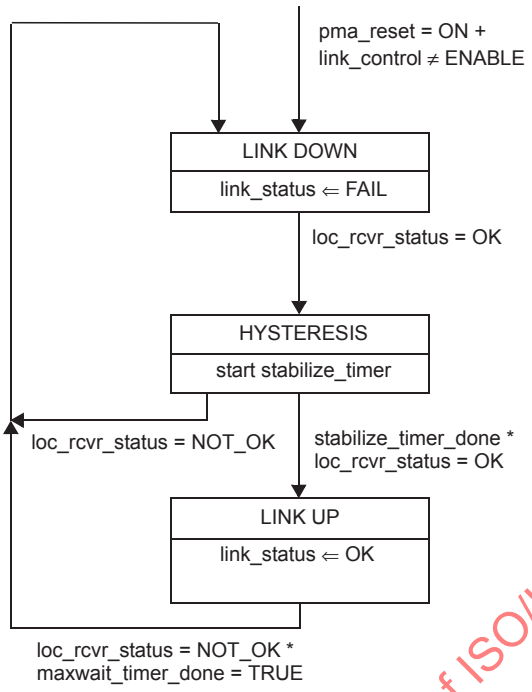
40.4.6.2 Link Monitor state diagram



NOTE 1—maxwait_timer is started in PHY Control state diagram (see Figure 40–16a).
NOTE 2—The variables link_control and link_status are designated as link_control_(1GigT) and link_status_(1GigT), respectively, by the Auto-Negotiation Arbitration state diagram (Figure 28–18).

Figure 40–17—Link Monitor state diagram

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40.4.6.2.1 Auto Crossover state diagram

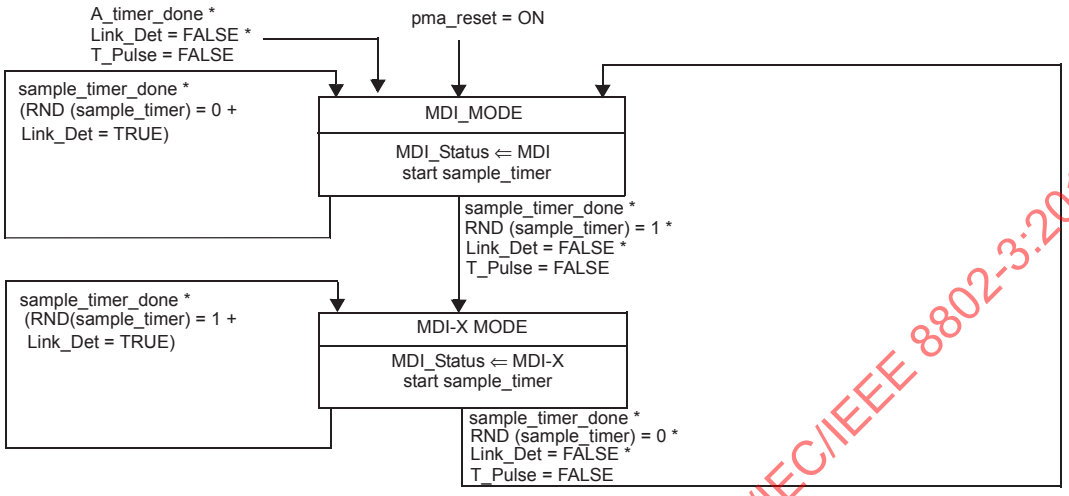

Figure 40–18—Auto Crossover state diagram

40.5 Management interface

1000BASE-T makes extensive use of the management functions provided by the MII Management Interface (see 22.2.4), and the communication and self-configuration functions provided by Auto-Negotiation (Clause 28).

40.5.1 Support for Auto-Negotiation

All 1000BASE-T PHYs shall provide support for Auto-Negotiation (Clause 28) and shall be capable of operating as MASTER or SLAVE.

Auto-Negotiation is performed as part of the initial set-up of the link, and allows the PHYs at each end to advertise their capabilities (speed, PHY type, half or full duplex) and to automatically select the operating mode for communication on the link. Auto-negotiation signaling is used for the following two primary purposes for 1000BASE-T:

a) To negotiate that the PHY is capable of supporting 1000BASE-T half duplex or full duplex transmission.
b) To determine the MASTER-SLAVE relationship between the PHYs at each end of the link.
c) To negotiate EEE capabilities as specified in 28C.12.

This relationship is necessary for establishing the timing control of each PHY. The 1000BASE-T MASTER PHY is clocked from a local source. The SLAVE PHY uses loop timing where the clock is recovered from the received data stream.

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40.5.1.1 1000BASE-T use of registers during Auto-Negotiation

A 1000BASE-T PHY shall use the management register definitions and values specified in Table 40–3.

Table 40–3—1000BASE-T Registers

Register	Bit	Name	Description	Type [a]
0	0.15:0	MII control register	Defined in 28.2.4.1.1	RO
1	1.15:0	MII status register	Defined in 28.2.4.1.2	RO
4	4.15:0	Auto-Negotiation advertisement register	The Selector Field (4.4:0) is set to the appropriate code as specified in Annex 28A. The Technology Ability Field bits 4.12:5 are set to the appropriate code as specified in Annexes 28B and 28D. Bit 4.15 is set to logical one to indicate the desired exchange of Next Pages describing the gigabit extended capabilities.	R/W
5	5.15:0	Auto-Negotiation link partner ability register	Defined in 28.2.4.1.4. 1000BASE-T implementations do not use this register to store Auto-Negotiation Link Partner Next Page data.	RO
6	6.15:0	Auto-Negotiation expansion register	Defined in 28.2.4.1.5	RO
7	7.15:0	Auto-Negotiation Next Page transmit register	Defined in 28.2.4.1.6	R/W
8	8.15:0	Auto-Negotiation link partner Next Page register	Defined in 28.2.4.1.8	RO
9	9.15:13	Test mode bits	Transmitter test mode operations are defined by bits 9.15:13 as described in 40.6.1.1.2 and Table 40–7. The default values for bits 9.15:13 are all zero.	R/W
9	9.12	MASTER-SLAVE Manual Config Enable	1=Enable MASTER-SLAVE Manual configuration value 0=Disable MASTER-SLAVE Manual configuration value Default bit value is 0.	R/W
9	9.11	MASTER-SLAVE Config Value	1=Configure PHY as MASTER during MASTER-SLAVE negotiation, only when 9.12 is set to logical one. 0=Configure PHY as SLAVE during MASTER-SLAVE negotiation, only when 9.12 is set to logical one. Default bit value is 0.	R/W
9	9.10	Port type	Bit 9.10 is to be used to indicate the preference to operate as MASTER (multiport device) or as SLAVE (single-port device) if the MASTER-SLAVE Manual Configuration Enable bit, 9.12, is not set. Usage of this bit is described in 40.5.2. 1=Multiport device 0=single-port device	R/W
9	9.9	1000BASE-T Full Duplex	1 = Advertise PHY is 1000BASE-T full duplex capable. 0 = Advertise PHY is not 1000BASE-T full duplex capable.	R/W
9	9.8	1000BASE-T Half Duplex	1 = Advertise PHY is 1000BASE-T half duplex capable. 0 = Advertise PHY is not 1000BASE-T half duplex capable.	R/W
9	9.7:0	Reserved	Write as 0, ignore on read.	R/W

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Table 40–3—1000BASE-T Registers *(continued)*

Register	Bit	Name	Description	Type [a]
10	10.15	MASTERSLAVE configuration fault	Configuration fault, as well as the criteria and method of fault detection, is PHY specific. The MASTER-SLAVE Configuration Fault bit will be cleared each time register 10 is read via the management interface and will be cleared by a 1000BASE-T PMA reset. This bit will self clear on Auto-Negotiation enable or Auto-Negotiation complete.This bit will be set if the number of failed MASTER-SLAVE resolutions reaches 7. For l000BASE-T, the fault condition will occur when both PHYs are forced to be MASTERs or SLAVEs at the same time using bits 9.12 and 9.11. Bit 10.15 should be set via the MASTER-SLAVE Configuration Resolution function described in 40.5.2. 1 = MASTER-SLAVE configuration fault detected 0 = No MASTER-SLAVE configuration fault detected	RO/LH/SC
10	10.14	MASTER-SLAVE configuration resolution	1 = Local PHY configuration resolved to MASTER 0 = Local PHY configuration resolved to SLAVE	RO
10	10.13	Local Receiver Status	1 = Local Receiver OK (loc_rcvr_status=OK) 0 = Local Receiver not OK (loc_rcvr_status=NOT_OK) Defined by the value of loc_rcvr_status as per 40.4.5.1.	RO
10	10.12	Remote Receiver Status	1 = Remote Receiver OK (rem_rcvr_status=OK) 0 = Remote Receiver not OK (rem_rcvr_status=NOT_OK) Defined by the value of rem_rcvr_status as per 40.4.5.1.	RO
10	10.11	LP 1000T FD	1 = Link Partner is capable of 1000BASE-T full duplex 0 = Link Partner is not capable of 1000BASE-T full duplex This bit is guaranteed to be valid only when the Page received bit (6.1) has been set to 1.	RO
10	10.10	LP 1000T HD	1 = Link Partner is capable of 1000BASE-T half duplex 0 = Link Partner is not capable of 1000BASE-T half duplex This bit is guaranteed to be valid only when the Page received bit (6.1) has been set to 1.	RO
10	10.9:8	Reserved	Reserved	RO
10	10.7:0	Idle Error Count	Bits 10.7:0 indicate the Idle Error count, where 10.7 is the most significant bit. These bits contain a cumulative count of the errors detected when the receiver is receiving idles and PMA_TXMODE.indication is equal to SEND_N (indicating that both local and remote receiver status have been detected to be OK). The counter is incremented every symbol period that rxerror_status is equal to ERROR. These bits are reset to all zeros when the error count is read by the management function or upon execution of the PCS Reset function and are to be held at all ones in case of overflow (see 30.5.1.1.13).	RO/SC
15	15.15:12	Extended status register	See 22.2.4.4	RO

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Table 40–3—1000BASE-T Registers *(continued)*

Register	Bit	Name	Description	Type [a]
3.0[b]	3.0.10	Clock stop enable	Defined in 45.2.3.1.4. When the PHY supports the optional EEE capability, it may stop the derived GMII receive clock while it is signaling LPI in the receive direction. If this bit is set to 1, then the PHY may stop the receive GMII clock while it is signaling LPI; otherwise it keeps the clock active.	R/W
3.1	3.1.11	Transmit LPI received	Defined in 45.2.3.2.1.	RO/LH
3.1	3.1.10	Receive LPI received	Defined in 45.2.3.2.2.	RO/LH
3.1	3.1.9	Transmit LPI indication	Defined in 45.2.3.2.3.	RO
3.1	3.1.8	Receive LPI indication	Defined in 45.2.3.2.4.	RO
3.1	3.1.6	Clock stop capable	Defined in 45.2.3.2.6. When the PHY supports the optional EEE capability, this bit may be set to 1 to allow the MAC to stop the GMII clock while it is signaling LPI in the transmit direction. If this bit is 0, then the MAC keeps the clock active.	RO
3.20	3.20.2	1000BASE-T EEE supported	If the local device supports the optional EEE capability for 1000BASE-T, this bit is set to 1.	RO
3.22	3.22.15:0	EEE wake error counter	This counter is incremented for each transition of lpi_wake_timer_done from FALSE to TRUE (see 40.4.5.2).	RO, NR
7.60	7.60.2	1000BASE-T EEE advertisement	If the local device supports the optional EEE capability for 1000BASE-T and EEE is desired, this bit is set to 1.	R/W
7.61	7.61.2	LP 1000BASE-T EEE advertisement	If the link partner supports the optional EEE capability for 1000BASE-T and EEE is desired, this bit is set to 1.	RO

[a] R/W = Read/Write, RO = Read only, SC = Self-clearing, LH = Latching high.
[b] This register resides in the Clause 45 management space and is designated by the format M.R.B where M is the MDIO manageable device address (MMD), R is the register address, and B is the bit.

40.5.1.2 1000BASE-T Auto-Negotiation page use

1000BASE-T PHYs shall exchange one Auto-Negotiation Base Page, a 1000BASE-T formatted Next Page, and two 1000BASE-T Unformatted Next Pages in sequence, without interruption, as specified in Table 40–4. Additional Next Pages can be exchanged as described in Annex 40C.

Note that the Acknowledge 2 bit is not utilized and has no meaning when used for the 1000BASE-T message page exchange.

When the PHY supports the optional EEE capability, a 1000BASE-T PHY shall exchange an additional formatted Next Page and Unformatted Next Page in sequence, without interruption, as specified in Table 40–4.

40.5.1.3 Sending Next Pages

Implementers who do not wish to send additional Next Pages (i.e., Next Pages in addition to those required to perform PHY configuration as defined in this clause) can use Auto-Negotiation as defined in Clause 28 and the Next Pages defined in 40.5.1.2. Implementers who wish to send additional Next Pages are advised to consult Annex 40C.

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Table 40–4—1000BASE-T Base and Next Pages bit assignments

Bit	Bit definition	Register location
Base Page		
D15	1 (to indicate that Next Pages follow)	
D14:D1	As specified in 28.2.1.2	Management register 4
PAGE 0 (Message Next Page)		
M10:M0	8	
PAGE 1 (Unformatted Next Page)		
U10:U5	Reserved transmit as 0	
U4	1000BASE-T half duplex (1 = half duplex and 0 = no half duplex)	GMII register 9.8 (MASTER-SLAVE Control register)
U3	1000BASE-T full duplex (1 = full duplex and 0 = no full duplex)	GMII register 9.9 (MASTER-SLAVE Control register)
U2	1000BASE-T port type bit (1 = multiport device and 0 = single-port device)	GMII register 9.10 (MASTER-SLAVE Control register)
U1	1000BASE-T MASTER-SLAVE Manual Configuration value (1 = MASTER and 0 = SLAVE.) This bit is ignored if 9.12 = 0.	GMII register 9.11 (MASTER-SLAVE Control register)
U0	1000BASE-T MASTER-SLAVE Manual Configuration Enable (1 = Manual Configuration Enable.) This bit is intended to be used for manual selection in a particular MASTER-SLAVE mode and is to be used in conjunction with bit 9.11.	GMII register 9.12 (MASTER-SLAVE Control register)
PAGE 2 (Unformatted Next Page)		
U10	1000BASE-T MASTER-SLAVE Seed Bit 10 (SB10) (MSB)	MASTER-SLAVE Seed Value (10:0)
U9	1000BASE-T MASTER-SLAVE Seed Bit 9 (SB9)	
U8	1000BASE-T MASTER-SLAVE Seed Bit 8 (SB8)	
U7	1000BASE-T MASTER-SLAVE Seed Bit 7 (SB7)	
U6	1000BASE-T MASTER-SLAVE Seed Bit 6 (SB6)	
U5	1000BASE-T MASTER-SLAVE Seed Bit 5 (SB5)	
U4	1000BASE-T MASTER-SLAVE Seed Bit 4 (SB4)	
U3	1000BASE-T MASTER-SLAVE Seed Bit 3 (SB3)	
U2	1000BASE-T MASTER-SLAVE Seed Bit 2 (SB2)	
U1	1000BASE-T MASTER-SLAVE Seed Bit 1 (SB1)	
U0	1000BASE-T MASTER-SLAVE Seed Bit 0 (SB0)	
PAGE 3 (Message page)		
M10:M0	10	
PAGE 4 (Unformatted Next Page)		
U10:U3	As specified in 45.2.7.13.	
U2	1000BASE-T EEE (1 = EEE is supported for 1000BASE-T, 0 = EEE is not supported for 1000BASE-T)	Management register 7.60.2[a]
U1:U0	As specified in 45.2.7.13.	

[a]This register resides in the Clause 45 management space and is designated by the format M.R.B where M is the MDIO manageable device address (MMD), R is the register address, and B is the bit.

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40.5.2 MASTER-SLAVE configuration resolution

Since both PHYs that share a link segment are capable of being MASTER or SLAVE, a prioritization scheme exists to ensure that the correct mode is chosen. The MASTER-SLAVE relationship shall be determined during Auto-Negotiation using Table 40–5 with the 1000BASE-T Technology Ability Next Page bit values specified in Table 40–4 and information received from the link partner. This process is conducted at the entrance to the FLP LINK GOOD CHECK state shown in the Arbitration state diagram (Figure 28–15.)

The following four equations are used to determine these relationships:

manual_MASTER = U0 * U1
manual_SLAVE = U0 * !U1
single-port device = !U0 * !U2,
multiport device = !U0 * U2

where

U0 is bit 0 of unformatted page 1,
U1 is bit 1 of unformatted page 1, and
U2 is bit 2 of unformatted page 1 (see Table 40–4).

A 1000BASE-T PHY is capable of operating either as the MASTER or SLAVE. In the scenario of a link between a single-port device and a multiport device, the preferred relationship is for the multiport device to be the MASTER PHY and the single-port device to be the SLAVE. However, other topologies may result in contention. The resolution function of Table 40–5 is defined to handle any relationship conflicts.

Table 40–5—1000BASE-T MASTER-SLAVE configuration resolution table

Local device type	Remote device type	Local device resolution	Remote device resolution
single-port device	multiport device	SLAVE	MASTER
single-port device	manual_MASTER	SLAVE	MASTER
manual_SLAVE	manual_MASTER	SLAVE	MASTER
manual_SLAVE	multiport device	SLAVE	MASTER
multiport device	manual_MASTER	SLAVE	MASTER
manual_SLAVE	single-port device	SLAVE	MASTER
multiport device	single-port device	MASTER	SLAVE
multiport device	manual_SLAVE	MASTER	SLAVE

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Table 40–5—1000BASE-T MASTER-SLAVE configuration resolution table *(continued)*

Local device type	Remote device type	Local device resolution	Remote device resolution
manual_MASTER	manual_SLAVE	MASTER	SLAVE
manual_MASTER	single-port device	MASTER	SLAVE
single-port device	manual_SLAVE	MASTER	SLAVE
manual_MASTER	multiport device	MASTER	SLAVE
multiport device	multiport device	The device with the higher SEED value is configured as MASTER, otherwise SLAVE.	The device with the higher SEED value is configured as MASTER, otherwise SLAVE.
single-port device	single-port device	The device with the higher SEED value is configured as MASTER, otherwise SLAVE	The device with the higher SEED value is configured as MASTER, otherwise SLAVE.
manual_SLAVE	manual_SLAVE	MASTER-SLAVE configuration fault	MASTER-SLAVE configuration fault
manual_MASTER	manual_MASTER	MASTER-SLAVE configuration fault	MASTER-SLAVE configuration fault

The rationale for the hierarchy illustrated in Table 40–5 is straightforward. A 1000BASE-T multiport device has higher priority than a single-port device to become the MASTER. In the case where both devices are of the same type, e.g., both devices are multiport devices, the device with the higher MASTER-SLAVE seed bits (SB0...SB10), where SB10 is the MSB, shall become the MASTER and the device with the lower seed value shall become the SLAVE. In case both devices have the same seed value, both should assert link_status_1GigT=FAIL (as defined in 28.3.1) to force a new cycle through Auto-Negotiation. Successful completion of the MASTER-SLAVE resolution shall be treated as MASTER-SLAVE configuration resolution complete.

The method of generating a random or pseudorandom seed is left to the implementer. The generated random seeds should belong to a sequence of independent, identically distributed integer numbers with a uniform distribution in the range of 0 to $2^{11} - 2$. The algorithm used to generate the integer should be designed to minimize the correlation between the number generated by any two devices at any given time. A seed counter shall be provided to track the number of seed attempts. The seed counter shall be set to zero at start-up and shall be incremented each time a seed is generated. When MASTER-SLAVE resolution is complete, the seed counter shall be reset to 0 and bit 10.15 shall be set to logical zero. A MASTER-SLAVE resolution fault shall be declared if resolution is not reached after the generation of seven seeds.

The MASTER-SLAVE Manual Configuration Enable bit (control register bit 9.12) and the MASTER-SLAVE Config Value bit (control register bit 9.11) are used to manually set a device to become the MASTER or the SLAVE. In case both devices are manually set to become the MASTER or the SLAVE, this condition shall be flagged as a MASTER-SLAVE Configuration fault condition, thus the MASTER-SLAVE Configuration fault bit (status register bit 10.15) shall be set to logical one. The MASTER-SLAVE Configuration fault condition shall be treated as MASTER-SLAVE configuration resolution complete and link_status_1GigT shall be set to FAIL, because the MASTER-SLAVE relationship was not resolved. This will force a new cycle through Auto-Negotiation after the link_fail_inhibit_timer has expired. Determination of MASTER-SLAVE values occur on the entrance to the FLP LINK GOOD CHECK state (Figure 28–18) when the highest common denominator (HCD) technology is 1000BASE-T. The resulting MASTER-SLAVE value is used by the 1000BASE-T PHY control (40.4.2.4).

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If MASTER-SLAVE Manual Configuration is disabled (bit 9.12 is set to 0) and the local device detects that both the local device and the remote device are of the same type (either multiport device or single-port device) and that both have generated the same random seed, it generates and transmits a new random seed for MASTER-SLAVE negotiation by setting link_status to FAIL and cycling through the Auto-Negotiation process again.

The MASTER-SLAVE configuration process returns one of the three following outcomes:

a) *Successful:* Bit 10.15 of the 1000BASE-T Status Register is set to logical zero and bit 10.14 is set to logical one for MASTER resolution or for logical zero for SLAVE resolution. 1000BASE-T returns control to Auto_Negotiation (at the entrance to the FLP LINK GOOD CHECK state in Figure 28–18) and passes the value MASTER or SLAVE to PMA_CONFIG.indication (see 40.2.4.)
b) *Unsuccessful:* link_status_1GigT is set to FAIL and Auto-Negotiation restarts (see Figure 28–18.)
c) *Fault detected:* (This happens when both end stations are set for manual configuration and both are set to MASTER or both are set to SLAVE.) Bit 10.15 of the 1000BASE-T Status Register is set to logical one to indicate that a configuration fault has been detected. This bit also is set when seven attempts to configure the MASTER SLAVE relationship via the seed method have failed. When a fault is detected, link_status_1GigT is set to FAIL, causing Auto-Negotiation to cycle through again.

NOTE—MASTER-SLAVE arbitration only occurs if 1000BASE-T is selected as the highest common denominator; otherwise, it is assumed to have passed this condition.

40.6 PMA electrical specifications

This subclause defines the electrical characteristics of the PMA.

Common-mode tests use the common-mode return point as a reference.

40.6.1 PMA-to-MDI interface tests

40.6.1.1 Isolation requirement

A PHY with a MDI that is a PI (see 33.1.3) shall meet the isolation requirements defined in 33.4.1.

A PHY with a MDI that is not a PI shall provide electrical isolation between the port device circuits, including frame ground (if any) and all MDI leads. This electrical isolation shall withstand at least one of the following electrical strength tests:

a) 1500 V rms at 50 Hz to 60 Hz for 60 s, applied as specified in subclause 5.2.2 of IEC 60950-1:2001.
b) 2250 Vdc for 60 s, applied as specified in subclause 5.2.2 of IEC 60950-1:2001.
c) A sequence of ten 2400 V impulses of alternating polarity, applied at intervals of not less than 1 s. The shape of the impulses shall be 1.2/50 µs (1.2 µs virtual front time, 50 µs virtual time of half value), as defined in IEC 60950-1:2001 Annex N.

There shall be no insulation breakdown, as defined in subclause 5.2.2 of IEC 60950-1:2001, during the test. The resistance after the test shall be at least 2 MΩ, measured at 500 V dc.

40.6.1.1.1 Test channel

To perform the transmitter MASTER-SLAVE timing jitter tests described in this clause, a test channel is required to ensure that jitter is measured under conditions of poor signal to echo ratio. This test channel shall be constructed by combining 100 and 120 Ω cable segments that both meet or exceed ISO/IEC 11801

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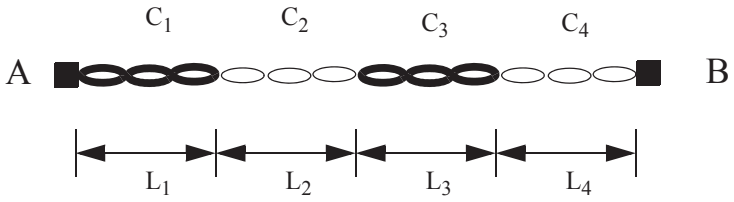
Category 5 specifications for each pair, as shown in Figure 40–19, with the lengths and additional restrictions on parameters described in Table 40–6. The ends of the test channel shall be terminated with connectors meeting or exceeding ISO/IEC 11801:1995 Category 5 specifications. The return loss of the resulting test channel shall meet the return loss requirements of 40.7.2.3 and the crosstalk requirements of 40.7.3.



Identical for each of the four pairs.

Figure 40–19—Test channel topology for each cable pair

Table 40–6—Test channel cable segment specifications

Cable segment	Length (meters)	Characteristic impedance (at frequencies > 1 MHz)	Attenuation (per 100 meters at 31.25 MHz)
1	L_1=1.20	120 Ω ± 5 Ω	7.8 to 8.8 dB
2	L_2=x	100 Ω ± 5 Ω	10.8 to 11.8 dB
3	L_3=1.48	120 Ω ± 5 Ω	7.8 to 8.8 dB
4	L_4=y	100 Ω ± 5 Ω	10.8 to 11.8 dB

NOTE—x is chosen so that the total delay of segments C1, C2, and C3, averaged across all pairs, is equal to 570 ns at 31.25 MHz; however, if this would cause the total attenuation of segments C1, C2, and C3, averaged across all pairs, to exceed the worst case insertion loss specified in 40.7.2.1 then x is chosen so that the total attenuation of segments C1, C2, and C3, averaged across all pairs, does not violate 40.7.2.1 at any frequencies. The value of y is chosen so that the total attenuation of segments C1, C2, C3, and C4, averaged across all pairs, does not violate 40.7.2.1 at any frequency (y may be 0).

40.6.1.1.2 Test modes

The test modes described below shall be provided to allow for testing of the transmitter waveform, transmitter distortion, and transmitted jitter.

For a PHY with a GMII interface, these modes shall be enabled by setting bits 9.13:15 (1000BASE-T Control Register) of the GMII Management register set as shown in Table 40–7. These test modes shall only change the data symbols provided to the transmitter circuitry and shall not alter the electrical and jitter characteristics of the transmitter and receiver from those of normal (non-test mode) operation. PHYs without a GMII shall provide a means to enable these modes for conformance testing.

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Table 40–7—GMII management register settings for test modes

Bit 1 (9.15)	Bit 2 (9.14)	Bit 3 (9.13)	Mode
0	0	0	Normal operation
0	0	1	Test mode 1—Transmit waveform test
0	1	0	Test mode 2—Transmit jitter test in MASTER mode
0	1	1	Test mode 3—Transmit jitter test in SLAVE mode
1	0	0	Test mode 4—Transmitter distortion test
1	0	1	Reserved, operations not identified.
1	1	0	Reserved, operations not identified.
1	1	1	Reserved, operations not identified.

When test mode 1 is enabled, the PHY shall transmit the following sequence of data symbols A_n, B_n, C_n, D_n, of 40.3.1.3.6 continually from all four transmitters:

{{+2 followed by 127 0 symbols}, {–2 followed by 127 0 symbols},{+1 followed by 127 0 symbols}, {–1 followed by 127 0 symbols}, {128 +2 symbols, 128 –2 symbols, 128 +2 symbols, 128 –2 symbols}, {1024 0 symbols}}

This sequence is repeated continually without breaks between the repetitions when the test mode is enabled. A typical transmitter output is shown in Figure 40–20. The transmitter shall time the transmitted symbols from a 125.00 MHz ± 0.01% clock in the MASTER timing mode.

When test mode 2 is enabled, the PHY shall transmit the data symbol sequence {+2, –2} repeatedly on all channels. The transmitter shall time the transmitted symbols from a 125.00 MHz ± 0.01% clock in the MASTER timing mode.

When test mode 3 is enabled, the PHY shall transmit the data symbol sequence {+2, –2} repeatedly on all channels. The transmitter shall time the transmitted symbols from a 125.00 MHz ± 0.01% clock in the SLAVE timing mode. A typical transmitter output for transmitter test modes 2 and 3 is shown in Figure 40–21.

When test mode 4 is enabled, the PHY shall transmit the sequence of symbols generated by the following scrambler generator polynomial, bit generation, and level mappings:

$$g_{s1} = 1 + x^9 + x^{11}$$

The maximum-length shift register used to generate the sequences defined by this polynomial shall be updated once per symbol interval (8 ns). The bits stored in the shift register delay line at a particular time n are denoted by $Scr_n[10:0]$. At each symbol period the shift register is advanced by one bit and one new bit represented by $Scr_n[0]$ is generated. Bits $Scr_n[8]$ and $Scr_n[10]$ are exclusive OR'd together to generate the next $Scr_n[0]$ bit. The bit sequences, $x0_n$, $x1_n$, and $x2_n$, generated from combinations of the scrambler bits as shown in the following equations, shall be used to generate the quinary symbols, s_n, as shown in Table 40–8. The quinary symbol sequence shall be presented simultaneously to all transmitters. The transmitter shall time the transmitted symbols from a 125.00 MHz ± 0.01% clock in the MASTER timing mode. A typical transmitter output for transmitter test mode 4 is shown in Figure 40–22.

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$x0_n = Scr_n[0]$

$x1_n = Scr_n[1] \wedge Scr_n[4]$

$x2_n = Scr_n[2] \wedge Scr_n[4]$

Table 40–8—Transmitter test mode 4 symbol mapping

x2n	x1n	x0n	quinary symbol, s_n
0	0	0	0
0	0	1	1
0	1	0	2
0	1	1	–1
1	0	0	0
1	0	1	1
1	1	0	–2
1	1	1	–1

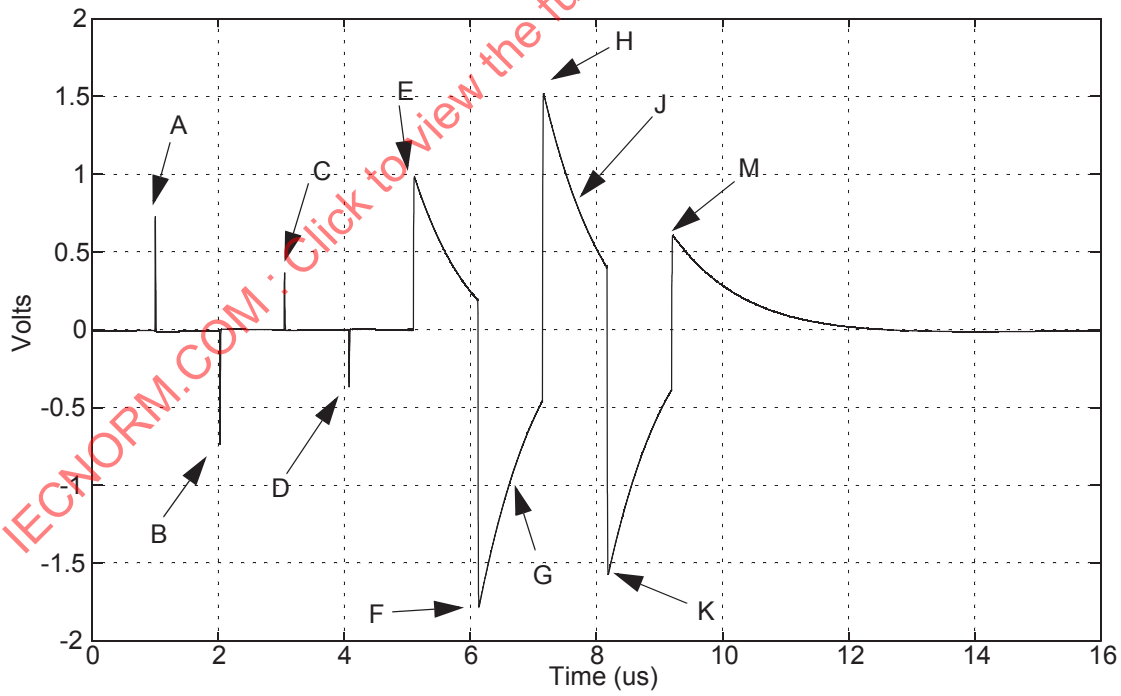

Figure 40–20—Example of transmitter test mode 1 waveform (1 cycle)

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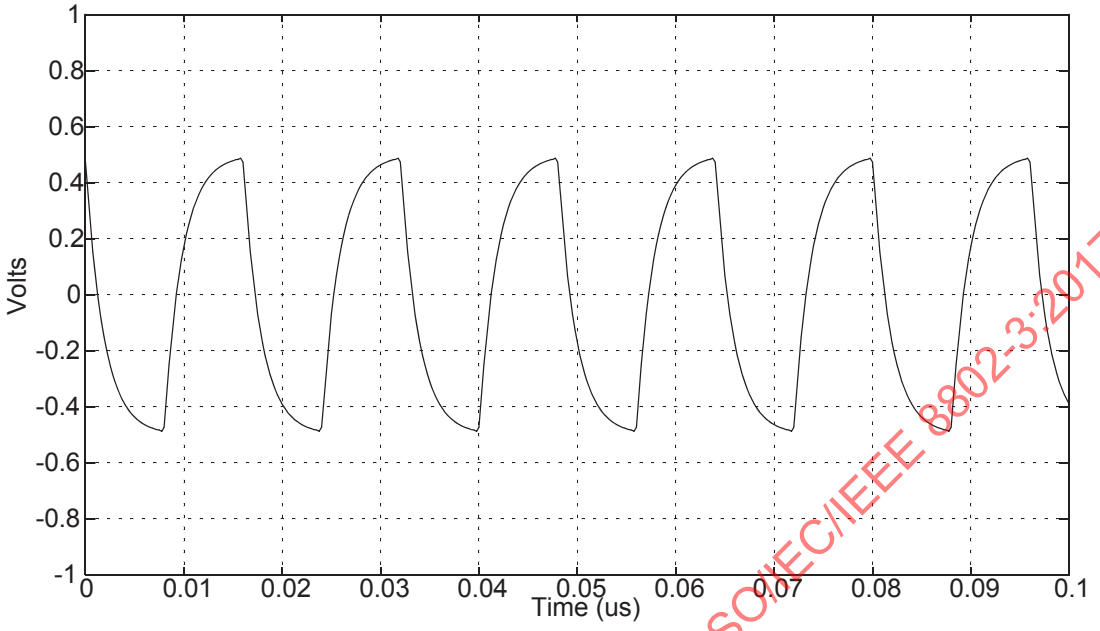

Figure 40–21—Example of transmitter test modes 2 and 3 waveform

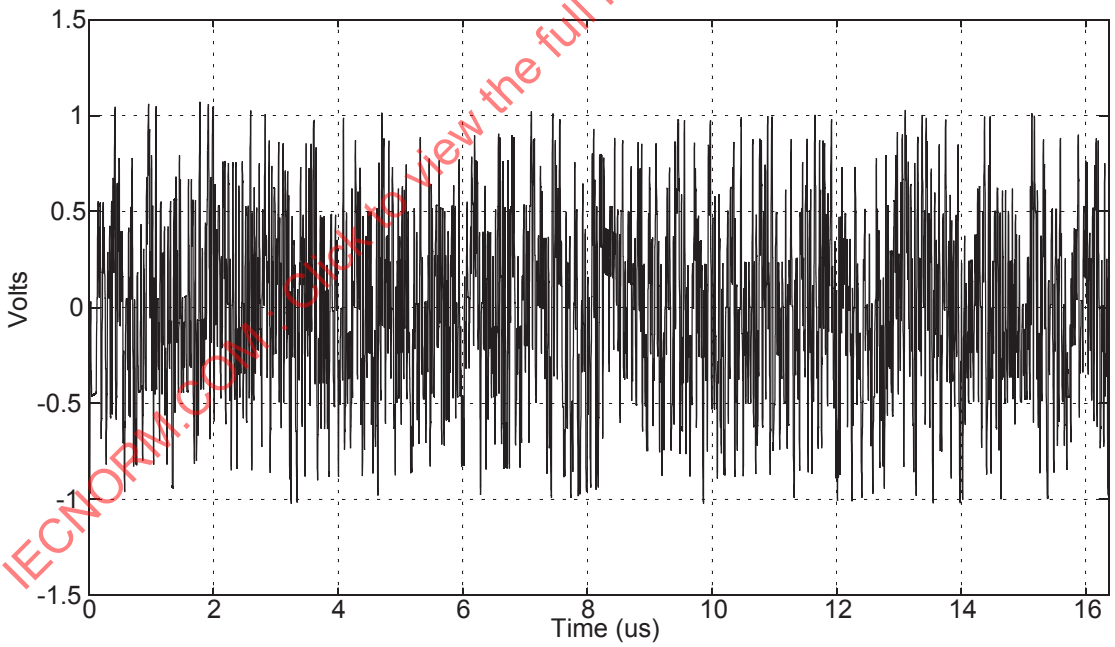

Figure 40–22—Example of Transmitter Test Mode 4 waveform (1 cycle)

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40.6.1.1.3 Test Fixtures

The following fixtures (illustrated by Figure 40–23, Figure 40–24, Figure 40–25, and Figure 40–26), or their functional equivalents, shall be used for measuring the transmitter specifications described in 40.6.1.2.

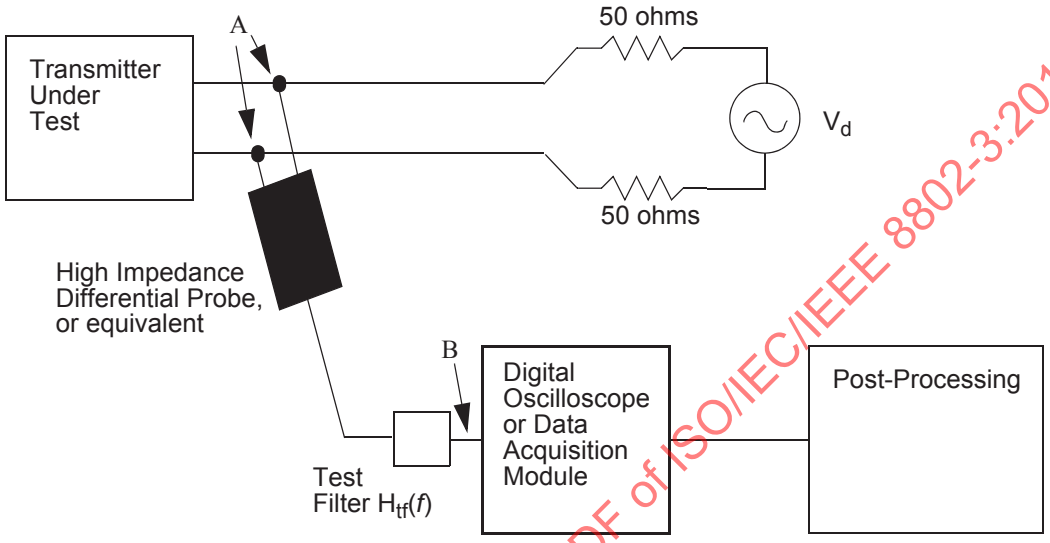

Figure 40–23—Transmitter test fixture 1 for template measurement

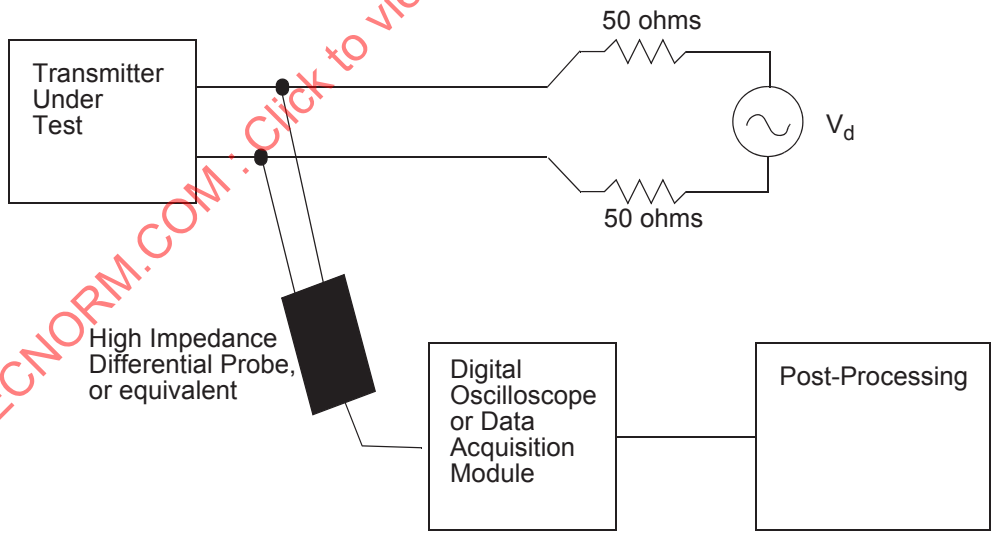

Figure 40–24—Transmitter test fixture 2 for droop measurement

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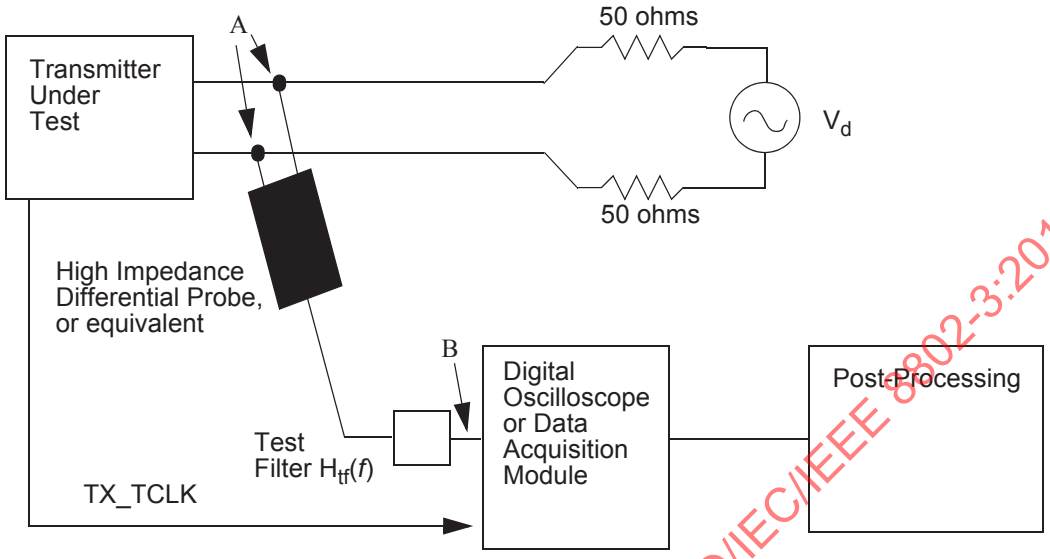

Figure 40–25—Transmitter test fixture 3 for distortion measurement

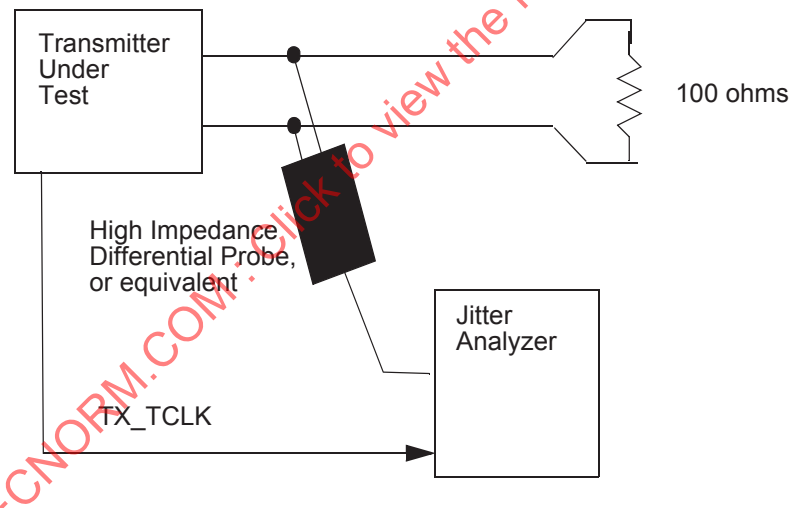

Figure 40–26—Transmitter test fixture 4 for transmitter jitter measurement

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The test filter, $H_{tf}(f)$, used in transmitter test fixtures 1 and 3 may be located between the points A and B as long as the test filter does not significantly alter the impedance seen by the transmitter. The test filter may instead be implemented as a digital filter in the post processing block. The test filter shall have the following continuous time transfer function or its discrete time equivalent:

$$H_{tf}(f) = \frac{jf}{jf + 2\times10^{6}} \qquad f \text{ in Hz}$$

NOTE—j denotes the square root of –1.

The disturbing signal, V_d, shall have the characteristics listed in Table 40–9.

Table 40–9—V_d Characteristics

Characteristic	Transmit test fixture 1	Transmit test fixture 2	Transmit test fixture 3
Waveform	Sine wave		
Amplitude	2.8 volts peak-to-peak	2.8 volts peak-to-peak	5.4 volts peak-to-peak
Frequency	31.25 MHz	31.25 MHz	20.833 MHz (125/6 MHz)
Purity	All harmonics >40 dB below fundamental		

The post-processing block has two roles. The first is to remove the disturbing signal from the measurement. A method of removing the disturbing signal is to take a single shot acquisition of the transmitted signal plus test pattern, then remove the best fit of a sine wave at the fundamental frequency of the disturbing signal from the measurement. It will be necessary to allow the fitting algorithm to adjust the frequency, phase, and amplitude parameters of the sine wave to achieve the best fit.

The second role of the post-processing block is to compare the measured data with the templates, droop specification, or distortion specification.

Trigger averaging of the transmitter output to remove measurement noise and increase measurement resolution is acceptable provided it is done in a manner that does not average out possible distortions caused by the interaction of the transmitter and the disturbing voltage. For transmitter template and droop measurements, averaging can be done by ensuring the disturbing signal is exactly synchronous to the test pattern so that the phase of the disturbing signal at any particular point in the test pattern remains constant. Trigger averaging also requires a triggering event that is synchronous to the test pattern. A trigger pulse generated by the PHY would be ideal for this purpose; however, in practice, triggering off the waveform generated by one of the other transmitter outputs that does not have the disturbing signal present may be possible.

NOTE—The disturbing signal may be made synchronous to the test pattern by creating the disturbing signal using a source of the transmit clock for the PHY under test, dividing it down to the proper frequency for the disturbing signal, passing the result through a high Q bandpass filter to eliminate harmonics and then amplifying the result to the proper amplitude.

The generator of the disturbing signal must have sufficient linearity and range so it does not introduce any appreciable distortion when connected to the transmitter output (see Table 40–9). This may be verified by replacing the transmitter under test with another identical disturbing signal generator having a different frequency output and verifying that the resulting waveform's spectrum does not show significant distortion products.

Additionally, to allow for measurement of transmitted jitter in master and slave modes, the PHY shall provide access to the 125 MHz symbol clock, TX_TCLK, that times the transmitted symbols (see 40.4.2.2). The PHY shall provide a means to enable this clock output if it is not normally enabled.

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40.6.1.2 Transmitter electrical specifications

The PMA shall provide the Transmit function specified in 40.4.2.2 in accordance with the electrical specifications of this clause.

Where a load is not specified, the transmitter shall meet the requirements of this clause with a 100 Ω resistive differential load connected to each transmitter output.

The tolerance on the poles of the test filters used in this subclause shall be ±1%.

Practical considerations prevent measurement of the local transmitter performance in the presence of the remotely driven signal in this standard; however, the design of the transmitter to tolerate the presence of the remotely driven signal with acceptable distortion or other changes in performance is a critical issue and must be addressed by the implementer. To this end, a disturbing sine wave is used to simulate the presence of a remote transmitter for a number of the transmitter tests described in the following subordinate subclauses.

40.6.1.2.1 Peak differential output voltage and level accuracy

The absolute value of the peak of the waveform at points A and B, as defined in Figure 40–20, shall fall within the range of 0.67 V to 0.82 V (0.75 V ± 0.83 dB). These measurements are to be made for each pair while operating in test mode 1 and observing the differential signal output at the MDI using transmitter test fixture 1 with no intervening cable.

The absolute value of the peak of the waveforms at points A and B shall differ by less than 1% from the average of the absolute values of the peaks of the waveform at points A and B.

The absolute value of the peak of the waveform at points C and D as defined in Figure 40–20 shall differ by less than 2% from 0.5 times the average of the absolute values of the peaks of the waveform at points A and B.

40.6.1.2.2 Maximum output droop

The magnitude of the negative peak value of the waveform at point G, as defined in Figure 40–20, shall be greater than 73.1% of the magnitude of the negative peak value of the waveform at point F. These measurements are to be made for each pair while in test mode 1 and observing the differential signal output at the MDI using transmit test fixture 2 with no intervening cable. Point G is defined as the point exactly 500 ns after point F. Point F is defined as the point where the waveform reaches its minimum value at the location indicated in Figure 40–20. Additionally, the magnitude of the peak value of the waveform at point J as defined in Figure 40–20 shall be greater than 73.1% of the magnitude of the peak value of the waveform at point H. Point J is defined as the point exactly 500 ns after point H. Point H is defined as the point where the waveform reaches its maximum value at the location indicated in Figure 40–20.

40.6.1.2.3 Differential output templates

The voltage waveforms around points A, B, C, D defined in Figure 40–20, after the normalization described herein, shall lie within the time domain template 1 defined in Figure 40–27 and the piecewise linear interpolation between the points in Table 40–10. These measurements are to be made for each pair while in test mode 1 and while observing the differential signal output at the MDI using transmitter test fixture 1 with no intervening cable. The waveforms may be shifted in time as appropriate to fit within the template.

The waveform around point A is normalized by dividing by the peak value of the waveform at A.

The waveform around point B is normalized by dividing by the negative of the peak value of the waveform at A.

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The waveform around point C is normalized by dividing by 1/2 the peak value of the waveform at A.

The waveform around point D is normalized by dividing by the negative of 1/2 the peak value of the waveform at A.

The voltage waveforms around points F and H defined in Figure 40–20, after the normalization described herein, shall lie within the time domain template 2 defined in Figure 40–27 and the piecewise linear interpolation between the points in Table 40–11. These measurements are to be made for each pair while in test mode 1 and while observing the differential signal output at the MDI using transmitter test fixture 1 with no intervening cable. The waveforms may be shifted in time as appropriate to fit within the template.

The waveform around point F is normalized by dividing by the peak value of the waveform at F.

The waveform around point H is normalized by dividing by the peak value of the waveform at H.

NOTE 1—The templates were created with the following assumptions about the elements in the transmit path:

1) Digital Filter: $0.75 + 0.25\ z^{-1}$
2) Ideal DAC
3) Single pole continuous time low-pass filter with pole varying from 70.8 MHz to 117 MHz or linear rise/fall time of 5 ns.
4) Single pole continuous time high-pass filter (transformer high pass) with pole varying from 1 Hz to 100 kHz.
5) Single pole continuous time high-pass filter (test filter) with pole varying from 1.8 MHz to 2.2 MHz.
6) Additionally, +0.025 was added to the upper template and –0.025 was added to the lower template to allow for noise and measurement error.

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NOTE 2—The transmit templates are not intended to address electromagnetic radiation limits.

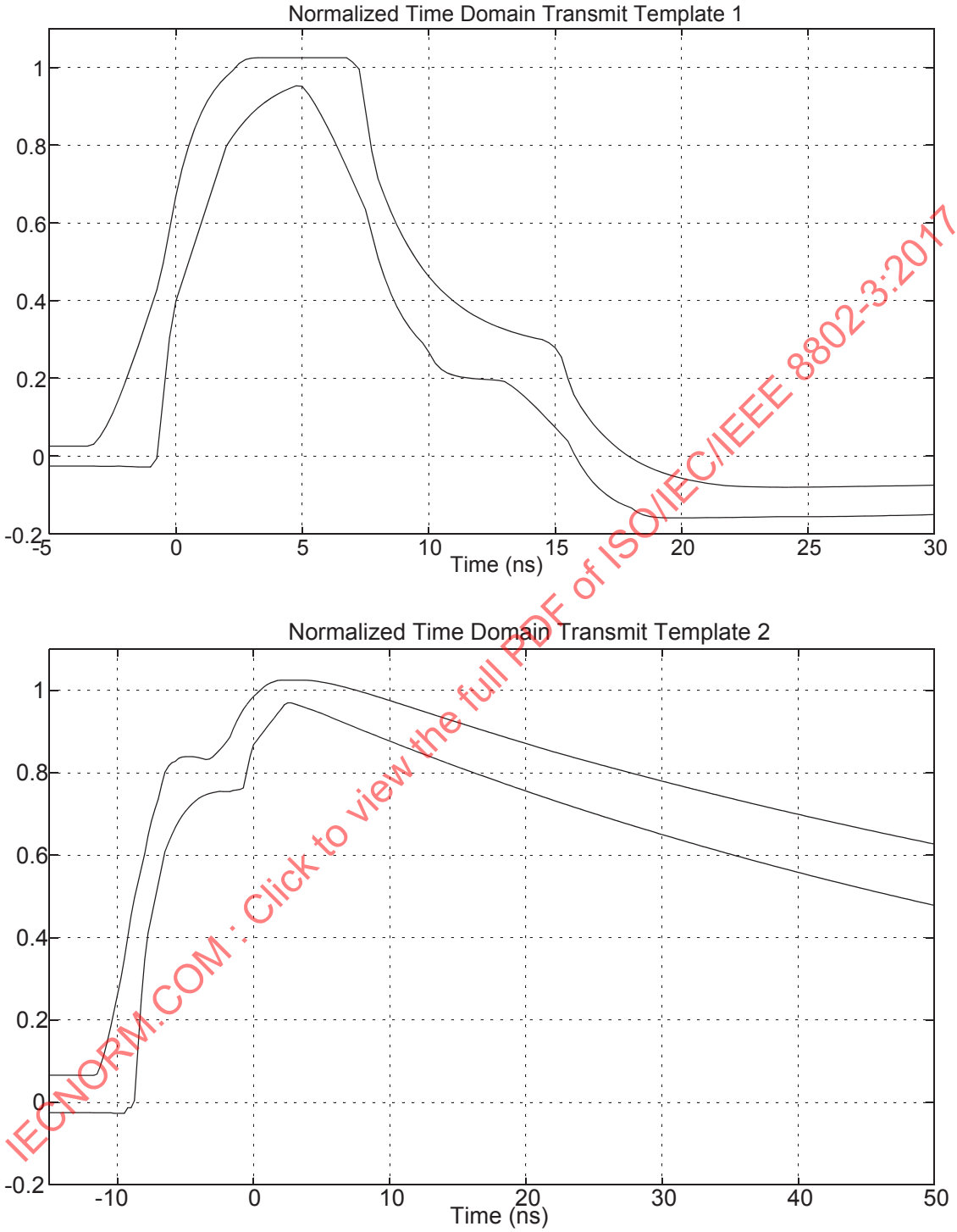

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Figure 40–27—Normalized transmit templates as measured at MDI using transmit test fixture 1

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NOTE 3—The ASCII for Tables 40–10 and 40–11 is available at http://standards.ieee.org/downloads/802.3/.[9]

Table 40–10—Normalized time domain voltage template 1

Time, ns	Normalized transmit time domain template, upper limit	Normalized transmit time domain template, lower limit	Time, ns	Normalized transmit time domain template, upper limit	Normalized transmit time domain template, lower limit
–5.00	0.025	–0.026	12.75	0.332	0.195
–4.75	0.025	–0.026	13.00	0.326	0.192
–4.50	0.025	–0.026	13.25	0.320	0.181
–4.25	0.025	–0.026	13.50	0.315	0.169
–4.00	0.025	–0.026	13.75	0.311	0.155
–3.75	0.025	–0.026	14.00	0.307	0.140
–3.50	0.025	–0.026	14.25	0.303	0.124
–3.25	0.031	–0.026	14.50	0.300	0.108
–3.00	0.050	–0.026	14.75	0.292	0.091
–2.75	0.077	–0.026	15.00	0.278	0.074
–2.50	0.110	–0.026	15.25	0.254	0.056
–2.25	0.148	–0.026	15.50	0.200	0.039
–2.00	0.190	–0.027	15.75	0.157	0.006
–1.75	0.235	–0.027	16.00	0.128	–0.023
–1.50	0.281	–0.028	16.25	0.104	–0.048
–1.25	0.329	–0.028	16.50	0.083	–0.068
–1.00	0.378	–0.028	16.75	0.064	–0.084
–0.75	0.427	–0.006	17.00	0.047	–0.098
–0.50	0.496	0.152	17.25	0.032	–0.110
–0.25	0.584	0.304	17.50	0.019	–0.119
0.00	0.669	0.398	17.75	0.007	–0.127
0.25	0.739	0.448	18.00	–0.004	–0.133
0.50	0.796	0.499	18.25	–0.014	–0.145
0.75	0.844	0.550	18.50	–0.022	–0.152
1.00	0.882	0.601	18.75	–0.030	–0.156
1.25	0.914	0.651	19.00	–0.037	–0.158
1.50	0.940	0.701	19.25	–0.043	–0.159

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Table 40–10—Normalized time domain voltage template 1 *(continued)*

Time, ns	Normalized transmit time domain template, upper limit	Normalized transmit time domain template, lower limit	Time, ns	Normalized transmit time domain template, upper limit	Normalized transmit time domain template, lower limit
1.75	0.960	0.751	19.50	–0.048	–0.159
2.00	0.977	0.797	19.75	–0.053	–0.159
2.25	0.992	0.822	20.00	–0.057	–0.159
2.50	1.010	0.845	20.25	–0.061	–0.159
2.75	1.020	0.864	20.50	–0.064	–0.159
3.00	1.024	0.881	20.75	–0.067	–0.159
3.25	1.025	0.896	21.00	–0.070	–0.159
3.50	1.025	0.909	21.25	–0.072	–0.159
3.75	1.025	0.921	21.50	–0.074	–0.158
4.00	1.025	0.931	21.75	–0.076	–0.158
4.25	1.025	0.939	22.00	–0.077	–0.158
4.50	1.025	0.946	22.25	–0.078	–0.158
4.75	1.025	0.953	22.50	–0.079	–0.158
5.00	1.025	0.951	22.75	–0.079	–0.157
5.25	1.025	0.931	23.00	–0.079	–0.157
5.50	1.025	0.905	23.25	–0.080	–0.157
5.75	1.025	0.877	23.50	–0.080	–0.157
6.00	1.025	0.846	23.75	–0.080	–0.156
6.25	1.025	0.813	24.00	–0.080	–0.156
6.50	1.025	0.779	24.25	–0.080	–0.156
6.75	1.025	0.743	24.50	–0.080	–0.156
7.00	1.014	0.707	24.75	–0.080	–0.156
7.25	0.996	0.671	25.00	–0.080	–0.156
7.50	0.888	0.634	25.25	–0.080	–0.156
7.75	0.784	0.570	25.50	–0.080	–0.156
8.00	0.714	0.510	25.75	–0.079	–0.156
8.25	0.669	0.460	26.00	–0.079	–0.156
8.50	0.629	0.418	26.25	–0.079	–0.156
8.75	0.593	0.383	26.50	–0.079	–0.155

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Table 40–10—Normalized time domain voltage template 1 *(continued)*

Time, ns	Normalized transmit time domain template, upper limit	Normalized transmit time domain template, lower limit	Time, ns	Normalized transmit time domain template, upper limit	Normalized transmit time domain template, lower limit
9.00	0.561	0.354	26.75	–0.079	–0.155
9.25	0.533	0.330	27.00	–0.078	–0.155
9.50	0.507	0.309	27.25	–0.078	–0.155
9.75	0.483	0.292	27.50	–0.078	–0.154
10.00	0.462	0.268	27.75	–0.078	–0.154
10.25	0.443	0.239	28.00	–0.077	–0.154
10.50	0.427	0.223	28.25	–0.077	–0.153
10.75	0.411	0.213	28.50	–0.077	–0.153
11.00	0.398	0.208	28.75	–0.076	–0.153
11.25	0.385	0.204	29.00	–0.076	–0.152
11.50	0.374	0.201	29.25	–0.076	–0.152
11.75	0.364	0.199	29.50	–0.076	–0.152
12.00	0.355	0.198	29.75	–0.075	–0.151
12.25	0.346	0.197	30.00	–0.075	–0.151
12.50	0.339	0.196			

Table 40–11—Normalized time domain voltage template 2

Time, ns	Normalized transmit time domain template, upper limit	Normalized transmit time domain template, lower limit	Time, ns	Normalized transmit time domain template, upper limit	Normalized transmit time domain template, lower limit
–15.00	0.066	–0.025	18.00	0.891	0.779
–14.50	0.066	–0.025	18.50	0.886	0.773
–14.00	0.066	–0.025	19.00	0.881	0.767
–13.50	0.066	–0.025	19.50	0.876	0.762
–13.00	0.066	–0.025	20.00	0.871	0.756
–12.50	0.066	–0.025	20.50	0.866	0.750
–12.00	0.066	–0.025	21.00	0.861	0.745
–11.50	0.069	–0.025	21.50	0.856	0.739
–11.00	0.116	–0.025	22.00	0.852	0.734
–10.50	0.183	–0.025	22.50	0.847	0.728

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Table 40–11—Normalized time domain voltage template 2 *(continued)*

Time, ns	Normalized transmit time domain template, upper limit	Normalized transmit time domain template, lower limit	Time, ns	Normalized transmit time domain template, upper limit	Normalized transmit time domain template, lower limit
–10.00	0.261	–0.027	23.00	0.842	0.723
–9.50	0.348	–0.027	23.50	0.838	0.717
–9.00	0.452	–0.013	24.00	0.833	0.712
–8.50	0.535	0.130	24.50	0.828	0.707
–8.00	0.604	0.347	25.00	0.824	0.701
–7.50	0.683	0.451	25.50	0.819	0.696
–7.00	0.737	0.531	26.00	0.815	0.691
–6.50	0.802	0.610	26.50	0.811	0.686
–6.00	0.825	0.651	27.00	0.806	0.680
–5.50	0.836	0.683	27.50	0.802	0.675
–5.00	0.839	0.707	28.00	0.797	0.670
–4.50	0.839	0.725	28.50	0.793	0.665
–4.00	0.837	0.739	29.00	0.789	0.660
–3.50	0.832	0.747	29.50	0.784	0.655
–3.00	0.839	0.752	30.00	0.780	0.650
–2.50	0.856	0.755	30.50	0.776	0.645
–2.00	0.875	0.755	31.00	0.772	0.641
–1.50	0.907	0.758	31.50	0.767	0.636
–1.00	0.941	0.760	32.00	0.763	0.631
–0.50	0.966	0.803	32.50	0.759	0.626
0.00	0.986	0.869	33.00	0.755	0.621
0.50	1.001	0.890	33.50	0.751	0.617
1.00	1.014	0.912	34.00	0.747	0.612
1.50	1.022	0.933	34.50	0.743	0.607
2.00	1.025	0.954	35.00	0.739	0.603
2.50	1.025	0.970	35.50	0.734	0.598
3.00	1.025	0.967	36.00	0.730	0.594
3.50	1.025	0.962	36.50	0.727	0.589
4.00	1.025	0.956	37.00	0.723	0.585

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Table 40–11—Normalized time domain voltage template 2 *(continued)*

Time, ns	Normalized transmit time domain template, upper limit	Normalized transmit time domain template, lower limit	Time, ns	Normalized transmit time domain template, upper limit	Normalized transmit time domain template, lower limit
4.50	1.023	0.950	37.50	0.719	0.580
5.00	1.020	0.944	38.00	0.715	0.576
5.50	1.017	0.937	38.50	0.711	0.571
6.00	1.014	0.931	39.00	0.707	0.567
6.50	1.010	0.924	39.50	0.703	0.563
7.00	1.005	0.917	40.00	0.699	0.558
7.50	1.001	0.910	40.50	0.695	0.554
8.00	0.996	0.903	41.00	0.692	0.550
8.50	0.991	0.897	41.50	0.688	0.546
9.00	0.986	0.890	42.00	0.684	0.541
9.50	0.981	0.884	42.50	0.680	0.537
10.00	0.976	0.877	43.00	0.677	0.533
10.50	0.970	0.871	43.50	0.673	0.529
11.00	0.965	0.864	44.00	0.669	0.525
11.50	0.960	0.858	44.50	0.666	0.521
12.00	0.954	0.852	45.00	0.662	0.517
12.50	0.949	0.845	45.50	0.659	0.513
13.00	0.944	0.839	46.00	0.655	0.509
13.50	0.938	0.833	46.50	0.651	0.505
14.00	0.933	0.827	47.00	0.648	0.501
14.50	0.928	0.820	47.50	0.644	0.497
15.00	0.923	0.814	48.00	0.641	0.493
15.50	0.917	0.808	48.50	0.637	0.490
16.00	0.912	0.802	49.00	0.634	0.486
16.50	0.907	0.796	49.50	0.631	0.482
17.00	0.902	0.791	50.00	0.627	0.478
17.50	0.897	0.785			

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40.6.1.2.4 Transmitter distortion

When in test mode 4 and observing the differential signal output at the MDI using transmitter test fixture 3, for each pair, with no intervening cable, the peak distortion as defined below shall be less than 10 mV.

The peak distortion is determined by sampling the differential signal output with the symbol rate TX_TCLK at an arbitrary phase and processing a block of any 2047 consecutive samples with the MATLAB (see 1.3) code listed below or equivalent. Note that this code assumes that the differential signal has already been filtered by the test filter. A PHY is considered to pass this test if the peak distortion is below 10mV for at least 60% of the UI within the eye opening.

NOTE—The ASCII for the following MATLAB code is available at http://standards.ieee.org/downloads/802.3/.[10]

MATLAB code for Distortion Post Processing is as follows:

```
%
% Distortion Specification Post Processing
%

% Initialize Variables
clear
symbolRate=125e6;                                   % symbol rate
dataFile=input('Data file name: ','s')

% Generate test pattern symbol sequence

scramblerSequence=ones(1,2047);
for i=12:2047
  scramblerSequence(i)=mod(scramblerSequence(i-11) + scramblerSequence(i-9),2);
end

for i=1:2047
  temp=scramblerSequence(mod(i-1,2047)+1) + ...
      2*mod(scramblerSequence(mod(i-2,2047)+1) + scramblerSequence(mod(i-
5,2047)+1),2) + ...
      4*mod(scramblerSequence(mod(i-3,2047)+1) + scramblerSequence(mod(i-
5,2047)+1),2);
  switch temp
    case 0,
      testPattern(i)=0;
    case 1,
      testPattern(i)=1;
    case 2,
      testPattern(i)=2;
    case 3,
      testPattern(i)=-1;
    case 4,
      testPattern(i)=0;
    case 5,
      testPattern(i)=1;
    case 6,
      testPattern(i)=-2;
    case 7,
      testPattern(i)=-1;
  end
end



% Input data file
```

[10]*Copyright release for MATLAB code*: Users of this standard may freely reproduce the MATLAB code in this subclause so it can be used for its intended purpose.

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```
fid=fopen(dataFile,'r');
sampledData=fscanf(fid,'%f');
fclose(fid);
sampledData=sampledData.';


if (length(sampledData) < 2047)
  error('Must have 2047 consecutive samples for processing');
elseif (length(sampledData) > 2047)
  fprintf(1,'\n Warning - only using first 2047 samples in data file');
  sampledData=sampledData(1:2047);
end


% Fit a sine wave to the data and temporarily remove it to yield processed data

options=foptions;
options(1)=0;
options(2)=1e-8;
options(3)=1e-8;
options(14)=2000;
gradfun=zeros(0);
P=fmins('sinefit',[2.0 0 125/6.],options,gradfun,sampledData,symbolRate);

P

processedData=sampledData - ...
    P(1)*sin(2*pi*(P(3)*1e6*[0:2046]/symbolRate + P(2)*1e-9*symbolRate));



% LMS Canceller

numberCoeff=70;  % Number of coefficients in canceller
coefficients=zeros(1,numberCoeff);
delayLine=testPattern;

% Align data in delayLine to sampled data pattern
temp=xcorr(processedData,delayLine);
index=find(abs(temp)==max(abs(temp)));
index=mod(mod(length(processedData) - index(1),2047)+numberCoeff-10,2047);
delayLine=[delayLine((end-index):end) delayLine(1:(end-index-1))];


% Compute coefficients that minimize squared error in cyclic block

for i=1:2047
  X(i,:)=delayLine(mod([0:(numberCoeff-1)]+i-1,2047)+1);
end
coefficients=(inv(X.' * X)*(processedData*X).').';



% Canceller
for i=1:2047
  err(i)=processedData(i) - sum(delayLine(1+mod((i-1):(i+numberCoeff-
2),2047)).*coefficients);
end

% Add back temporarily removed sine wave

err=err+P(1)*sin(2*pi*(P(3)*1e6*[0:2046]./symbolRate + P(2)*1e-9*symbolRate));
```

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```
% Re-fit sine wave and do a final removal

options=foptions;
options(1)=0;
options(2)=1e-12;
options(3)=1e-12;
options(14)=10000;
gradfun=zeros(0);
P=fmins('sinefit',[2.0 0 125/6.],options,gradfun,err,symbolRate);

P

processedData=sampledData - ...
    P(1)*sin(2*pi*(P(3)*1e6*[0:2046]/symbolRate + P(2)*1e-9*symbolRate));


% Compute coefficients that minimize squared error in cyclic block

coefficients=(inv(X.' * X)*(processedData*X).').';



% Canceller
for i=1:2047
  err(i)=processedData(i) - sum(delayLine(1+mod((i-1):(1+numberCoeff-
2),2047)).*coefficients);
end

% SNR Calculation
signal=0.5;
noise=mean(err.^2);

SNR=10*log10(signal./noise);

% Output Peak Distortion

peakDistortion=max(abs(err))


% Function for fitting sine wave
function err=sinefit(parameters,data,symbolRate)
err=sum((data- ...
    parameters(1)*sin(2*pi*(parameters(3)*1e6*[0:(length(data)-1)]/symbolRate +
parameters(2)*1e-9*symbolRate))).^2);
```

40.6.1.2.5 Transmitter timing jitter

When in test mode 2 or test mode 3, the peak-to-peak jitter J_{txout} of the zero crossings of the differential signal output at the MDI relative to the corresponding edge of TX_TCLK is measured. The corresponding edge of TX_TCLK is the edge of the transmit test clock, in polarity and time, that generates the zero-crossing transition being measured.

When in the normal mode of operation as the MASTER, the peak-to-peak value of the MASTER TX_TCLK jitter relative to an unjittered reference shall be less than 1.4 ns. When the jitter waveform on TX_TCLK is filtered by a high-pass filter, $H_{jf1}(f)$, having the transfer function below, the peak-to-peak value of the resulting filtered timing jitter plus J_{txout} shall be less than 0.3 ns.

$$H_{jf1}(f) = \frac{jf}{jf + 5000} \qquad f \text{ in Hz}$$

When in the normal mode of operation as the SLAVE, receiving valid signals from a compliant PHY operating as the MASTER using the test channel defined in 40.6.1.1.1, with test channel port A connected to the SLAVE, the peak-to-peak value of the SLAVE TX_TCLK jitter relative to the MASTER TX_TCLK

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shall be less than 1.4 ns after the receiver is properly receiving the data and has set bit 10.13 of the GMII management register set to 1. When the jitter waveform on TX_TCLK is filtered by a high-pass filter, $H_{jf2}(f)$, having the transfer function below, the peak-to-peak value of the resulting filtered timing jitter plus J_{txout} shall be no more than 0.4 ns greater than the simultaneously measured peak-to-peak value of the MASTER jitter filtered by $H_{jf1}(f)$.

$$H_{jf2}(f) = \frac{jf}{jf + 32000} \qquad f \text{ in Hz}$$

NOTE—j denotes the square root of –1.

For all high-pass filtered jitter measurements, the peak-to-peak value shall be measured over an unbiased sample of at least 10^5 clock edges. For all unfiltered jitter measurements, the peak-to-peak value shall be measured over an interval of not less than 100 ms and not more than 1 second.

When the PHY supports the optional EEE capability, the unfiltered jitter requirements shall also be satisfied during the LPI mode, with the exception that clock edges corresponding to the WAIT_QUIET, QUIET, WAKE, and WAKE_SILENT states are not considered in the measurement. The PHY may turn off TX_TCLK during these states. For a MASTER PHY operating in the LPI mode, the unjittered reference shall be continuous.

40.6.1.2.6 Transmit clock frequency

The quinary symbol transmission rate on each pair of the master PHY shall be 125.00 MHz ± 0.01%.

40.6.1.2.7 Transmitter operation following a transition from the QUIET to the WAKE state

When the PHY supports the optional EEE capability, it transmits Idle symbols while in the WAKE state (see Figure 40–16b). This signal may be transmitted during reactivation of the PHY analog front-end and is not guaranteed or intended to be compliant.

The transmit levels of the Idle symbols transmitted during the WAKE state shall exceed 65% of the transmit levels of compliant Idle symbols for a period of at least 500 ns.

The PHY shall achieve compliant operation upon entry to the WAKE_TRAINING state (see Figure 40–16b).

40.6.1.3 Receiver electrical specifications

The PMA shall provide the Receive function specified in 40.4.2.3 in accordance with the electrical specifications of this clause. The patch cabling and interconnecting hardware used in test configurations shall be within the limits specified in 40.7.

40.6.1.3.1 Receiver differential input signals

Differential signals received at the MDI that were transmitted from a remote transmitter within the specifications of 40.6.1.2 and have passed through a link specified in 40.7 are translated into one of the PMA_UNITDATA.indication messages with a bit error ratio less than 10^{-10} and sent to the PCS after link reset completion. Since the 4-D symbols are not accessible, this specification shall be satisfied by a frame error ratio less than 10^{-7} for 125 octet frames.

40.6.1.3.2 Receiver frequency tolerance

The receive feature shall properly receive incoming data with a 5-level symbol rate within the range 125.00 MHz ± 0.01%.

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40.6.1.3.3 Common-mode noise rejection

This specification is provided to limit the sensitivity of the PMA receiver to common-mode noise from the cabling system. Common-mode noise generally results when the cabling system is subjected to electromagnetic fields. Figure 40–28 shows the test configuration, which uses a capacitive cable clamp, that injects common-mode signals into a cabling system.

A 100-meter, 4-pair Category 5 cable that meets the specification of 40.7 is connected between two 1000BASE-T PHYs and inserted into the cable clamp. The cable should be terminated on each end with an MDI connector plug specified in 40.8.1. The clamp should be located a distance of ~20 cm from the receiver. It is recommended that the cable between the transmitter and the cable clamp be installed either in a linear run or wrapped randomly on a cable rack. The cable rack should be at least 3 m from the cable clamp. In addition, the cable clamp and 1000BASE-T receiver should be placed on a common copper ground plane and the ground of the receiver should be in contact with the ground plane. The chassis grounds of all test equipment used should be connected to the copper ground plane. No connection is required between the copper ground plane and an external reference. A description of the cable clamp, as well as the validation procedure, can be found in Annex 40B.

A signal generator with a 50 Ω impedance is connected to one end of the clamp and an oscilloscope with a 50 Ω input is connected to the other end of the clamp. The signal generator shall be capable of providing a sine wave signal of 1 MHz to 250 MHz. The output of the signal generator is adjusted for a voltage of 1.0 Vrms (1.414 Vpeak) on the oscilloscope.

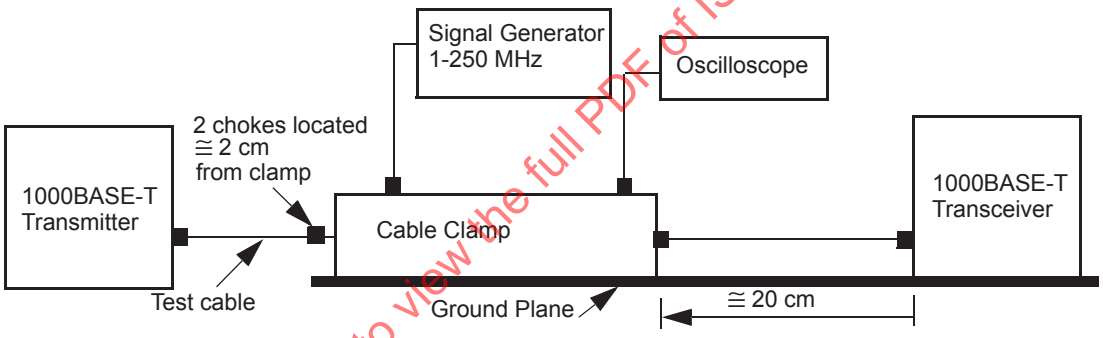

Figure 40–28—Receiver common-mode noise rejection test

While sending data from the transmitter, the receiver shall send the proper PMA_UNITDATA.indication messages to the PCS as the signal generator frequency is varied from 1 MHz to 250 MHz.

NOTE—Although the signal specification is constrained within the 1–100 MHz band, this test is performed up to 250 MHz to ensure the receiver under test can tolerate out-of-band (100–250 MHz) noise.

40.6.1.3.4 Alien Crosstalk noise rejection

While receiving data from a transmitter specified in 40.6.1.2 through a link segment specified in 40.7 connected to all MDI duplex channels, a receiver shall send the proper PMA_UNITDATA.indication message to the PCS when any one of the four pairs is connected to a noise source as described in Figure 40–29. Because symbol encoding is employed, this specification shall be satisfied by a frame error ratio of less than 10^{-7} for 125 octet frames. The level of the noise signal at the MDI is nominally 25 mV

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peak-to-peak. (Measurements are to be made on each of the four pairs.) The noise source shall be connected to one of the MDI inputs using Category 5 balanced cable of a maximum length of 0.5 m.

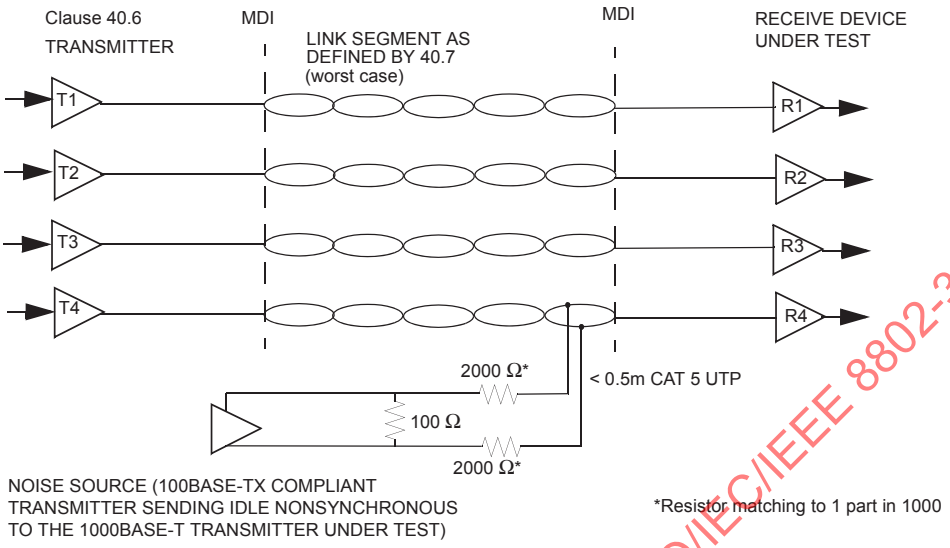

Figure 40–29—Differential mode noise rejection test

40.6.1.3.5 Signal_detect

When the PHY supports the optional EEE capability, the PMA Receive function shall convey an indicator of signal presence, referred to as signal_detect, to the PMA PHY Control function. The value of signal_detect shall be set to TRUE within 0.5 µs of the receipt of a wake signal meeting the requirements of 40.6.1.2.7. The value of signal_detect shall be set to FALSE within 0.5 µs of the receipt of a continuous sequence of zeros.

40.7 Link segment characteristics

1000BASE-T is designed to operate over a 4-pair Category 5/Class D balanced cabling system. Each of the four pairs supports an effective data rate of 250 Mb/s in each direction simultaneously. The term “link segment” used in this clause refers to four duplex channels. The term “duplex channel” will be used to refer to a single channel with full duplex capability. Specifications for a link segment apply equally to each of the four duplex channels. All implementations of the balanced cabling link shall be compatible at the MDI.

40.7.1 Cabling system characteristics

1000BASE-T requires 4-pair Class D cabling with a nominal impedance of 100 Ω, as specified in ISO/IEC 11801:1995. The cabling system components (cables, cords, and connectors) used to provide the link segment shall consist of Category 5 components as specified in ANSI/TIA/EIA-568-A:1995 and ISO/IEC 11801:1995. Additionally:

a) 1000BASE-T is an ISO/IEC 11801 Class D application, with additional installation requirements and transmission parameters specified in Annex 40A.
b) The width of the PMD transmit signal spectrum is approximately 80 MHz.
c) The use of shielding is outside the scope of this standard.

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40.7.2 Link transmission parameters

The transmission parameters contained in this subclause are specified to ensure that a Class D link segment of up to at least 100 m will provide a reliable medium. The transmission parameters of the link segment include insertion loss, delay parameters, characteristic impedance, NEXT loss, ELFEXT loss, and return loss.

Link segment testing shall be conducted using source and load impedances of 100 Ω. The tolerance on the poles of the test filter used in this subclause shall be no worse than 1%.

40.7.2.1 Insertion loss

The insertion loss of each duplex channel shall be less than

$$Insertion_Loss(f) < 2.1\, f^{0.529} + 0.4/f \quad \text{(dB)}$$

at all frequencies from 1 MHz to 100 MHz. This includes the attenuation of the balanced cabling pairs, including work area and equipment cables plus connector losses within each duplex channel. The insertion loss specification shall be met when the duplex channel is terminated in 100 Ω.

NOTE—The above equation approximates the insertion loss specification at discrete frequencies for Class D 100 m channels specified by ISO/IEC 11801:1995.

40.7.2.2 Differential characteristic impedance

The nominal differential characteristic impedance of each link segment duplex channel, which includes cable cords and connecting hardware, is 100 Ω for all frequencies between 1 MHz and 100 MHz.

40.7.2.3 Return loss

Each link segment duplex channel shall meet or exceed the return loss specified in the following equation at all frequencies from 1 MHz to 100 MHz.

$$Return_Loss(f) \begin{cases} 15 & (1 - 20\ \text{MHz}) \\ 15 - 10\log_{10}(f/20) & (20 - 100\ \text{MHz}) \end{cases} \quad \text{(dB)}$$

where f is the frequency in MHz. The reference impedance shall be 100 Ω.

40.7.3 Coupling parameters

In order to limit the noise coupled into a duplex channel from adjacent duplex channels, Near-End Crosstalk (NEXT) loss and Equal Level Far-End Crosstalk (ELFEXT) loss are specified for each link segment. Each duplex channel can be disturbed by more than one duplex channel. Requirements for Multiple Disturber Near-End Crosstalk (MDNEXT) are satisfied even when worst case conditions of differential pair-to-pair NEXT as specified under 40.7.3.1.1 occur. Therefore, there are no separate requirements for MDNEXT. Requirements for Multiple Disturber Equal-Level Far-End Crosstalk (MDELFEXT) loss are specified in 40.7.3.2.2.

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40.7.3.1 Near-End Crosstalk (NEXT)

40.7.3.1.1 Differential Near-End Crosstalk

In order to limit the crosstalk at the near end of a link segment, the differential pair-to-pair Near-End Crosstalk (NEXT) loss between a duplex channel and the other three duplex channels is specified to meet the symbol error ratio objective specified in 40.1. The NEXT loss between any two duplex channels of a link segment shall be at least

$$27.1 - 16.8\log_{10}(f/100)$$

where f is the frequency over the range of 1 MHz to 100 MHz.

NOTE—The above equation approximates the NEXT loss specification at discrete frequencies for Class D 100 m channels specified by ISO/IEC 11801:1995.

40.7.3.2 Far-End Crosstalk (FEXT)

40.7.3.2.1 Equal Level Far-End Crosstalk (ELFEXT) loss

Equal Level Far-End Crosstalk (ELFEXT) loss is specified in order to limit the crosstalk at the far end of each link segment duplex channel and meet the BER objective specified in 40.6.1.3.1. Far-End Crosstalk (FEXT) is crosstalk that appears at the far end of a duplex channel (disturbed channel), which is coupled from another duplex channel (disturbing channel) with the noise source (transmitters) at the near end. FEXT loss is defined as

$$FEXT_Loss(f) = 20\log_{10}[Vpds(f)/Vpcn(f)]$$

and ELFEXT_Loss is defined as

$$ELFEXT_Loss(f) = 20\log_{10}[Vpds(f)/Vpcn(f)] - SLS_Loss(f)$$

where

Vpds	is the peak voltage of disturbing signal (near-end transmitter)
Vpcn	is the peak crosstalk noise at far end of disturbed channel
SLS_Loss	is the insertion loss of disturbed channel in dB

The worst pair ELFEXT loss between any two duplex channels shall be greater than $17 - 20\log_{10}(f/100)$ dB where f is the frequency over the range of 1 MHz to 100 MHz.

40.7.3.2.2 Multiple Disturber Equal Level Far-End Crosstalk (MDELFEXT) loss

Since four duplex channels are used to transfer data between PMDs, the FEXT that is coupled into a data carrying channel will be from the three adjacent disturbing duplex channels. This specification is consistent with three channel-to-channel disturbers—one with a ELFEXT loss of at least $17 - 20\log_{10}(f/100)$ dB, one with a ELFEXT loss of at least $19.5 - 20\log_{10}(f/100)$ dB, and one with a ELFEXT loss of at least $23 - 20\log_{10}(f/100)$ dB. To ensure the total FEXT coupled into a duplex channel is limited, multiple disturber ELFEXT loss is specified as the power sum of the individual ELFEXT losses.

The Power Sum loss between a duplex channel and the three adjacent disturbers shall be

$$PSELFEXT\ loss > 14.4 - 20\log_{10}(f/100)\ \text{dB}$$

where f is the frequency over the range of 1 MHz to 100 MHz.

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40.7.3.2.3 Multiple-Disturber Power Sum Equal Level Far-End Crosstalk (PSELFEXT) loss

PSELFEXT loss is determined by summing the magnitude of the three individual pair-to-pair differential ELFEXT loss values over the frequency range 1 to 100 MHz as follows:

$$\text{PSELFEXT_Loss(f)} = -10\log_{10}\sum_{i=1}^{i=3} 10^{-(NL(f)i)/10}$$

where

NL(*f*)i is the magnitude of ELFEXT loss at frequency *f* of pair combination *i*
i is the 1, 2, or 3 (pair-to-pair combination)

40.7.4 Delay

In order to simultaneously send data over four duplex channels in parallel, the propagation delay of each duplex channel as well as the difference in delay between any two of the four channels are specified. This ensures the 1000 Mb/s data that is divided across four channels can be properly reassembled at the far-end receiver. This also ensures the round-trip delay requirement for effective collision detection is met.

40.7.4.1 Maximum link delay

The propagation delay of a link segment shall not exceed 570 ns at all frequencies between 2 MHz and 100 MHz.

40.7.4.2 Link delay skew

The difference in propagation delay, or skew, between all duplex channel pair combinations of a link segment, under all conditions, shall not exceed 50 ns at all frequencies from 2 MHz to 100 MHz. It is a further functional requirement that, once installed, the skew between any two of the four duplex channels due to environmental conditions shall not vary more than 10 ns within the above requirement.

40.7.5 Noise environment

The 1000BASE-T noise environment consists of noise from many sources. The primary noise sources that impact the objective BER are NEXT and echo interference, which are reduced to a small residual noise using cancelers. The remaining noise sources, which are secondary sources, are discussed in the following list.

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The 1000BASE-T noise environment consists of the following:

a) Echo from the local transmitter on the same duplex channel (cable pair). Echo is caused by the hybrid function used to achieve simultaneous bidirectional transmission of data and by impedance discontinuities in the link segment. It is impractical to achieve the objective BER without using echo cancellation. Since the symbols transmitted by the local disturbing transmitter are available to the cancellation processor, echo interference can be reduced to a small residual noise using echo cancellation methods.

b) Near-End Crosstalk (NEXT) interference from the local transmitters on the duplex channels (cable pairs) of the link segment. Each receiver will experience NEXT interference from three adjacent transmitters. NEXT cancelers are used to reduce the interference from each of the three disturbing transmitters to a small residual noise. NEXT cancellation is possible since the symbols transmitted by the three disturbing local transmitters are available to the cancellation processor. NEXT cancelers can reduce NEXT interference by at least 20 dB.

c) Far-End Crosstalk (FEXT) noise at a receiver is from three disturbing transmitters at the far end of the duplex channel (cable pairs) of the link segment. FEXT noise can be cancelled in the same way as echo and NEXT interference although the symbols from the remote transmitters are not immediately available. However, FEXT noise is much smaller than NEXT interference and can generally be tolerated.

d) Intersymbol interference (ISI). ISI is the extraneous energy from one signaling symbol that interferes with the reception of another symbol on the same channel.

e) Noise from non-idealities in the duplex channel, transmitters, and receivers; for example, DAC/ADC non-linearity, electrical noise (shot and thermal), and non-linear channel characteristics.

f) Noise from sources outside the cabling that couple into the link segment via electric and magnetic fields.

g) Noise from signals in adjacent cables. This noise is referred to as alien NEXT noise and is generally present when cables are bound tightly together. Since the transmitted symbols from the alien NEXT noise source are not available to the cancellation processor (they are in another cable), it is not possible to cancel the alien NEXT noise. To ensure robust operation the alien NEXT noise must meet the specification of 40.7.6.

40.7.6 External coupled noise

The noise coupled from external sources that is measured at the output of a filter connected to the output of the near end of a disturbed duplex channel should not exceed 40 mV peak-to-peak. The filter for this measurement is a fifth order Butterworth filter with a 3 dB cutoff at 100MHz.

40.8 MDI specification

This subclause defines the MDI. The link topology requires a crossover function in a DTE-to-DTE connection. See 40.4.4 for a description of the automatic MDI/MDI-X configuration.

40.8.1 MDI connectors

Eight-pin connectors meeting the requirements of subclause 3 and Figures 1 through 4 of IEC 60603-7:1990 shall be used as the mechanical interface to the balanced cabling. The plug connector shall be used on the balanced cabling and the jack on the PHY. These connectors are depicted (for informational use only) in Figure 40–30 and Figure 40–31. The assignment of PMA signals to connector contacts for PHYs is shown in Table 40-12.

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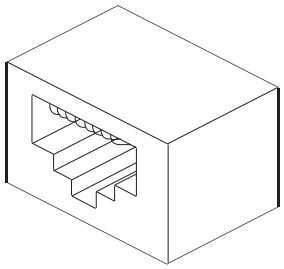

Figure 40–30—MDI connector

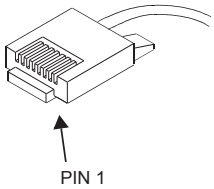

Figure 40–31—Balanced cabling connector

Table 40–12—Assignment of PMA signal to MDI and MDI-X pin-outs

Contact	MDI	MDI-X
1	BI_DA+	BI_DB+
2	BI_DA–	BI_DB–
3	BI_DB+	BI_DA+
4	BI_DC+	BI_DD+
5	BI_DC–	BI_DD–
6	BI_DB–	BI_DA–
7	BI_DD+	BI_DC+
8	BI_DD–	BI_DC–

40.8.2 Crossover function

Although the automatic MDI/MDI-X configuration (see 40.4.4) is not required for successful operation of 1000BASE-T, a crossover function must be implemented for every link segment to support the operation of Auto-Negotiation. The crossover function connects the transmitters of one PHY to the receivers of the PHY at the other end of the link segment. Crossover functions may be implemented internally to a PHY or elsewhere in the link segment. For a PHY that does not implement the crossover function, the MDI labels in the middle column of Table 40–12 refer to its own internal circuits. For PHYs that do implement the internal crossover, the MDI labels in the last column of Table 40–12 refer to the internal circuits of the remote PHY of the link segment. Additionally, the MDI connector for a PHY that implements the crossover function shall be marked with the graphical symbol X. The crossover function specified here is not compatible with the crossover function specified in 14.5.2 for pairs TD and RD.

When a link segment connects a single-port device to a multiport device, it is recommended that the crossover be implemented in the PHY local to the multiport device. If neither or both PHYs of a link segment contain internal crossover functions, an additional external crossover is necessary. It is recommended that the crossover be visible to an installer from one of the PHYs. When both PHYs contain

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internal crossovers, it is further recommended that, in networks in which the topology identifies either a central backbone segment or a central device, the PHY furthest from the central element be assigned the external crossover to maintain consistency.

Implicit implementation of the crossover function within a twisted-pair cable or at a wiring panel, while not expressly forbidden, is beyond the scope of this standard.

40.8.3 MDI electrical specifications

The MDI connector (jack) when mated with a specified balanced cabling connector (plug) shall meet the electrical requirements for Category 5 connecting hardware for use with 100-ohm Category 5 cable as specified in ISO/IEC 11801:1995.

The mated MDI/balanced cabling connector pair shall have a FEXT loss not less than $40 - 20\log_{10}(f/100)$ (where f is the frequency over the range 1 MHz to 100 MHz) between all contact pair combinations shown in Table 40–12.

No spurious signals shall be emitted onto the MDI when the PHY is held in power-down mode (as defined in 22.2.4.1.5) independent of the value of TX_EN, when released from power-down mode, or when external power is first applied to the PHY.

40.8.3.1 MDI return loss

The differential impedance at the MDI for each transmit/receive channel shall be such that any reflection due to differential signals incident upon the MDI from a balanced cabling having an impedance of 100 Ω ± 15% is attenuated, relative to the incident signal, at least 16 dB over the frequency range of 1.0 MHz to 40 MHz and at least $10 - 20\log_{10}(f/80)$ dB over the frequency range 40 MHz to 100 MHz (f in MHz). This return loss shall be maintained at all times when the PHY is transmitting data or control symbols.

40.8.3.2 MDI impedance balance

Impedance balance is a measurement of the impedance-to-ground difference between the two MDI contacts used by a duplex link channel and is referred to as common-mode-to-differential-mode impedance balance. Over the frequency range 1.0 MHz to 100.0 MHz, the common-mode-to-differential-mode impedance balance of each channel of the MDI shall exceed

$$34 - 19.2\log_{10}\left(\frac{f}{50}\right) \text{ dB}$$

where f is the frequency in MHz when the transmitter is transmitting random or pseudo random data. Test-mode 4 may be used to generate an appropriate transmitter output.

The balance is defined as

$$20\log_{10}\left(\frac{E_{cm}}{E_{dif}}\right)$$

where E_{cm} is an externally applied sine wave voltage as shown in Figure 40–32 and E_{dif} is the resulting waveform due only to the applied sine wave and not the transmitted data.

NOTE 1—Triggered averaging can be used to separate the component due to the applied common-mode sine wave from the transmitted data component.

NOTE 2—The imbalance of the test equipment (such as the matching of the test resistors) must be insignificant relative to the balance requirements.

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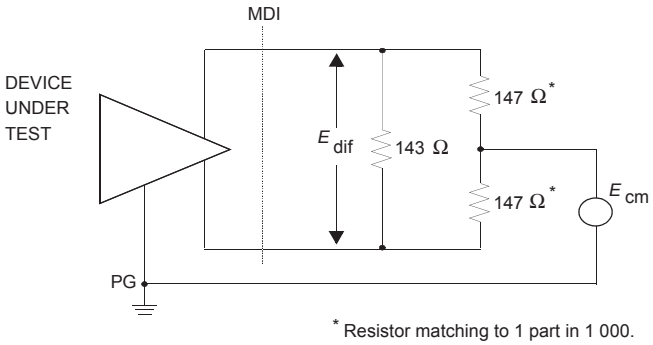

Figure 40–32—MDI impedance balance test circuit

40.8.3.3 MDI common-mode output voltage

The magnitude of the total common-mode output voltage, E_{cm_out}, on any transmit circuit, when measured as shown in Figure 40–33, shall be less than 50 mV peak-to-peak when transmitting data at frequencies above 1 MHz.

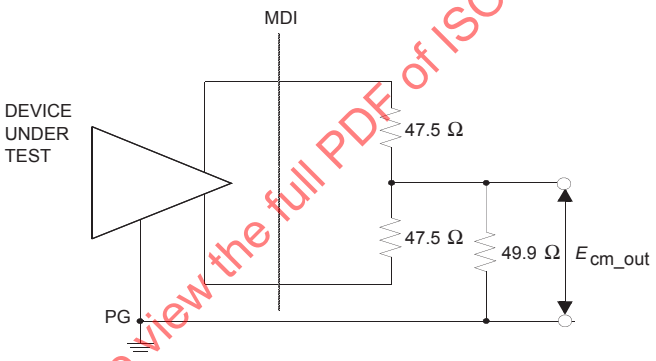

Figure 40–33—Common-mode output voltage test circuit

NOTE—The imbalance of the test equipment (such as the matching of the test resistors) must be insignificant relative to the balance requirements.

40.8.3.4 MDI fault tolerance

Each wire pair of the MDI shall, under all operating conditions, withstand without damage the application of short circuits of any wire to any other wire within the 4-pair cable for an indefinite period of time and shall resume normal operation after the short circuit(s) are removed. The magnitude of the current through such a short circuit shall not exceed 300 mA.

Each wire pair shall withstand without damage a 1000 V common-mode impulse applied at E_{cm} of either polarity (as indicated in Figure 40–34). The shape of the impulse shall be 0.3/50 µs (300 ns virtual front time, 50 µs virtual time of half value), as defined in IEC 60060.

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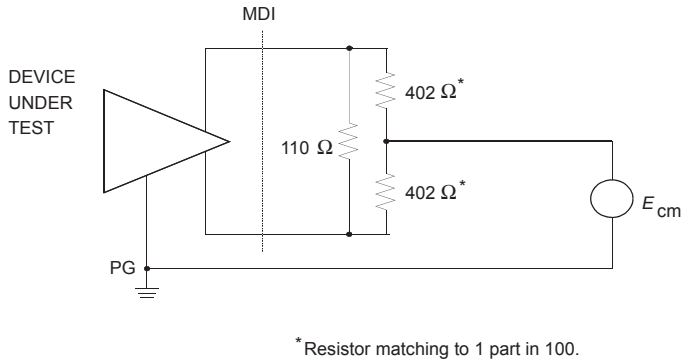

Figure 40–34—MDI fault tolerance test circuit

40.9 Environmental specifications

40.9.1 General safety

All equipment meeting this standard shall conform to IEC 60950:1991.

40.9.2 Network safety

This subclause sets forth a number of recommendations and guidelines related to safety concerns; the list is neither complete nor does it address all possible safety issues. The designer is urged to consult the relevant local, national, and international safety regulations to ensure compliance with the appropriate requirements.

LAN cabling systems described in this subclause are subject to at least four direct electrical safety hazards during their installation and use. These hazards are as follows:

a) Direct contact between LAN components and power, lighting, or communications circuits.
b) Static charge buildup on LAN cabling and components.
c) High-energy transients coupled onto the LAN cabling system.
d) Voltage potential differences between safety grounds to which various LAN components are connected.

Such electrical safety hazards must be avoided or appropriately protected against for proper network installation and performance. In addition to provisions for proper handling of these conditions in an operational system, special measures must be taken to ensure that the intended safety features are not negated during installation of a new network or during modification or maintenance of an existing network.

40.9.2.1 Installation

It is a mandatory requirement that sound installation practice, as defined by applicable local codes and regulations, is followed in every instance in which such practice is applicable.

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40.9.2.2 Installation and maintenance guidelines

It is a mandatory requirement that, during installation and maintenance of the cabling plant, care is taken to ensure that non-insulated network cabling conductors do not make electrical contact with unintended conductors or ground.

40.9.2.3 Telephony voltages

The use of building wiring brings with it the possibility of wiring errors that may connect telephony voltages to 1000BASE-T equipment. Other than voice signals (which are low voltage), the primary voltages that may be encountered are the "battery" and ringing voltages. Although there is no universal standard, the following maximums generally apply:

Battery voltage to a telephone line is generally 56 Vdc applied to the line through a balanced 400 Ω source impedance.

Ringing voltage is a composite signal consisting of an ac component and a dc component. The ac component is up to 175 V peak at 20 Hz to 60 Hz with a 100 Ω source resistance. The dc component is 56 Vdc with a 300 Ω to 600 Ω source resistance. Large reactive transients can occur at the start and end of each ring interval.

Although 1000BASE-T equipment is not required to survive such wiring hazards without damage, application of any of the above voltages shall not result in any safety hazard.

NOTE—Wiring errors may impose telephony voltages differentially across 1000BASE-T transmitters or receivers. Because the termination resistance likely to be present across a receiver's input is of substantially lower impedance than an off-hook telephone instrument, receivers will generally appear to the telephone system as off-hook telephones. Therefore, full-ring voltages will be applied for only short periods. Transmitters that are coupled using transformers will similarly appear like off-hook telephones (though perhaps a bit more slowly) due to the low resistance of the transformer coil.

40.9.3 Environment

40.9.3.1 Electromagnetic emission

A system integrating the 1000BASE-T PHY shall comply with applicable local and national codes for the limitation of electromagnetic interference.

40.9.3.2 Temperature and humidity

A system integrating the 1000BASE-T PHY is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

It is recommended that manufacturers indicate in the literature associated with the PHY the operating environmental conditions to facilitate selection, installation, and maintenance.

40.10 PHY labeling

It is recommended that each PHY (and supporting documentation) be labeled in a manner visible to the user with at least the following parameters:

a) Data rate capability in Mb/s
b) Power level in terms of maximum current drain (for external PHYs)

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c) Port type (i.e., 1000BASE-T)

d) Any applicable safety warnings

40.11 Delay constraints

In half duplex mode, proper operation of a CSMA/CD LAN demands that there be an upper bound on the propagation delays through the network. This implies that MAC, PHY, and repeater implementers must conform to certain delay minima and maxima, and that network planners and administrators conform to constraints regarding the cabling topology and concatenation of devices. MAC constraints are specified in 35.2.4. Topological constraints are contained in Clause 42.

In full duplex mode, predictable operation of the MAC Control PAUSE operation (Clause 31, Annex 31B) also demands that there be an upper bound on the propagation delays through the network. This implies that MAC, MAC Control sublayer, and PHY implementers must conform to certain delay maxima, and that network planners and administrators conform to constraints regarding the cable topology and concatenation of devices.

The reference point for all MDI measurements is the peak point of the mid-cell transition corresponding to the reference code-bit, as measured at the MDI.

40.11.1 MDI to GMII delay constraints

Every 1000BASE-T PHY associated with a GMII shall comply with the bit delay constraints specified in Table 40–13 for half duplex operation and Table 40–14 for full duplex operation. These constraints apply for all 1000BASE-T PHYs. For any given implementation, the assertion and de-assertion delays on CRS shall be equal.

Table 40–13—MDI to GMII delay constraints (half duplex mode)

Sublayer measurement points	Event	Min (bit times)	Max (bit times)	Input timing reference	Output timing reference
GMII ⇔ MDI	TX_EN Sampled to MDI Output	—	84	GTX_CLK rising	1st symbol of SSD/CSReset/ CSExtend/ CSExtend_Err
	MDI input to CRS assert	—	244	1st symbol of SSD/CSReset	—
	MDI input to CRS de-assert	—	244	1st symbol of SSD/CSReset	—
	MDI input to COL assert	—	244	1st symbol of SSD/CSReset	—
	MDI input to COL de-assert	—	244	1st symbol of SSD/CSReset	—
	TX_EN sampled to CRS assert	—	16	GTX_CLK rising	—
	TX_EN sampled to CRS de-assert	—	16	GTX_CLK rising	—

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Table 40–14—MDI to GMII delay constraints (full duplex mode)

Sublayer measurement points	Event	Min (bit times)	Max (bit times)	Input timing reference	Output timing reference
GMII ⇔ MDI	TX_EN Sampled to MDI Output	—	84	GTX_CLK rising	1st symbol of SSD/CSReset/ CSExtend/ CSExtend_Err
	MDI input to RX_DV de-assert	—	244	1st symbol of CSReset	—

40.11.2 DTE delay constraints (half duplex only)

Every DTE with a 1000BASE-T PHY shall comply with the bit delay constraints specified in Table 40–15 for half duplex operation.

Table 40–15— DTE delay constraints (half duplex mode)

Sublayer measurement points	Event	Min (bit times)	Max (bit times)	Input timing reference	Output timing reference
MAC ⇔ MDI	MAC transmit start to MDI output	—	132	—	1st symbol of SSD
	MDI input to collision detect	—	292	1st symbol of SSD	—
	MDI input to MDI output (nondeferred or Jam)	—	440	1st symbol of SSD	1st symbol of SSD
	MDI Input to MDI output (worse-case non-deferred transmit)	—	440	1st symbol of SSD	1st symbol of SSD

40.11.3 Carrier de-assertion/assertion constraint (half duplex mode)

To ensure fair access to the network, each DTE operating in half duplex mode shall, additionally, satisfy the following: (MAX MDI to MAC Carrier De-assert Detect) – (MIN MDI to MAC Carrier Assert Detect) < 16 Bit Times.

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40.12 Protocol implementation conformance statement (PICS) proforma for Clause 40—Physical coding sublayer (PCS), physical medium attachment (PMA) sublayer and baseband medium, type 1000BASE-T[11]

The supplier of a protocol implementation that is claimed to conform to this clause shall complete the protocol implementation conformance statement (PICS) proforma listed in the following subclauses.

Instructions for interpreting and filling out the PICS proforma may be found in Clause 21.

40.12.1 Identification

40.12.1.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

40.12.1.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 40, Physical coding sublayer (PCS), physical medium attachment (PMA) sublayer, and baseband medium, type 1000BASE-T
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exceptions items been required? No [ ] Yes [ ] (See Clause 21—The answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	
Date of Statement	

40.12.2 Major capabilities/options

Item	Feature	Subclause	Status	Support	Value/Comment
*GMII	PHY associated with GMII	40.1	O	Yes [ ] No [ ]	
*DTE	DTE with PHY not associated with GMII	40.1	O	Yes [ ] No [ ]	
*EEE	EEE	40.1.3	O	Yes [ ] No [ ]	
AN	Support for Auto-Negotiation (Clause 28)	40.5.1	M	Yes [ ]	Required

[11] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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Item	Feature	Subclause	Status	Support	Value/Comment
OMS	Operation as MASTER or SLAVE	40.5.1	M	Yes [ ]	Required
*FDX	PHY supports full duplex mode	40.1	O	Yes [ ] No [ ]	
*HDX	PHY support half duplex mode	40.1	O	Yes [ ] No [ ]	
*INS	Installation / cabling	40.7	O	Yes [ ] No [ ]	Items marked with INS include installation practices and cabling specifications not applicable to a PHY manufacturer.
*AXO	Auto-Crossover	40.4.4	O	Yes [ ] No [ ]	PHY supports auto-crossover
*PD	Powered Device	40.6.1.1	O	Yes [ ] No [ ]	PHY encompasses the PI of a PD within its MDI.

40.12.3 Clause conventions

Item	Feature	Subclause	Status	Support	Value/Comment
CCO1	The values of all components in test circuits shall be	40.1.6	M	Yes [ ]	Accurate to within ±1% unless otherwise stated.

40.12.4 Physical Coding Sublayer (PCS)

Item	Feature	Subclause	Status	Support	Value/Comment
PCT1	The PCS shall	40.3.1.2	M	Yes [ ]	Implement the Data Transmission Enabling process as depicted in Figure 40–8 including compliance with the associated state variables specified in 40.3.3.
PCT2	PCS Transmit function shall	40.3.1.3	M	Yes [ ]	Conform to the PCS Transmit state diagram in Figure 40–10.
PCT3	PCS Transmit shall	40.4.5.1	M	Yes [ ]	Send code-groups according to the value assumed by the tx_mode variable.
PCT4	If the parameter config provided to the PCS by the PHY Control function via the PMA_CONFIG.indication message assumes the value MASTER, PCS Transmit shall	40.3.1.3.1	M	Yes [ ]	Employ the transmitter side-stream scrambler generator polynomial specified for use with MASTER in 40.3.1.3.1.

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Item	Feature	Subclause	Status	Support	Value/Comment
PCT5	If the parameter config provided to the PCS by the PHY Control function via the PMA_CONFIG.indication message assumes the value SLAVE, PCS Transmit shall	40.3.1.3.1	M	Yes [ ]	Employ the transmitter side-stream scrambler generator polynomial specified for use with SLAVE in 40.3.1.3.1.
PCT6	In no case shall	40.3.1.3.1	M	Yes [ ]	The scrambler state be initialized to all zeros.
PCT7	If tx_error_n=1 when the condition (tx_enable_n * tx_enable_{n-2}) = 1, error indication is signaled by means of symbol substitution, wherein the values of Sd_n[5:0] are ignored during mapping and the symbols corresponding to the row denoted as "xmt_err" in Table 40–1 and Table 40–2 shall be used.	40.3.1.3.5	M	Yes [ ]	
PCT8	If tx_error_n=0 when the variable $csreset_n$ = 1, the convolutional encoder reset condition is normal. This condition is indicated by means of symbol substitution, where the values of Sd_n[5:0] are ignored during mapping and the symbols corresponding to the row denoted as "CSReset" in Table 40–1 and Table 40–2 shall be used.	40.3.1.3.5	M	Yes [ ]	
PCT9	If tx_error_n=1 is asserted when the variable $csreset_n$ = 1, the convolutional encoder reset indicates carrier extension. In this condition, the values of Sd_n[5:0] are ignored during mapping and the symbols corresponding to the row denoted as "CSExtend" in Table 40–1 and Table 40–2 shall be used when TXD_n = 0x'0F, and the row denoted as "CSExtend_Err" in Table 40–1 and Table 40–2 shall be used when TXD_n ¦ 0x'0F.	40.3.1.3.5	M	Yes [ ]	
PCT10	In case carrier extension with error is indicated during the first octet of CSReset, the error condition shall be encoded during the second octet of CSReset, and during the subsequent two octets of the End-of-Stream delimiter.	40.3.1.3.5	M	Yes [ ]	

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Item	Feature	Subclause	Status	Support	Value/Comment
PCT11	The symbols corresponding to the SSD1 row in Table 40–1 shall be used when the condition (tx_enable_n) * ($!tx_enable_{n-1}$) = 1.	40.3.1.3.5	M	Yes [ ]	
PCT12	The symbols corresponding to the SSD2 row in Table 40–1 shall be used when the condition (tx_enable_{n-1})* ($!tx_enable_{n-2}$) = 1.	40.3.1.3.5	M	Yes [ ]	
PCT13	If carrier extend error is indicated during ESD, the symbols corresponding to the ESD_Ext_Err row in Table 40–1 shall be used.	40.3.1.3.5	M	Yes [ ]	
PCT14	The symbols corresponding to the ESD1 row in Table 40–1 shall be used when the condition ($!tx_enable_{n-2}$) * (tx_enable_{n-3}) = 1, in the absence of carrier extend error indication at time n.	40.3.1.3.5	M	Yes [ ]	
PCT15	The symbols corresponding to the ESD2_Ext_0 row in shall be used when the condition ($!tx_enable_{n-3}$) * (tx_enable_{n-4}) * ($!tx_error_n$) * ($!tx_error_{n-1}$) = 1.	40.3.1.3.5	M	Yes [ ]	
PCT16	The symbols corresponding to the ESD2_Ext_1 row in Table 40–1 shall be used when the condition ($!tx_enable_{n-3}$) * (tx_enable_{n-4}) * ($!tx_error_n$) * (tx_error_{n-1}) * (tx_error_{n-2}) * (tx_error_{n-3})= 1.	40.3.1.3.5	M	Yes [ ]	
PCT17	The symbols corresponding to the ESD2_Ext_2 row in Table 40–1 shall be used when the condition ($!tx_enable_{n-3}$) * (tx_enable_{n-4}) * (tx_error_n) * (tx_error_{n-1}) * (tx_error_{n-2}) * (tx_error_{n-3}) * (TXD_n=0x0F)= 1, in the absence of carrier extend error indication.	40.3.1.3.5	M	Yes [ ]	
PCT18	The PCS shall	40.3.1.6	EEE:M	Yes [ ]	Conform to the Local LPI Request state diagram as depicted in Figure 40–9 including compliance with the associated state variables specified in 40.3.3.
PCT19	In the absence of the optional EEE capability, the PHY shall	40.3.3.1	!EEE:M	Yes [ ]	Operate as if the value of loc_lpi_req is FALSE.

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40.12.4.1 PCS receive functions

Item	Feature	Subclause	Status	Support	Value/Comment
PCR1	PCS Receive function shall	40.3.1.4	M	Yes [ ]	Conform to the PCS Receive state diagram shown in Figure 40–11a including compliance with the associated state variables as specified in 40.3.3.
PCR2	The PHY shall	40.3.1.4.2	M	Yes [ ]	Descramble the data stream and return the proper sequence of data bits RXD<7:0> to the GMII.
PCR3	For side-stream descrambling, the MASTER PHY shall employ	40.3.1.4.2	M	Yes [ ]	The receiver scrambler generator polynomial specified for MASTER operation in 40.3.1.4.2.
PCR4	For side-stream descrambling, the SLAVE PHY shall employ	40.3.1.4.2	M	Yes [ ]	The receiver scrambler generator polynomial specified for SLAVE operation in 40.3.1.4.2.
PCR5	In the absence of the optional EEE capability, the PHY shall	40.3.3.1	!EEE:M	Yes [ ]	Operate as if the value of rem_lpi_req is FALSE.

40.12.4.2 Other PCS functions

Item	Feature	Subclause	Status	Support	Value/Comment
PCO1	The PCS Reset function shall	40.3.1.1	M	Yes [ ]	Be executed any time “power on” or receipt of a request for reset from the management entity occurs, including compliance with the associated state variables as specified in 40.3.3.
PCO2	The PCS shall	40.3.1.5	M	Yes [ ]	Implement the Carrier Sense process as depicted in Figure 40–12, including compliance with the associated state variables as specified in 40.3.3.
PCO3	Symb-timer shall be generated	40.3.3.3	M	Yes [ ]	Synchronously with TX_TCLK.

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40.12.5 Physical Medium Attachment (PMA)

Item	Feature	Subclause	Status	Support	Value/Comment
PMF1	PMA Reset function shall be executed	40.4.2.1	M	Yes [ ]	At power on and upon receipt of a reset request from the management entity or from PHY Control.
PMF2	PMA Transmit shall	40.4.2.2	M	Yes [ ]	Continuously transmit onto the MDI pulses modulated by the quinary symbols given by tx_symb_vector[BI_DA], tx_symb_vector[BI_DB], tx_symb_vector[BI_DC], and tx_symb_vector[BI_DD], respectively.
PMF3	The four transmitters shall be driven by the same transmit clock, TX_TCLK	40.4.2.2	M	Yes [ ]	
PMF4	PMA Transmit shall	40.4.2.2	M	Yes [ ]	Follow the mathematical description given in 40.4.3.1.
PMF5	PMA Transmit shall comply with	40.4.2.2	M	Yes [ ]	The electrical specifications given in 40.6.
PMF6	When the PMA_CONFIG.indication parameter config is MASTER, the PMA Transmit function shall	40.4.2.2	M	Yes [ ]	Source the transmit clock TX_TCLK from a local clock source while meeting the transmit jitter requirements of 40.6.1.2.5.
PMF7	When the PMA_CONFIG.indication parameter config is SLAVE, the PMA Transmit function shall	40.4.2.2	M	Yes [ ]	Source the transmit clock TX_TCLK from the recovered clock of 40.4.2.5 while meeting the jitter requirements of 40.6.1.2.5.
PMF8	PMA Receive function shall translate	40.4.2.3	M	Yes [ ]	The signals received on pairs BI_DA BI_DB, BI_DC and BI_DD into the PMA_UNITDATA.indication parameter rx_symb_vector with a symbol error ratio of less than one part in 10^{10}.
PMF9	PHY Control function shall	40.4.2.4	M	Yes [ ]	Comply with the state diagram descriptions given in Figure 40–16a.
PMF10	The Link Monitor function shall	40.4.2.5	M	Yes [ ]	Comply with the state diagram shown in Figure 40–17.
PMF11	Clock Recovery function shall provide	40.4.2.6	M	Yes [ ]	Clocks suitable for signal sampling on each line so that the symbol error ratio indicated in 40.4.2.3 is achieved.
PMF12	The symbol response shall comply with	40.4.3.1	M	Yes [ ]	The electrical specifications given in 40.6.

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Item	Feature	Subclause	Status	Support	Value/Comment
PMF13	The four signals received on pairs BI_DA, BI_DB, BI_DC, and BI_DD shall be processed within the PMA Receive function to yield	40.4.3.2	M	Yes [ ]	The quinary received symbols rx_symb_vector[BI_DA], rx_symb_vector[BI_DB], rx_symb_vector[BI_DC], and rx_symb_vector[BI_DD].
PMF14	If an automatic configuration method is used, it shall	40.4.4	M	Yes [ ]	Comply with the specifications of 40.4.4.
PMF15	The PMA shall	40.4.5.1	M	Yes [ ]	Generate the config variable continuously and pass it to the PCS via the PMA_CONFIG.indication primitive.
PMF16	The variable link_det shall take the value	40.4.5.1	AXO:M	N/A [ ] Yes [ ]	TRUE or FALSE as per 40.4.4.1.
PMF17	The variable MDI_status shall take the value	40.4.5.1	AXO:M	N/A [ ] Yes [ ]	MDI or MDI-X as per Table 40–12.
PMF18	PCS Transmit shall	40.4.5.1	M	Yes [ ]	Send code-groups according to the value assumed by tx_mode.
PMF19	The A_timer shall have a period of	40.4.5.2	AXO:M	N/A [ ] Yes [ ]	1.3s ± 25%.
PMF20	The maxwait_timer timer shall expire	40.4.5.2	M	Yes [ ]	750 ms ± 10 ms if config = MASTER or 350 ms ± 5ms if config = SLAVE
PMF21	The minwait_timer timer shall expire	40.4.5.2	M	Yes [ ]	1 µs ±0.1µs after being started.
PMF22	The sample_timer shall have a period of	40.4.5.2	AXO:M	N/A [ ] Yes [ ]	62 ms ± 2ms.
PMF23	The stabilize_timer shall expire	40.4.5.2	M	Yes [ ]	1 µs ± 0.1 µs after being started.
PMF24	PHY Control shall	40.4.2.4	EEE:M	Yes [ ]	Comply with the state diagram description given in Figure 40–16a and Figure 40–16b.
PMF25	In the WAIT_QUIET state, the PHY shall	40.4.2.4	EEE:M	Yes [ ]	Be capable of correctly decoding rem_lpi_req.
PMF26	In the absence of the optional EEE capability, the PHY shall	40.4.5.1	EEE:M	Yes [ ]	Operate as if the value of loc_update_done is FALSE.
PMF27	In the absence of the optional EEE capability, the PHY shall	40.4.5.1	EEE:M	Yes [ ]	Operate as if the value of lpi_mode is OFF.
PMF28	In the absence of the optional EEE capability, the PHY shall	40.4.5.1	EEE:M	Yes [ ]	Operate as if the value of rem_lpi_req is FALSE.
PMF29	lpi_link_fail_timer shall	40.4.5.2	EEE:M	Yes [ ]	Have a period between 90 µs and 110 µs.
PMF30	lpi_postupdate_timer shall	40.4.5.2	EEE:M	Yes [ ]	Have a period between 2.0 µs and 3.2 µs.

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Item	Feature	Subclause	Status	Support	Value/Comment
PMF31	lpi_quiet_timer shall	40.4.5.2	EEE:M	Yes [ ]	Have a period between 20 ms and 24 ms.
PMF32	lpi_waitwq_timer shall	40.4.5.2	EEE:M	Yes [ ]	Have a period between 10 µs and 12 µs.
PMF33	For each transition of lpi_wake_timer_done from false to true, the wake error counter shall	40.4.5.2	EEE:M	Yes [ ]	Be incremented.
PMF34	lpi_wake_timer shall	40.4.5.2	EEE:M	Yes [ ]	Have a period that does not exceed 16.5 µs.
PMF35	lpi_waketx_timer shall	40.4.5.2	EEE:M	Yes [ ]	Have a period between 1.2_µs and 1.4 µs.
PMF36	lpi_wakemz_timer shall	40.4.5.2	EEE:M	Yes [ ]	Have a period between 4.25 µs and 5.00 µs.
PMF37	lpi_update_timer shall	40.4.5.2	EEE:M	Yes [ ]	Have a period between 0.23 ms and 0.25 ms for a PHY configured as the MASTER and a period between 0.18 ms and 0.20 ms for a PHY configured as the SLAVE.

40.12.6 Management interface

Item	Feature	Subclause	Status	Support	Value/Comment
MF1	All 1000BASE-T PHYs shall provide support for Auto-Negotiation (Clause 28) and shall be capable of operating as MASTER or SLAVE.	40.5.1	M	Yes [ ]	
MF2	A 100BASE-T PHY shall	40.5.1.1	M	Yes [ ]	Use the management register definitions and values specified in Table 40–3.

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40.12.6.1 1000BASE-T Specific Auto-Negotiation Requirements

Item	Feature	Subclause	Status	Support	Value/Comment
AN1	1000BASE-T PHYs shall	40.5.1.2	M	Yes [ ]	Exchange one Auto-Negotiation Base Page, a 1000BASE-T formatted Next Page, and two 1000BASE-T Unformatted Next Pages in sequence, without interruption, as specified in Table 40–4.
AN2	The MASTER-SLAVE relationship shall be determined during Auto-Negotiation	40.5.2	M	Yes [ ]	Using Table 40–5 with the 1000BASE-T Technology Ability Next Page bit values specified in Table 40–4 and information received from the link partner.
AN3	Successful completion of the MASTER-SLAVE resolution shall	40.5.2	M	Yes [ ]	Be treated as MASTER-SLAVE configuration resolution complete.
AN4	A seed counter shall be provided to	40.5.2	M	Yes [ ]	Track the number of seed attempts.
AN5	At start-up, the seed counter shall be set to	40.5.2	M	Yes [ ]	Zero.
AN6	The seed counter shall be incremented	40.5.2	M	Yes [ ]	Every time a new random seed is sent.
AN7	When MASTER-SLAVE resolution is complete, the seed counter shall be reset to 0 and bit 10.15 shall be set to logical zero.	40.5.2	M	Yes [ ]	
AN8	Maximum seed attempts before declaring a MASTER_SLAVE configuration Resolution Fault	40.5.2	M	Yes [ ]	Seven.
AN9	During MASTER_SLAVE configuration, the device with the higher seed value shall	40.5.2	M	Yes [ ]	Become the MASTER.
AN10	During MASTER_SLAVE configuration, the device with the lower seed value shall	40.5.2	M	Yes [ ]	Become the SLAVE.
AN11	Both PHYs set in manual mode to be either MASTER or SLAVE shall be treated as	40.5.2	M	Yes [ ]	MASTER-SLAVE resolution fault (failure) condition.
AN12	MASTER-SLAVE resolution fault (failure) condition shall result in	40.5.2	M	Yes [ ]	MASTER-SLAVE Configuration Resolution Fault bit (10.15) to be set to logical one.

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Item	Feature	Subclause	Status	Support	Value/Comment
AN13	MASTER-SLAVE Configuration resolution fault condition shall be treated as	40.5.2	M	Yes [ ]	MASTER-SLAVE Configuration Resolution complete.
AN14	MASTER-SLAVE Configuration resolution fault condition shall	40.5.2	M	Yes [ ]	Cause link_status_1000BASE-T to be set to FAIL.
AN15	When EEE is supported, a 1000BASE-T PHY shall	40.5.1.2	EEE:M	Yes [ ]	Exchange an additional formatted Next Page and Unformatted Next Page in sequence, without interruption, as specified in Table 40–4.

40.12.7 PMA Electrical Specifications

Item	Feature	Subclause	Status	Support	Value/Comment
PME1	The PHY shall provide electrical isolation between	40.6.1.1	!PD:M	Yes [ ] N/A [ ]	The port device circuits including frame ground, and all MDI leads.
PME2	The PHY shall provide electrical isolation between	40.6.1.1	PD:M	Yes [ ] N/A [ ]	All external conductors, including frame ground, and all MDI leads.
PME3	PHY-provided electrical isolation shall withstand at least one of three electrical strength tests	40.6.1.1	M	Yes [ ]	a) 1500 V rms at 50Hz to 60Hz for 60 s, applied as specified in subclause 5.2.2 of IEC 60950-1:2001. b) 2250 V dc for 60 s, applied as specified in subclause 5.2.2 of IEC 60950-1:2001. c) A sequence of ten 2400 V impulses of alternating polarity, applied at intervals of not less than 1 s. The shape of the impulses shall be 1.2/50 µs. (1.2 µs virtual front time, 50 µs virtual time or half value), as defined in IEC IEC 60950-1:2001 Annex N.
PME4	There shall be no insulation breakdown as defined in Section 5.3.2 of IEC 60950, during the test.	40.6.1.1	M	Yes [ ]	
PME5	The resistance after the test shall be at least	40.6.1.1	M	Yes [ ]	2 MΩ, measured at 500 Vdc.

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Item	Feature	Subclause	Status	Support	Value/Comment
PME6	The transmitter MASTER-SLAVE timing jitter test channel shall	40.6.1.1.1	M	Yes [ ]	Be constructed by combining 100 Ω and 120 Ω cable segments that meet or exceed ISO/IEC 11801 Category 5 specifications for each pair as shown in Figure 40–19 with the lengths and additional restrictions on parameters described in Table 40–6.
PME7	The ends of the MASTER-SLAVE timing jitter test channel shall	40.6.1.1.1	M	Yes [ ]	Be connectorized with connectors meeting or exceeding ISO/IEC 11801:1995 Category 5 specifications.
PME8	The return loss of the MASTER-SLAVE timing jitter test channel shall	40.6.1.1.1	M	Yes [ ]	Meet the return loss requirements of 40.7.2.3.
PME9	The return loss of the MASTER-SLAVE timing jitter test channel shall	40.6.1.1.1	M	Yes [ ]	Meet the crosstalk requirements of 40.7.3 on each pair.
PME10	The test modes described in 40.6.1.1.2 shall be provided for testing of the transmitted waveform, transmitter distortion and transmitted jitter.	40.6.1.1.2	M	Yes [ ]	
PME11	For a PHY with a GMII interface the test modes shall be enabled by	40.6.1.1.2	M	Yes [ ]	Setting bits 9:13-15 (1000BASE-T Control Register) of the GMII Management register set as shown in Table 40–7.
PME12	The test modes shall only change the data symbols provided to the transmitter circuitry and shall not alter the electrical and jitter characteristics of the transmitter and receiver from those of normal operation.	40.6.1.1.2	M	Yes [ ]	
PME13	A PHY without a GMII shall provide a means to enable the test modes for conformance testing.	40.6.1.1.2	M	Yes [ ]	
PME14	When transmit test mode 1 is enabled, the PHY shall transmit	40.6.1.1.2	M	Yes [ ]	The sequence of data symbols specified in 40.6.1.1.2 continuously from all four transmitters.
PME15	When in test mode 1, the transmitter shall time the transmitted symbols	40.6.1.1.2	M	Yes [ ]	From a 125.00 MHz ± 0.01% clock in the MASTER timing mode.
PME16	When test mode 2 is enabled, the PHY shall transmit	40.6.1.1.2	M	Yes [ ]	The data symbol sequence {+2,–2} repeatedly on all four channels.

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Item	Feature	Subclause	Status	Support	Value/Comment
PME17	When in test mode 2, the transmitter shall time the transmitted symbols	40.6.1.1.2	M	Yes [ ]	From a 125.00 MHz ± 0.01% clock in the MASTER timing mode.
PME18	When transmit test mode 3 is enabled, the PHY shall transmit	40.6.1.1.2	M	Yes [ ]	The data symbol sequence {+2,–2} repeatedly on all four channels.
PME19	When in test mode 3, the transmitter shall time the transmitted symbols	40.6.1.1.2	M	Yes [ ]	From a 125 MHz ± 1% clock in the SLAVE timing mode.
PME20	When test mode 4 is enabled, the PHY shall transmit	40.6.1.1.2	M	Yes [ ]	The data symbols generated by the scrambler polynomial specified in 40.6.1.1.2.
PME21	When test mode 4 is enabled, the PHY shall	40.6.1.1.2	M	Yes [ ]	Use the bit sequences generated by the scrambler bits shown in 40.6.1.1.2 to generate the quinary symbols, s_n, as shown in Table 40–8.
PME22	When test mode 4 is enabled, the maximum-length shift register used to generate the sequences defined by this polynomial shall be	40.6.1.1.2	M	Yes [ ]	Updated once per symbol interval (8 ns).
PME23	When test mode 4 is enabled, the bit sequences, $x0_n$, $x1_n$, and $x2_n$, generated from combinations of the scrambler bits shown in 40.6.1.1.2 shall be	40.6.1.1.2	M	Yes [ ]	Used to generate the quinary symbols, s_n, as shown in Table 40–8.
PME24	When test mode 4 is enabled, the quinary symbol sequence shall be	40.6.1.1.2	M	Yes [ ]	Presented simultaneously to all transmitters.
PME25	When in test mode 4, the transmitter shall time the transmitted symbols	40.6.1.1.2	M	Yes [ ]	From a 125.00 MHz ± 0.01% clock in the MASTER timing mode.
PME26	The test fixtures defined in Figure 40–23, Figure 40–24, Figure 40–25, and Figure 40–26 or their functional equivalents shall be used for measuring transmitter specifications.	40.6.1.1.3	M	Yes [ ]	
PME27	The test filter used in transmitter test fixtures 1 and 3 shall	40.6.1.1.3	M	Yes [ ]	Have the continuous time transfer function specified in 40.6.1.1.3 or its discrete time equivalent.
PME28	The disturbing signal V_d shall	40.6.1.1.3	M	Yes [ ]	Have the characteristics listed in Table 40–9.

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Item	Feature	Subclause	Status	Support	Value/Comment
PME29	To allow for measurement of transmitted jitter in MASTER and SLAVE modes the PHY shall provide access to the 125 MHz symbol clock, TX_TCLK that times the transmitted symbols.	40.6.1.1.3	M	Yes [ ]	
PME30	To allow for measurement of transmitted jitter in MASTER and SLAVE modes the PHY shall provide a means to enable the TX_TCLK output if it is not normally enabled.	40.6.1.1.3	M	Yes [ ]	
PME31	The PMA shall	40.6.1.2	M	Yes [ ]	Provide the Transmit function specified in 40.4.2.2 in accordance with the electrical specifications of this clause.
PME32	Where a load is not specified, the transmitter shall	40.6.1.2	M	Yes [ ]	Meet the requirements of this clause with a 100 Ω resistive differential load connected to each transmitter output.
PME33	The tolerance on the poles of the test filters used in 40.6 shall be ± 1%.	40.6.1.2	M	Yes [ ]	
PME34	When in transmit test mode 1 and observing the differential signal output at the MDI using test fixture 1, for each pair, with no intervening cable, the absolute value of the peak of the waveform at points A and B as defined in Figure 40–20 shall fall within	40.6.1.2.1	M	Yes [ ]	The range of 0.67 V to 0.82 V (0.75 V ± 0.83 dB).
PME35	The absolute value of the peak of the waveforms at points A and B shall	40.6.1.2.1	M	Yes [ ]	Differ by less than 1%.
PME36	The absolute value of the peak of the waveform at points C and D as defined in Figure 40–20 shall differ	40.6.1.2.1	M	Yes [ ]	From 0.5 times the average of the absolute values of the peaks of the waveform at points A and B by less than 2%.
PME37	When in transmit test mode 1 and observing the differential transmitted output at the MDI, for either pair, with no intervening cabling, the peak value of the waveform at point F as defined in Figure 40–20 shall be	40.6.1.2.2	M	Yes [ ]	Greater than 73.1% of the magnitude of the negative peak value of the waveform at point F. Point G is defined as the point exactly 500 ns after point F. Point F is defined as the point where the waveform reaches its minimum value at the location indicated in Figure 40–20.

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Item	Feature	Subclause	Status	Support	Value/Comment
PME38	When in transmit test mode 1 and observing the differential transmitted output at the MDI, for either pair, with no intervening cabling, the peak value of the waveform at point J as defined in Figure 40–20 shall be	40.6.1.2.2	M	Yes [ ]	Greater than 73.1% of the magnitude of the peak value of the waveform at point H. Point J is defined as the point exactly 500 ns after point H. Point H is defined as the point where the waveform reaches its maximum value at the location indicated in Figure 40–20.
PME39	When in test mode 1 and observing the differential signal output at the MDI using transmitter test fixture 1, for each pair, with no intervening cable, the voltage waveforms at points A, B, C, D defined in Figure 40–20, after the normalization described within the referenced subclause, shall	40.6.1.2.3	M	Yes [ ]	Lie within the time domain template 1 defined in Figure 40–27 and the piecewise linear interpolation between the points in Table 40–10. The waveforms may be shifted in time as appropriate to fit within the template.
PME40	When in test mode 1 and observing the differential signal output at the MDI using transmitter test fixture 1, for each pair, with no intervening cable, the voltage waveforms at points F and H defined in Figure 40–20, after the normalization described within the referenced subclause, shall	40.6.1.2.3	M	Yes [ ]	Lie within the time domain template 2 defined in Figure 40–27 and the piecewise linear interpolation between the points in Table 40–11. The waveforms may be shifted in time as appropriate to fit within the template.
PME41	When in test mode 4 and observing the differential signal output at the MDI using transmitter test fixture 3, for each pair, with no intervening cable, the peak distortion as defined below shall be	40.6.1.2.4	M	Yes [ ]	Less than 10 mV.
PME42	When in the normal mode of operation as the MASTER, the peak-to-peak value of the MASTER TX_TCLK jitter relative to an unjittered reference shall be	40.6.1.2.5	M	Yes [ ]	Less than 1.4 ns.
PME43	When the jitter waveform on TX_TCLK is filtered by a high-pass filter, $H_{jf1}(f)$ having the transfer function specified in 40.6.1.2.5, the peak-to-peak value of the resulting filtered timing jitter plus J_{txout}, shall be	40.6.1.2.5	M	Yes [ ]	Less than 0.3 ns.

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Item	Feature	Subclause	Status	Support	Value/Comment
PME44	When in the normal mode of operation as the SLAVE, receiving valid signals from a compliant PHY operating as the MASTER using the test channel defined in 40.6.1.1.1, with test channel port A connected to the SLAVE, the peak-to-peak value of the SLAVE TX_TCLK jitter relative to the MASTER TX_TCLK shall be	40.6.1.2.5	M	Yes [ ]	Less than 1.4 ns after the receiver is properly receiving the data and has set bit 10.13 of the GMII management register set to 1.
PME45	When the jitter waveform on TX_TCLK is filtered by a high-pass filter, $H_{jf2}(f)$, having the transfer function specified in 40.6.1.2.5, the peak-to-peak value of the resulting filtered timing jitter plus J_{txout} shall be	40.6.1.2.5	M	Yes [ ]	No more than 0.4 ns greater than the simultaneously measured peak-to-peak value of the MASTER jitter filtered by $H_{jf1}(f)$
PME46	For all jitter measurements the peak-to-peak value shall be	40.6.1.2.5	M	Yes [ ]	Measured over an unbiased sample of at least 10^5 clock edges.
PME47	For all unfiltered jitter measurements the peak-to-peak value shall be	40.6.1.2.5	M	Yes [ ]	Measured over an interval of not less than 100 ms and not more than 1 second.
PME48	The quinary symbol transmission rate on each pair of the MASTER PHY shall be	40.6.1.2.6	M	Yes [ ]	125.00 MHz ± 0.01%
PME49	The PMA shall provide the Receive function specified in 40.3.1.4 in accordance with the electrical specifications of this clause.	40.6.1.3	M	Yes [ ]	
PME50	The patch cabling and interconnecting hardware used in test configurations shall be	40.6.1.3	M	Yes [ ]	Within the limits specified in 40.7.
PME51	Differential signals received on the receive inputs that were transmitted within the specifications given in 40.6.1.2 and have then passed through a link compatible with 40.7, shall be translated into	40.6.1.3.1	M	Yes [ ]	One of the PMA_UNITDATA.indication messages with a 4-D symbol rate error less than 10^{-10} and sent to the PCS after link bring-up. Since the 4-D symbols are not accessible, this specification shall be satisfied by a frame error ratio less than 10^{-7} for 125 octet frames.
PME52	The receive feature shall	40.6.1.3.2	M	Yes [ ]	Properly receive incoming data with a 5-level symbol rate within the range 125.00 MHz ± 0.01%.
PME53	The signal generator for the common-mode test shall be	40.6.1.3.3	M	Yes [ ]	Capable of providing a sine wave signal of 1 MHz to 250 MHz.

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Item	Feature	Subclause	Status	Support	Value/Comment
PME54	While sending data from the transmitter the receiver shall	40.6.1.3.3	M	Yes [ ]	Send the proper PMA_UNITDATA.indication messages to the PCS as the signal generator frequency is varied from 1 MHz to 250 MHz.
PME55	While receiving data from a transmitter specified in 40.6.1.2 through a link segment specified in 40.7 connected to all MDI duplex channels, a receiver shall	40.6.1.3.4	M	Yes [ ]	Send the proper PMA_UNITDATA.indication message to the PCS when any one of the four pairs is connected to a noise source as described in Figure 40–29.
PME56	The alien crosstalk test specified in 40.6.1.3.4 shall be satisfied by	40.6.1.3.4	M	Yes [ ]	A frame error ratio of less than 10^{-7} for 125 octet frames
PME57	The noise source shall be	40.6.1.3.4	M	Yes [ ]	Connected to one of the MDI inputs using Category 5 balanced cable of a maximum length of 0.5 m.
PME58	The unfiltered jitter requirements shall	40.6	EEE:M	Yes [ ]	Be satisfied during the LPI mode, with the exception that clock edges corresponding to the WAIT_QUIET, QUIET, WAKE, and WAKE_SILENT states are not considered in the measurement.
PME59	For a MASTER PHY operating in the LPI mode, the unjittered reference shall	40.6	EEE:M	Yes [ ]	Be continuous.
PME60	The transmit levels of the Idle symbols transmitted during the WAKE state shall	40.6.1.2.7	EEE:M	Yes [ ]	Exceed 65% of the transmit levels of compliant Idle symbols for a period of at least 500 ns.
PME61	The PHY shall	40.6.1.2.7	EEE:M	Yes [ ]	Achieve compliant operation upon entry to the WAKE_TRAINING state (see Figure 40–16b).
PME62	PMA Receive function shall	40.6.1.3.5	EEE:M	Yes [ ]	Convey an indicator of signal presence, referred to as signal_detect, to the PMA PHY Control function.
PME63	The value of signal_detect shall	40.6.1.3.5	EEE:M	Yes [ ]	Be set to TRUE within 0.5 µs of the receipt of a wake signal meeting the requirements of 40.6.1.2.7.
PME64	The value of signal_detect shall	40.6.1.3.5	EEE:M	Yes [ ]	Be set to FALSE within 0.5 µs of the receipt of a continuous sequence of zeros.

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40.12.8 Characteristics of the link segment

Item	Feature	Subclause	Status	Support	Value/Comment
LKS1	All implementations of the balanced cabling link shall	40.7.1	INS:M	N/A [ ] Yes [ ]	Be compatible at the MDI.
LKS2	1000BASE-T links shall be compliant	40.7.1	INS:M	N/A [ ] Yes [ ]	With Class D performance requirements, as specified by ISO/IEC 11801:1995.
LKS3	Link segment testing shall be conducted using	40.7.2	INS:M	N/A [ ] Yes [ ]	Source and load impedances of 100 Ω.
LKS4	The tolerance on the poles of the test filter used in this section shall be	40.7.2	INS:M	N/A [ ] Yes [ ]	± 1%.
LKS5	The insertion loss of each duplex channel shall be	40.7.2.1	INS:M	N/A [ ] Yes [ ]	Less than $2.1 f^{0.529} + 0.4/f$ (dB) at all frequencies from 1 MHz to 100 MHz. This includes the attenuation of the balanced cabling pairs, connector losses, and patch cord losses of the duplex channel.
LKS6	The insertion loss specification shall be met when	40.7.2.1	INS:M	N/A [ ] Yes [ ]	The duplex channel is terminated in 100 Ω.
LKS7	The return loss of each duplex channel shall be	40.7.2.3	INS:M	N/A [ ] Yes [ ]	As specified in 40.7.2.3 at all frequencies from 1 MHz to 100 MHz.
LKS8	The reference impedance for return loss measurement shall be	40.7.2.3	INS:M	N/A [ ] Yes [ ]	100 Ω.
LKS9	The NEXT loss between duplex channel pairs of a link segment shall be	40.7.3.1.1	INS:M	N/A [ ] Yes [ ]	At least $27.1 - 16.8\log_{10}(f/100)$ (where f is the frequency in MHz over the frequency range 1 MHz to 100 MHz.)
LKS10	The worst case ELFEXT loss between duplex channel pairs of a link segment shall be	40.7.3.2	INS:M	N/A [ ] Yes [ ]	Greater than $17 - 20\log_{10}(f/100)$ dB (where f is the frequency in MHz) over the frequency range 1 MHz to 100 MHz.
LKS11	The Power Sum loss between a duplex channel and the three adjacent disturbers shall be	40.7.3.2.2	INS:M	N/A [ ] Yes [ ]	Greater than $14.4 - 20\log_{10}(f/100)$ dB where f is the frequency in MHz over the frequency range of 1 MHz to 100 MHz.

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Item	Feature	Subclause	Status	Support	Value/Comment
LKS12	The propagation delay of a link segment shall	40.7.4.1	INS:M	N/A [ ] Yes [ ]	Not exceed 570 ns at all frequencies from 2 MHz to 100 MHz.
LKS13	The difference in propagation delay, or skew, between all duplex channel pair combinations of a link segment under all conditions shall not exceed	40.7.4.2	INS:M	N/A [ ] Yes [ ]	50 ns at all frequencies between 2 MHz and 100 MHz.
LKS14	Once installed, the skew between pairs due to environmental conditions shall not vary	40.7.4.2	INS:M	N/A [ ] Yes [ ]	More than ± 10 ns.

40.12.9 MDI requirements

Item	Feature	Subclause	Status	Support	Value/Comment
MDI1	MDI connector	40.8.1	M	Yes [ ]	8-Way connector as per IEC 60603-7:1990.
MDI2	Connector used on cabling	40.8.1	INS:M	N/A [ ] Yes [ ]	Plug.
MDI3	Connector used on PHY	40.8.1	M	Yes [ ]	Jack (as opposed to plug).
MDI4	MDI connector	40.8.2	M	Yes [ ]	A PHY that implements the crossover function shall be marked with the graphical symbol X.
MDI5	The MDI connector (jack) when mated with a balanced cabling connector (plug) shall meet	40.8.3	INS:M	N/A [ ] Yes [ ]	The electrical requirements for Category 5 connecting hardware for use with 100 Ω Category 5 cable as specified in ISO/IEC 11801:1995.
MDI6	The mated MDI connector and balanced cabling connector shall	40.8.3	INS:M	N/A [ ] Yes [ ]	Not have a FEXT loss greater than $40 - 20\log_{10}(f/100)$ over the frequency range 1 MHz to 100 MHz between all contact pair combinations shown in Table 40–12.
MDI7	No spurious signals shall be emitted onto the MDI when the PHY is held in power down mode as defined in 22.2.4.1.5, independent of the value of TX_EN, when released from power down mode, or when external power is first applied to the PHY.	40.8.3	M	Yes [ ]	

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Item	Feature	Subclause	Status	Support	Value/Comment
MDI8	The differential impedance as measured at the MDI for each transmit/receive channel shall be such that	40.8.3.1	M	Yes [ ]	Any reflection due to differential signals incident upon the MDI from a balanced cabling having an impedance of 100 Ω ± 15% is at least 16 dB over the frequency range of 2.0 MHz to 40 MHz and at least $10 - 20\log_{10}(f/80)$ dB over the frequency range 40 MHz to 100 MHz (f in MHz).
MDI9	This return loss shall be maintained	40.8.3.1	M	Yes [ ]	At all times when the PHY is transmitting data or control symbols.
MDI10	The common-mode to differential-mode impedance balance of each transmit output shall exceed	40.8.3.2	M	Yes [ ]	The value specified by the equations specified in 40.8.3.2. Test mode 4 may be used to generate an appropriate transmitter output.
MDI11	The magnitude of the total common-mode output voltage, E_{cm_out}, on any transmit circuit, when measured as shown in Figure 40–33, shall be	40.8.3.3	M	Yes [ ]	Less than 50 mv peak-to-peak when transmitting data.
MDI12	Each wire pair of the MDI shall	40.8.3.4	M	Yes [ ]	Withstand without damage the application of short circuits across the MDI port for an indefinite period of time without damage.
MDI13	Each wire pair of the MDI shall resume	40.8.3.4	M	Yes [ ]	Normal operation after such faults are removed.
MDI14	The magnitude of the current through the short circuit specified in PME64 shall not exceed	40.8.3.4	M	Yes [ ]	300 mA.
MDI15	Each wire pair shall withstand without damage	40.8.3.4	M	Yes [ ]	A 1000 V common-mode impulse of either polarity (E_{cm} as indicated in Figure 40–34).
MDI16	The shape of the impulse shall be	40.8.3.4	M	Yes [ ]	0.3/50 µs (300 ns virtual front time, 50 µs virtual time of half value), as defined in IEC 60060.

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40.12.10 General safety and environmental requirements

Item	Feature	Subclause	Status	Support	Value/Comment
ENV1	Conformance to safety specifications	40.9.1	M	Yes [ ]	IEC 60950.
ENV2	Installation practice	40.9.2.1	INS:M	N/A [ ] Yes [ ]	Sound practice, as defined by applicable local codes.
ENV3	Care taken during installation to ensure that non-insulated network cabling conductors do not make electrical contact with unintended conductors or ground.	40.9.2.2	INS:M	N/A [ ] Yes [ ]	
ENV4	1000BASE-T equipment shall be capable of withstanding a telephone battery supply from the outlet as described in 40.9.2.3.	40.9.2.3	M	Yes [ ]	
ENV5	A system integrating the 1000BASE-T PHY shall comply with applicable local and national codes for the limitation of electromagnetic interference.	40.9.3.1	INS:M	N/A [ ] Yes [ ]	

40.12.11 Timing requirements

Item	Feature	Subclause	Status	Support	Value/Comment
TR1	Every 1000BASE-T PHY associated with a GMII shall	40.11.1	M	Yes [ ]	Comply with the bit delay constraints specified in Table 40–13 for half duplex operation and Table 40–14 for full duplex operation. These constraints apply for all 1000BASE-T PHYs.
TR2	For any given implementation, the assertion delays on CRS shall	40.11.1	M	Yes [ ]	Be equal.
TR3	Every DTE with a 1000BASE-T PHY shall	40.11.2	M	Yes [ ]	Comply with the bit delay constraints specified in Table 40–15.
TR4	To ensure fair access to the network, each DTE operating in half duplex mode shall, additionally, satisfy the following:	40.11.3	M	Yes [ ]	(MAX MDI to MAC Carrier De-assert Detect) – (MIN MDI to MAC Carrier Assert Detect) < 16 Bit Times.

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41. Repeater for 1000 Mb/s baseband networks

NOTE—This repeater is not recommended for new installations. Since September 2011, maintenance changes are no longer being considered for this clause.

41.1 Overview

41.1.1 Scope

Clause 41 defines the functional and electrical characteristics of a repeater for use with Ethernet 1000 Mb/s baseband networks. A repeater for any other Ethernet network type is beyond the scope of this clause. The relationship of this standard to the OSI Reference Model is shown in Figure 41–1. The purpose of the repeater is to provide a simple, inexpensive, and flexible means of coupling two or more segments.

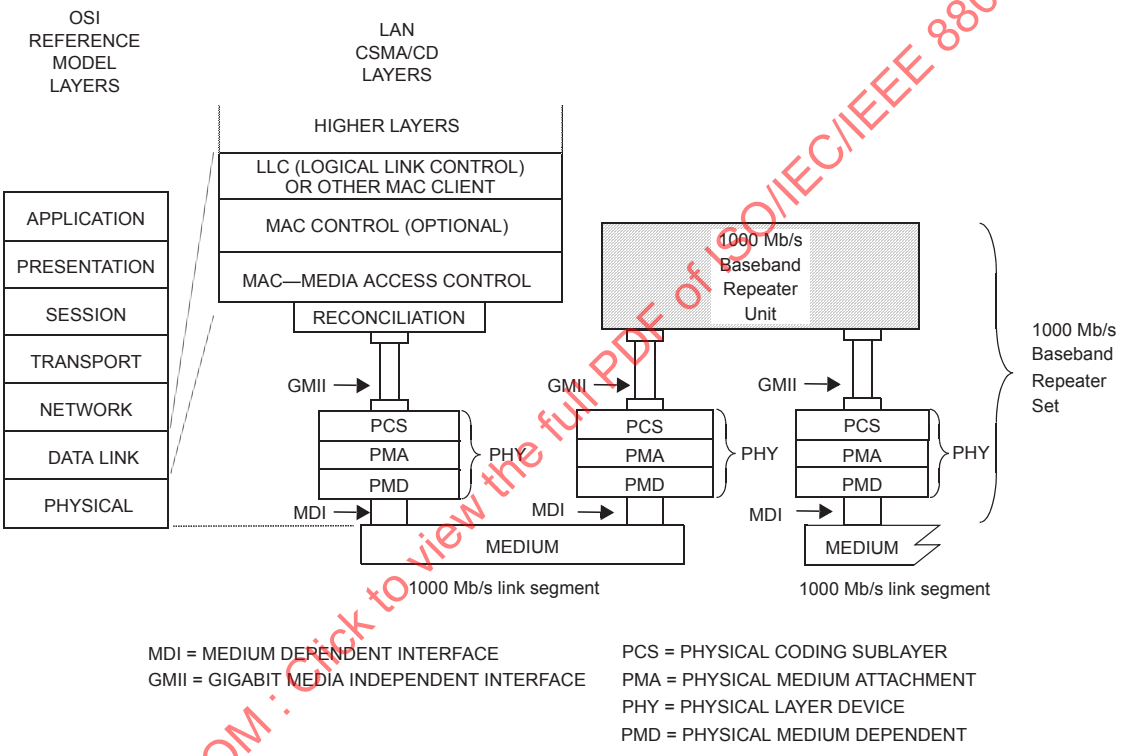

Figure 41–1—1000 Mb/s repeater set relationship to the ISO/IEC OSI reference model

41.1.1.1 Repeater set

Repeater sets are an integral part of all 1000 Mb/s baseband networks with more than two DTEs and are used to extend the physical system topology by providing a means of coupling two or more segments. A single repeater set is permitted within a single collision domain to provide the maximum connection path length. Allowable topologies contain only one operative signal path between any two points on the network. A repeater set is not a station and does not count toward the overall limit of 1024 stations on a network.

A repeater set can receive and decode data from any segment under worst-case noise, timing, and signal amplitude conditions. It retransmits the data to all other segments attached to it with timing, amplitude, and coding restored. The retransmission of data occurs simultaneously with reception. If a collision occurs, the repeater set propagates the collision event throughout the network by transmitting a Jam signal. A repeater

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set also provides a degree of protection to a network by isolating a faulty segment's carrier activity from propagating through the network.

41.1.1.2 Repeater unit

A repeater unit is a subset of a repeater set containing all the repeater-specific components and functions, exclusive of PHY components and functions. A repeater unit connects to the PHYs using the Gigabit Media Independent Interface (GMII) defined in Clause 35.

41.1.2 Application perspective

This subclause states the broad objectives and assumptions underlying the specification defined through Clause 41.

41.1.2.1 Objectives

a) Provide physical means for coupling two or more LAN segments at the Physical Layer.
b) Support interoperability of independently developed physical, electrical, and optical interfaces.
c) Provide a communication channel with a mean bit error ratio, at the physical service interface equivalent to that for the attached PHY.
d) Provide for ease of installation and service.
e) Ensure that fairness of DTE access is not compromised.
f) Provide for low-cost networks, as related to both equipment and cabling.

41.1.2.2 Compatibility considerations

All implementations of the repeater set shall be compatible at the MDI. The repeater set is defined to provide compatibility among devices designed by different manufacturers. Designers are free to implement circuitry within the repeater set in an application-dependent manner provided the appropriate PHY specifications are met.

41.1.2.2.1 Internal segment compatibility

Implementations of the repeater set that contain a MAC layer for network management or other purposes, irrespective of whether they are connected through an exposed repeater port or are internally ported, shall conform to the requirements of Clause 30 on that port if repeater management is implemented.

41.1.3 Relationship to PHY

A close relationship exists between Clause 41 and the GMII clause (Clause 35) and the PHY clauses (Clauses 36–39 for 1000BASE-X PHYs and Clause 40 for 1000BASE-T PHYs). The PHY's PMA, PCS, and MDI specification provide the actual medium attachment, including drivers, receivers, and Medium Interface Connectors for the various supported media. The repeater clause does not define a new PHY; it utilizes the existing PHYs complete and without modification. The repeater_mode variable in each PHY is set, so that the CRS signal of the GMII is asserted only in response to receive activity (see 36.2.5.1.3).

41.2 Repeater functional specifications

A repeater set provides the means whereby data from any segment can be received under worst-case noise, timing, and amplitude conditions and then retransmitted with timing and amplitude restored to all other attached segments. Retransmission of data occurs simultaneously with reception. If a collision occurs, the repeater set propagates the collision event throughout the network by transmitting a Jam signal. If an error is

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received by the repeater set, no attempt is made to correct it and it is propagated throughout the network by transmitting an explicit error code.

The repeater set provides the following functional capability to handle data flow between ports:

a) *Signal restoration.* Provides the ability to restore the timing and amplitude of the received signal prior to retransmission.
b) *Transmit function.* Provides the ability to output signals on the appropriate port and encoded appropriately for that port. Details of signal processing are described in the specifications for the PHYs.
c) *Receive function.* Provides the ability to receive input signals presented to the ports. Details of signal processing are described in the specifications for the PHYs.
d) *Data-Handling function.* Provides the ability to transfer code-elements between ports in the absence of a collision.
e) *Received Event-Handling requirement.* Provides the ability to derive a carrier signal from the input signals presented to the ports.
f) *Collision-Handling function.* Provides the ability to detect the simultaneous reception of frames at two or more ports and then to propagate a Jam message to all connected ports.
g) *Error-Handling function.* Provides the ability to prevent substandard links from generating streams of false carrier and interfering with other links.
h) *Partition function.* Provides the ability to prevent a malfunctioning port from generating an excessive number of consecutive collisions and indefinitely disrupting data transmission on the network.
i) *Receive Jabber function.* Provides the ability to interrupt the reception of abnormally long streams of input data.

41.2.1 Repeater functions

The repeater set shall provide the Signal Restoration, Transmit, Receive, Data Handling, Received Event Handling, Collision Handling, Error Handling, Partition, and Receive Jabber functions. The repeater is transparent to all network acquisition activity and to all DTEs. The repeater will not alter the basic fairness criterion for all DTEs to access the network or weigh it toward any DTE or group of DTEs regardless of network location.

The Transmit and Receive functional requirements are specified by the PHY clauses, Clause 40 for 1000BASE-T and Clauses 36 to 39 for 1000BASE-X.

41.2.1.1 Signal restoration functional requirements

41.2.1.1.1 Signal amplification

The repeater set (including its integral PHYs) shall ensure that the amplitude characteristics of the signals at the MDI outputs of the repeater set are within the tolerances of the specification for the appropriate PHY type. Therefore, any loss of signal-to-noise ratio due to cable loss and noise pickup is regained at the output of the repeater set as long as the incoming data is within system specification.

41.2.1.1.2 Signal wave-shape restoration

The repeater set (including its integral PHYs) shall ensure that the wave-shape characteristics of the signals at the MDI outputs of a repeater set are within the specified tolerance for the appropriate PHY type. Therefore, any loss of wave-shape due to PHYs and media distortion is restored at the output of the repeater set.

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41.2.1.1.3 Signal retiming

The repeater set (including its integral PHYs) shall ensure that the timing of the encoded data output at the MDI outputs of a repeater set are within the specified tolerance for the appropriate PHY type. Therefore, any receive jitter from the media is removed at the output of the repeater set.

41.2.1.2 Data-handling functional requirements

41.2.1.2.1 Data frame forwarding

The repeater set shall ensure that the data frame received on a single input port is distributed to all other output ports in a manner appropriate for the PHY type of that port. The data frame is that portion of the packet after the SFD and before the end-of-frame delimiter. The only exceptions to this rule are when contention exists among any of the ports, when the receive port is partitioned as defined in 41.2.1.6, when the receive port is in the Jabber state as defined in 41.2.1.7, or when the receive port is in the Link Unstable state as defined in 41.2.1.5.1. Between unpartitioned ports, the rules for collision handling (see 41.2.1.4) take precedence.

41.2.1.2.2 Received code violations

The repeater set shall ensure that any code violations received while forwarding a packet are propagated to all outgoing segments. These code violations shall be replaced by a code-group that provide an explicit indication that an error was received, as appropriate for the outgoing PHY type. Once a received code violation has been replaced by a code-group indicating a receive error, this substitution shall continue for the remainder of the received event regardless of its content. The only exception to this rule is when contention exists among any of the ports, where the rules for collision handling (see 41.2.1.4) then take precedence.

41.2.1.3 Received event-handling functional requirements

41.2.1.3.1 Received event handling

For all its ports, the repeater set shall detect received events by monitoring the port for any assertion of the GMII CRS signal that is the result of receive activity. The repeater_mode variable in the PHY shall be set to ensure that the CRS signal is not asserted in response to transmit activity. Received events include both the data frame and any encapsulation of the data frame such as Preamble, SFD, start and end of packet delimiters, carrier extension symbols, and error propagation symbols. A received event is exclusive of the IDLE pattern. Upon detection of a received event from one port, the repeater set shall repeat all received signals in the data frame from that port to the other ports as described in Figure 41–2.

41.2.1.3.2 Preamble regeneration

The repeater set shall output preamble as appropriate for the outgoing PHY type followed by the SFD. The duration of the output preamble shall not vary more than 8 bit times from the duration of the received preamble.

41.2.1.3.3 Start-of-packet propagation delay

The start-of-packet propagation delay for a repeater set is the time delay between the start of a received event on a repeated-from (input) port to the start of transmit on the repeated-to (output) port (or ports). This parameter is referred to as the SOP delay, and is measured at the MDI of the repeater ports. The maximum value of this delay is constrained such that the sum of the SOP delay and SOJ delay shall not exceed the value specified in 41.2.1.4.3.

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41.2.1.3.4 Start-of-packet variability

The start-of-packet variability for a repeater set is defined as the total worst-case difference between start-of-packet propagation delays for successive received events separated by 112 bit times or less at the same input port. The variability shall be less than or equal to 16 bit times.

41.2.1.4 Collision-handling functional requirements

41.2.1.4.1 Collision detection

The repeater performs collision detection by monitoring all its enabled input ports for received events. When the repeater detects received events on more than one input port, it shall enter a collision state and transmit the Jam message to all of its output ports.

41.2.1.4.2 Jam generation

While a collision is occurring between any of its ports, the repeater unit shall transmit the Jam message to all of the ports. The Jam message shall be transmitted in accordance with the repeater state diagram in Figure 41–2. The Jam message is signalled across the GMII using the Transmit Error Propagation encoding if the collision is detected during Normal Data Transmission, or using the Carrier Extend Error encoding if the collision is detected during Carrier Extension.

41.2.1.4.3 Start-of-collision-jam propagation delay

The start-of-collision Jam propagation delay for a repeater set is the time delay between the start of the second received event (that results in a collision) to arrive at its port and the start of Jam out on all ports. This parameter is referred to as the SOJ delay, and is measured at the MDI of the repeater ports. The sum of the SOP delay and SOJ delay shall not exceed 976 bit times (BT).

41.2.1.4.4 Cessation-of-collision Jam propagation delay

The cessation-of-collision Jam propagation delay for a repeater set is the time delay between the end of the received event that creates a state such that Jam should end at a port and the end of Jam at that port. The states of the input signals that should cause Jam to end are covered in detail in the repeater state diagram in Figure 41–2. This parameter is referred to as the EOJ delay. This delay shall not exceed the SOP delay.

41.2.1.5 Error-handling functional requirements

41.2.1.5.1 Carrier integrity functional requirements

It is desirable that the repeater set protect the network from some transient fault conditions that would disrupt network communications. Potential likely causes of such conditions are DTE and repeater power-up and power-down transients, cable disconnects, and faulty wiring.

The repeater unit shall provide a self-interrupt capability at each port, as described in Figure 41–5, to prevent a segment's spurious carrier activity from propagating through the network.

At each port the repeater shall count consecutive false carrier events signalled across the GMII. The count shall be incremented on each false carrier event and shall be reset on reception of a valid carrier event. In addition, each port shall have a false carrier timer, which is enabled at the beginning of a false carrier event and reset at the conclusion of such an event. A repeater unit shall transmit the Jam signals to all ports for the duration of the false carrier event or until the duration of the event exceeds the time specified by the false_carrier_timer (see 41.2.2.1.4), whichever is shorter. The Jam message shall be transmitted in accordance with the repeater state diagram in Figure 41–2. The LINK UNSTABLE condition shall be

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detected when the False Carrier Event Count equals the value FCELimit (see 41.2.2.1.1) or the duration of a false carrier event exceeds the time specified by the false_carrier_timer. In addition, the LINK UNSTABLE condition shall be detected upon power-up reset.

Upon detection of LINK UNSTABLE at a port, the repeater unit shall perform the following:

a) Inhibit sending further messages from that port to the repeater unit.
b) Inhibit sending further output messages to that port from the repeater unit.
c) Continue to monitor activity on that port.

The repeater unit shall exit the LINK UNSTABLE condition at the port when one of the following is met:

a) The repeater has detected no activity (Idle) for more than the time specified by ipg_timer plus idle_timer (see 41.2.2.1.4) on port X.
b) A valid carrier event with a duration greater than the time specified by valid_carrier_timer (see 41.2.2.1.4) has been received, preceded by no activity (Idle) for more than the time specified by ipg_timer (see 41.2.2.1.4) on port X.

The false_carrier_timer duration is longer than the maximum round-trip latency from a repeater to a DTE, but less than a slot time. This allows a properly functioning DTE to respond to the Jam message by detecting collision and terminating the transmission prior to the expiration of the timer. The upper limit on the false_carrier_timer prevents the Jam message from exceeding the maximum fragment size.

The combination of the ipg_timer, idle_timer, and valid_carrier_timer filter transient activity that can occur on a link during power cycles or mechanical connection. The duration of the ipg_timer is greater than two-thirds of the minimum IPG, and less than the minimum IPG less some shrinkage. The idle_timer is specified as approximately 320 µs based upon empirical data on such transients. The valid_carrier_timer duration is less than the duration of a minimum valid carrier event, but long enough to filter most spurious carrier events (note that there can be no valid collision fragments on an isolated link in a single repeater topology). The range of the valid_carrier_timer is specified to be the same as the false_carrier_timer range for the convenience of implementations.

41.2.1.5.2 Speed handling

If the PHY has the capability of detecting speeds other than 1000 Mb/s, then the repeater set shall have the capability of blocking the flow of non-1000 Mb/s signals. The incorporation of 1000 Mb/s and 100 Mb/s or 10 Mb/s repeater functionality within a single repeater set is beyond the scope of this standard.

41.2.1.6 Partition functional requirements

It is desirable that the repeater set protect the network from some fault conditions that would disrupt network communications. A potentially likely cause of this condition could be due to a cable fault.

The repeater unit shall provide a self-interrupt capability at each port, as described in Figure 41–4, to prevent a faulty segment's carrier activity from propagating through the network. The repeater unit shall count consecutive collision events at each port. The count shall be incremented on each transmission that suffers a collision and shall be reset on a successful transmission or reception. If this count equals or exceeds the value CELimit (see 41.2.2.1.1), the Partition condition shall be detected. In addition, the partition condition shall be detected due to a carrier event of duration in excess of jabber_timer in which a collision has occurred.

Upon detection of Partition at a port, the repeater unit shall perform the following:

a) Inhibit sending further input messages from that port to the repeater unit.

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b) Continue to output messages to that port from the repeater unit.
c) Continue to monitor activity on that port.

The repeater unit shall reset the Partition function at the port when one of the following conditions is met:

— On power-up reset.
— The repeater has detected activity on the port for more than the number of bits specified for no_collision_timer (see 41.2.2.1.4) without incurring a collision.
— The repeater has transmitted on the port for more than the number of bits specified for no_collision_timer (see 41.2.2.1.4) without incurring a collision.

The no_collision_timer duration is longer than the maximum round-trip latency from a repeater to a DTE (maximum time required for a repeater to detect a collision), and less than the minimum valid carrier event duration (slot time plus header_size minus preamble shrinkage).

41.2.1.7 Receive jabber functional requirements

The repeater unit shall provide a self-interrupt capability at each port, as described in Figure 41–3, to prevent an illegally long reception of data from propagating through the network. The repeater unit shall provide a window of duration jabber_timer bit times (see 41.2.2.1.4) during which the input messages from a port may be passed on to other repeater unit functions. If a reception exceeds this duration, the jabber condition shall be detected.

Upon detection of the jabber condition at a port, the repeater unit shall perform the following:

a) Inhibit sending further input messages from that port to the repeater unit.
b) Inhibit sending further output messages to that port from the repeater unit.

The repeater shall reset the Jabber function at the port, and re-enable data transmission and reception, when either one of the following conditions is met:

— On power-up reset.
— When carrier is no longer detected at that port.

The lower bound of the jabber_timer is longer than the carrier event of a maximum length burst. The upper bound is large enough to permit a wide variety of implementations.

41.2.2 Detailed repeater functions and state diagrams

A precise algorithmic definition is given in this subclause, providing a complete procedural model for the operation of a repeater, in the form of state diagrams. Note that whenever there is any apparent ambiguity concerning the definition of repeater operation, the state diagrams should be consulted for the definitive statement.

The model presented in this subclause is intended as a primary specification of the functions to be provided by any repeater unit. It is important to distinguish, however, between the model and a real implementation. The model is optimized for simplicity and clarity of presentation, while any realistic implementation should place heavier emphasis on such constraints as efficiency and suitability to a particular implementation technology.

It is the functional behavior of any repeater set implementation that is expected to match the standard, not the internal structure. The internal details of the procedural model are useful only to the extent that they help specify the external behavior clearly and precisely. For example, the model uses a separate Receive Port Jabber state diagram for each port. However, in actual implementation, the hardware may be shared.

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The notation used in the state diagram follows the conventions of 1.2.1. Note that transitions shown without source states are evaluated at the completion of every state and take precedence over other transition conditions.

41.2.2.1 State diagram variables

41.2.2.1.1 Constants

CELimit

The number of consecutive Collision Events that must occur before a segment is partitioned.

Values: Positive integer greater than 60.

FCELimit

The number of consecutive False Carrier Events that must occur before a segment is isolated.

Value: 2.

41.2.2.1.2 Variables

begin

The Interprocess flag controlling state diagram initialization values.

Values: true
false

CRS(X), RXD(X), RX_DV(X), RX_ER(X), TXD(X), TX_EN(X), TX_ER(X)

GMII signals received from or sent to the PHY at port X (see Clause 35). The repeater_mode variable in the PHY is set to ensure that the CRS(X) signal is asserted in response to receive activity only.

RXERROR(X)

A combination of the GMII signal encodings indicating that the PHY has detected a Data Error, Carrier Extend Error, or False Carrier Error.

Value: RXERROR(X) ⇐ ((RX_ER(X) = true) *
((RX_DV(X) = true) + (RXD(X) = FalseCarrier) + (RXD(X) = CarrierExtendError)))

TX(X)

A combination of the GMII signal encodings indicating that port X is transmitting a frame.

Value: TX(X) ⇐ ((TX_EN(X) = true) + (TX_ER(X) = true))

isolate(X)

Flag from Carrier Integrity state diagram for port X, which determines whether a port should be enabled or disabled.

Values: true; the Carrier Integrity Monitor has determined the port should be disabled.
false; the Carrier Integrity Monitor has determined the port should be enabled.

force_jam(X)

Flag from Carrier Integrity state diagram for port X, which causes the Repeater Unit to enter the Jam state.

Values: true; the port is in the False Carrier state.
false; the port is not in the False Carrier state.

jabber(X)

Flag from Receive Timer state diagram for port X which indicates that the port has received

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excessive length activity.

Values: true; port has exceeded the continuous activity limit.
false; port has not exceeded the continuous activity limit.

link_status(X)

Indication from the Auto-Negotiation process (Clauses 28 and 37) that Auto-Negotiation has completed and the priority resolution function has determined that the link will be operated in half duplex mode.

Values: OK; the link is operational in half duplex mode.
FAIL; the link is not operational in half duplex mode.

partition(X)

Flag from Partition state diagram for port X, which determines whether a port receive path should be enabled or disabled.

Values: true; port has exceeded the consecutive collision limit.
false; port has not exceeded the consecutive collision limit.

41.2.2.1.3 Functions

port(Test)

A function that returns the designation of a port passing the test condition. For example, port(CRS = true) returns the designation: X for a port for which CRS is asserted. If multiple ports meet the test condition, the Port function will be assigned one and only one of the acceptable values.

41.2.2.1.4 Timers

All timers operate in the same fashion. A timer is reset and starts timing upon entering a state where "start x_timer" is asserted. At time "x" after the timer has been started, "x_timer_done" is asserted and remains asserted until the timer is reset. At all other times, "x_timer_not_done" is asserted.

When entering a state where "start x_timer" is asserted, the timer is reset and restarted even if the entered state is the same as the exited state.

The timers used in the repeater state diagrams are defined as follows:

false_carrier_timer

Timer for length of false carrier (41.2.1.5.1) that must be present to set isolate(X) to true. The timer is done when it reaches 3600–4000 BT.

idle_timer

Timer for length of time without carrier activity that must be present to set isolate(X) to false. The timer is done when it reaches 240 000–400 000 BT.

ipg_timer

Timer for length of time without carrier activity that must be present before carrier integrity tests (41.2.1.5.1) are re-enabled. The timer is done when it reaches 64–86 BT.

jabber_timer

Timer for length of carrier which must be present before the Jabber state is entered (41.2.1.7). The timer is done when it reaches 80 000–150 000 BT.

no_collision_timer

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Timer for length of packet without collision before partition(X) is set to false (41.2.1.6). The timer is done when it reaches 3600–4144 BT.

valid_carrier_timer

Timer for length of valid carrier that must be present to cause isolate(X) to be set to false at the end of the carrier event. The timer is done when it reaches 3600–4000 BT.

41.2.2.1.5 Counters

CE(X)

Consecutive port Collision Event count for port X. Partitioning occurs on a terminal count of CELimit being reached.

Values: Non-negative integers up to a terminal count of CELimit.

FCE(X)

False Carrier Event count for port X. Isolation occurs on a terminal count of FCELimit being reached.

Values: Non-negative integers up to a terminal count of FCELimit.

41.2.2.1.6 Port designation

Ports are referred to by number. Port information is obtained by replacing the X in the desired function with the number of the port of interest. Ports are referred to in general as follows:

X

Generic port designator. When X is used in a state diagram, its value is local to that diagram and not global to the set of state diagrams.

N

Identifies the port that caused the exit from the IDLE or JAM states of Figure 41–2. The value is assigned in the term assignment statement on the transition out of these states (see 1.2.1 for State Diagram Conventions).

ALL

Indicates all repeater ports are to be considered. The test passes when all ports meet the test conditions.

ALLXJIPN

The test passes when all ports, excluding those indicated by J, I, P, or N, meet the test conditions. One or more of the J, I, P, or N indications are used to exclude from the test ports with Jabber = true, Isolate = true, Partition = true, or port N, respectively.

ANY

Indicates all ports are to be considered. The test passes when one or more ports meet the test conditions.

ANYXJIPN

The test passes when one or more ports, excluding those indicated by J, I, P, or N, meet the test conditions. One or more of the J, I, P, or N indications are used to exclude from the test ports with Jabber = true, Isolate = true, Partition = true, or port N, respectively.

ONLY1

Indicates all ports except those with Jabber = true, Isolate = true, or Partition = true are to be considered. The test passes when one and only one port meet the test conditions.

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41.2.2.2 State diagrams

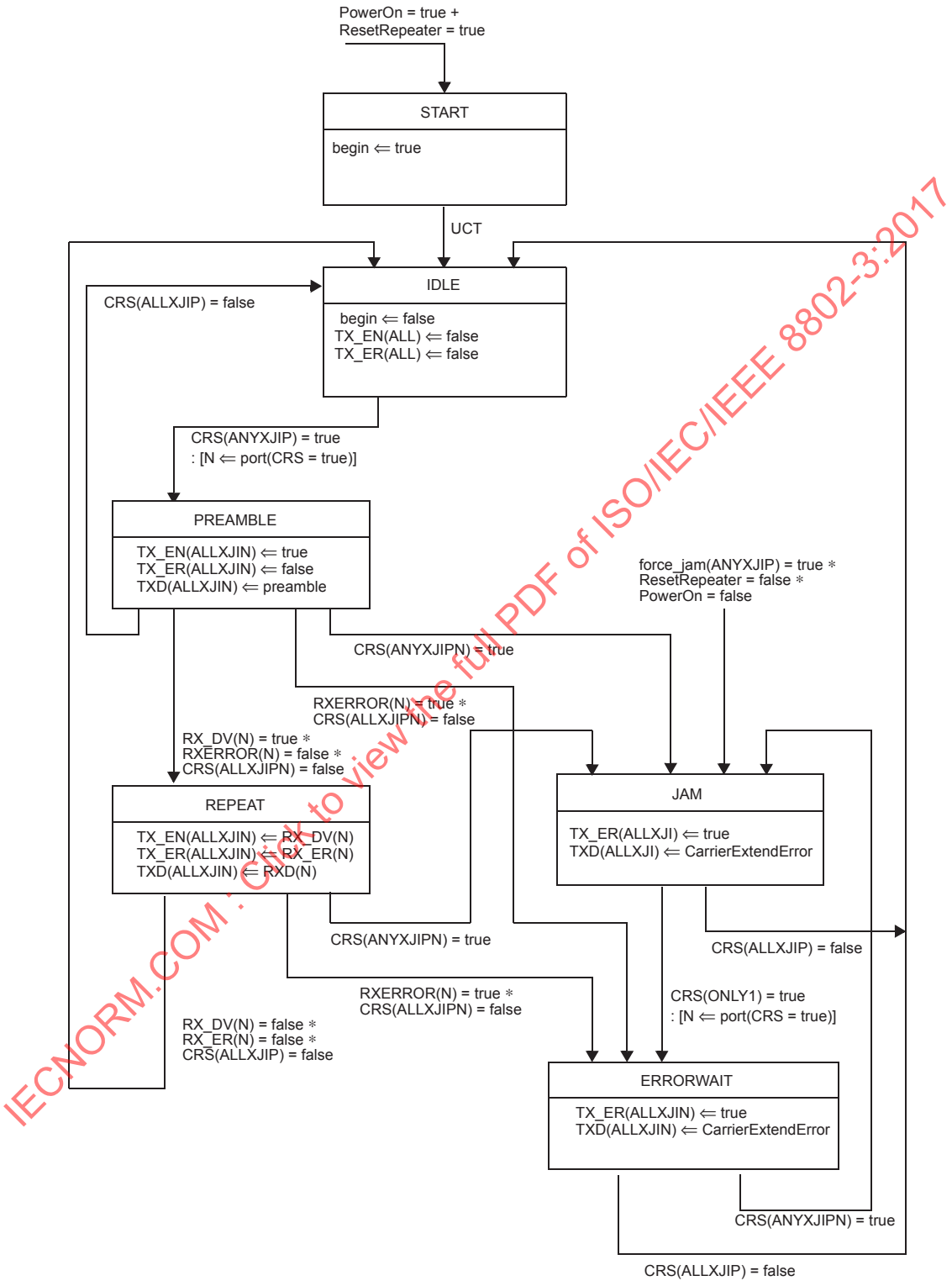

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Figure 41–2—Repeater unit state diagram

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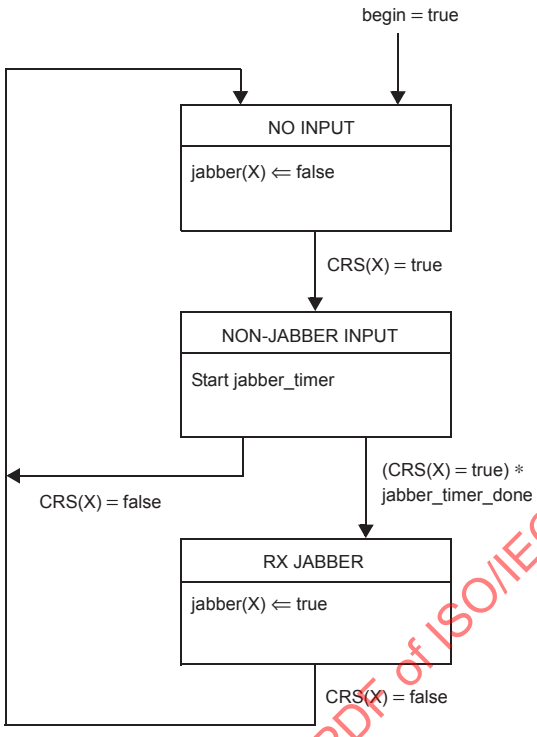

Figure 41–3—Receive timer state diagram for port X

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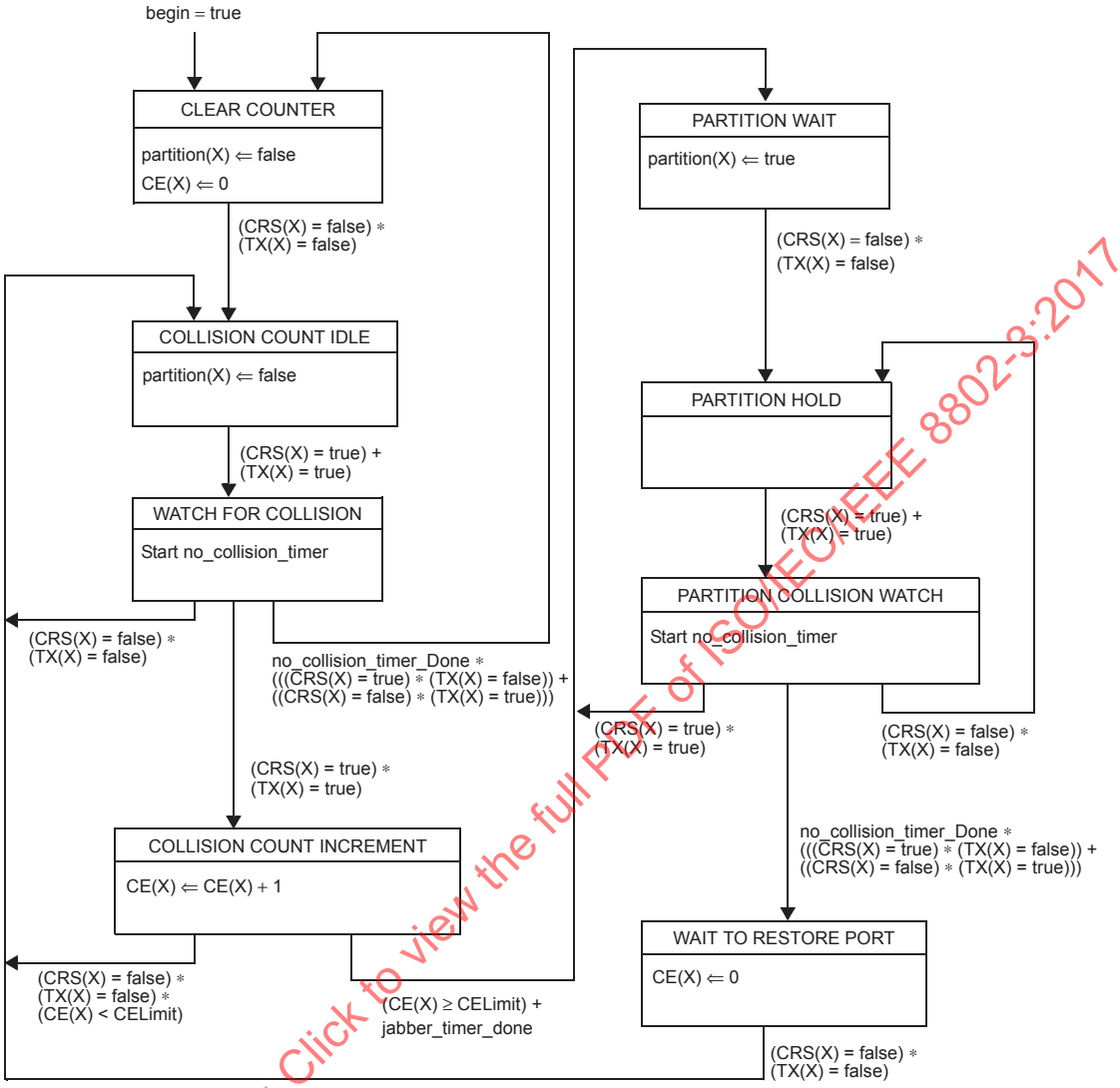

Figure 41–4—Partition state diagram for port X

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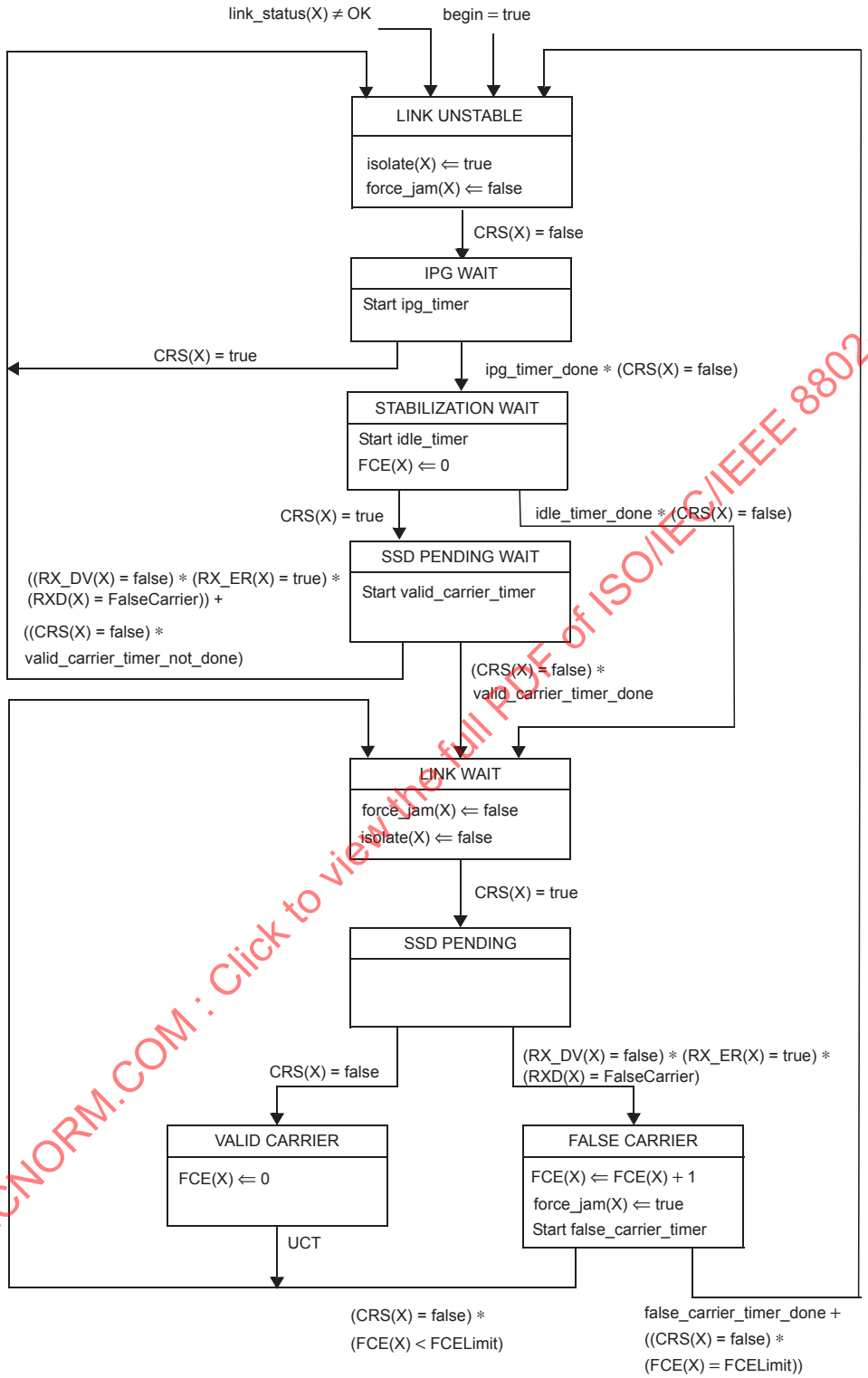

Figure 41–5—Carrier integrity monitor state diagram for port X

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41.3 Repeater electrical specifications

41.3.1 Electrical isolation

Network segments that have different isolation and grounding requirements shall have those requirements provided by the port-to-port isolation of the repeater set.

41.4 Environmental specifications

41.4.1 General safety

All equipment meeting this standard shall conform to IEC 60950: 1991.

41.4.2 Network safety

This subclause sets forth a number of recommendations and guidelines related to safety concerns; the list is neither complete nor does it address all possible safety issues. The designer is urged to consult the relevant local, national, and international safety regulations to ensure compliance with the appropriate requirements.

LAN cable systems described in this subclause are subject to at least four direct electrical safety hazards during their installation and use. These hazards are as follows:

a) Direct contact between LAN components and power, lighting, or communications circuits.
b) Static charge buildup on LAN cables and components.
c) High-energy transients coupled onto the LAN cable system.
d) Voltage potential differences between safety grounds to which the various LAN components are connected.

Such electrical safety hazards must be avoided or appropriately protected against for proper network installation and performance. In addition to provisions for proper handling of these conditions in an operational system, special measures must be taken to ensure that the intended safety features are not negated during installation of a new network or during modification or maintenance of an existing network. Isolation requirements are defined in 41.4.3.

41.4.2.1 Installation

Sound installation practice, as defined by applicable local codes and regulations, shall be followed in every instance in which such practice is applicable.

41.4.2.2 Grounding

The safety ground, or chassis ground for the repeater set, shall be provided through the main ac power cord via the third wire ground as defined by applicable local codes and regulations.

If the MDI connector should provide a shield connection, the shield may be connected to the repeater safety ground. A network segment connected to the repeater set through the MDI may use a shield. If both ends of the network segment have a shielded MDI connector available, then the shield may be grounded at both ends according to local regulations and ISO/IEC 11801: 1995, and as long as the ground potential difference between both ends of the network segment is less than 1 V rms.

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WARNING

It is assumed that the equipment to which the repeater is attached is properly grounded and not left floating nor serviced by a "doubly insulated ac power distribution system." The use of floating or insulated equipment, and the consequent implications for safety, are beyond the scope of this standard.

41.4.2.3 Installation and maintenance guidelines

During installation and maintenance of the cable plant, care should be taken to ensure that uninsulated network cable connectors do not make electrical contact with unintended conductors or ground.

41.4.3 Electrical isolation

There are two electrical power distribution environments to be considered that require different electrical isolation properties:

a) *Environment A.* When a LAN or LAN segment, with all its associated interconnected equipment, is entirely contained within a single low-voltage power distribution system and within a single building.
b) *Environment B.* When a LAN crosses the boundary between separate power distribution systems or the boundary of a single building.

41.4.3.1 Environment A requirements

Attachment of network segments via repeater sets requires electrical isolation of 500 V rms, one-minute withstand, between the segment and the protective ground of the repeater unit.

41.4.3.2 Environment B requirements

The attachment of network segments that cross environment B boundaries requires electrical isolation of 1500 Vrms, one-minute withstand, between each segment and all other attached segments and also the protective ground of the repeater unit.

The requirements for interconnected electrically conducting LAN segments that are partially or fully external to a single building environment may require additional protection against lightning strike hazards. Such requirements are beyond the scope of this standard. It is recommended that the above situation be handled by the use of nonelectrically conducting segments (e.g., fiber optic).

It is assumed that any nonelectrically conducting segments will provide sufficient isolation within that media to satisfy the isolation requirements of environment B.

41.4.4 Reliability

A two-port repeater set shall be designed to provide a mean time between failure (MTBF) of at least 50 000 hours of continuous operation without causing a communications failure among stations attached to the network medium. Repeater sets with more than two ports shall add no more than 3.46×10^{-6} failures per hour for each additional port.

The repeater set electronics should be designed to minimize the probability of component failures within the repeater electronics that prevent communications among other PHYs on the individual segments. Connectors and other passive components comprising the means of connecting the repeater to the cable should be designed to minimize the probability of total network failure.

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41.4.5 Environment

41.4.5.1 Electromagnetic emission

The repeater shall comply with applicable local and national codes for the limitation of electromagnetic interference.

41.4.5.2 Temperature and humidity

The repeater is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

It is recommended that manufacturers indicate in the literature associated with the repeater the operating environmental conditions to facilitate selection, installation, and maintenance.

41.5 Repeater labeling

It is required that each repeater (and supporting documentation) shall be labeled in a manner visible to the user with these parameters:

a) Crossover ports appropriate to the respective PHY shall be marked with an X.

Additionally it is recommended that each repeater (and supporting documentation) also be labeled in a manner visible to the user with at least these parameters:

b) Data rate capability in Mb/s
c) Any applicable safety warnings
d) Port type, i.e., 1000BASE-CX, 1000BASE-SX, 1000BASE-LX, and 1000BASE-T
e) Worst-case bit time delays between any two ports appropriate for
    1) Start-of-packet propagation delay
    2) Start-of-collision Jam propagation delay
    3) Cessation-of-collision Jam propagation delay

41.6 Protocol implementation conformance statement (PICS) proforma for Clause 41, Repeater for 1000 Mb/s baseband networks[12]

41.6.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 41, Repeater for 1000 Mb/s baseband networks, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

[12]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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41.6.2 Identification

41.6.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

41.6.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 41, Repeater for 1000 Mb/s baseband networks
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	

Date of Statement	

41.6.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*SXP	Repeater supports 1000BASE-SX connections	41.1.2.2		O	Yes [ ] No [ ]
*LXP	Repeater supports 1000BASE-LX connections	41.1.2.2		O	Yes [ ] No [ ]
*CXP	Repeater supports 1000BASE-CX connections	41.1.2.2		O	Yes [ ] No [ ]
*TP	Repeater supports 1000BASE-T connections	41.1.2.2		O	Yes [ ] No [ ]
*PHYS	PHYs capable of detecting non 1000 Mb/s signals	41.2.1.5.2		O	Yes [ ] No [ ]

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In addition, the following predicate name is defined for use when different implementations from the set above have common parameters:

*XP:SXP or LXP or CXP

41.6.4 PICS proforma tables for the Repeater for 1000 Mb/s baseband networks

41.6.4.1 Compatibility considerations

Item	Feature	Subclause	Value/Comment	Status	Support
CC1	1000BASE-SX port compatible at the MDI	41.1.2.2		SXP:M	Yes [ ] N/A [ ]
CC2	1000BASE-LX port compatible at the MDI	41.1.2.2		LXP:M	Yes [ ] N/A [ ]
CC3	1000BASE-CX port compatible at the MDI	41.1.2.2		CXP:M	Yes [ ] N/A [ ]
CC4	1000BASE-T port compatible at the MDI	41.1.2.2		TP:M	Yes [ ] N/A [ ]
CC5	Internal segment compatibility	41.1.2.2.1	Internal port meets Clause 30 when repeater management implemented	M	Yes [ ]

41.6.4.2 Repeater functions

Item	Feature	Subclause	Value/Comment	Status	Support
RF1	Signal Restoration	41.2.1		M	Yes [ ]
RF2	Data Handling	41.2.1		M	Yes [ ]
RF3	Received Event Handling	41.2.1		M	Yes [ ]
RF4	Collision Handling	41.2.1		M	Yes [ ]
RF5	Error Handling	41.2.1		M	Yes [ ]
RF6	Partition	41.2.1		M	Yes [ ]
RF7	Received Jabber	41.2.1		M	Yes [ ]
RF8	Transmit	41.2.1		M	Yes [ ]
RF9	Receive	41.2.1		M	Yes [ ]

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41.6.4.3 Signal restoration function

Item	Feature	Subclause	Value/Comment	Status	Support
SR1	Output amplitude as required by 1000BASE-SX	41.2.1.1.1		SXP:M	Yes [ ] N/A [ ]
SR2	Output amplitude as required by 1000BASE-LX	41.2.1.1.1		LXP:M	Yes [ ] N/A [ ]
SR3	Output amplitude as required by 1000BASE-CX	41.2.1.1.1		CXP:M	Yes [ ] N/A [ ]
SR4	Output amplitude as required by 1000BASE-T	41.2.1.1.1		TP:M	Yes [ ] N/A [ ]
SR5	Output signal wave-shape as required by 1000BASE-SX	41.2.1.1.2		SXP:M	Yes [ ] N/A [ ]
SR6	Output signal wave-shape as required by 1000BASE-LX	41.2.1.1.2		LXP:M	Yes [ ] N/A [ ]
SR7	Output signal wave-shape as required by 1000BASE-CX	41.2.1.1.2		CXP:M	Yes [ ] N/A [ ]
SR8	Output signal wave-shape as required by 1000BASE-T	41.2.1.1.2		TP:M	Yes [ ] N/A [ ]
SR9	Output data timing as required by 1000BASE-SX	41.2.1.1.3		SXP:M	Yes [ ] N/A [ ]
SR10	Output data timing as required by 1000BASE-LX	41.2.1.1.3		LXP:M	Yes [ ] N/A [ ]
SR11	Output data timing as required by 1000BASE-CX	41.2.1.1.3		CXP:M	Yes [ ] N/A [ ]
SR12	Output data timing as required by 1000BASE-T	41.2.1.1.3		TP:M	Yes [ ] N/A [ ]

41.6.4.4 Data-Handling function

Item	Feature	Subclause	Value/Comment	Status	Support
DH1	Data frames forwarded to all ports except receiving port	41.2.1.2.1		M	Yes [ ]
DH2	Code Violations forwarded to all transmitting ports	41.2.1.2.2		M	Yes [ ]
DH3	Received Code Violation forwarded as code-group explicitly indicating received error	41.2.1.2.2		M	Yes [ ]
DH4	Code element substitution for remainder of packet after received Code Violation	41.2.1.2.2		M	Yes [ ]

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41.6.4.5 Receive Event-Handling function

Item	Feature	Subclause	Value/Comment	Status	Support
RE1	Detect all received events	41.2.1.3.1		M	Yes [ ]
RE2	Repeat all received signals	41.2.1.3.1		M	Yes [ ]
RE3	Preamble repeated as required	41.2.1.3.2		M	Yes [ ]
RE4	Start-of-packet propagation delay	41.2.1.3.3	SOP + SOJ ≤ 976 BT	M	Yes [ ]
RE5	Start-of-packet variability	41.2.1.3.4	SOP variation ≤ 16 BT	M	Yes [ ]
RE6	PHY repeater_mode variable	41.2.1.3.1	Shall be set to ensure CRS signal not asserted in response to transmit activity	M	Yes [ ]
RE7	Output preamble variation	41.2.1.3.2	Variation between received and transmitted preamble ≤ 8 BT	M	Yes [ ]

41.6.4.6 Collision-Handling function

Item	Feature	Subclause	Value/Comment	Status	Support
CO1	Collision Detection	41.2.1.4.1	Receive event on more than one port	M	Yes [ ]
CO2	Jam Generation	41.2.1.4.2	Transmit Jam message while collision is detected	M	Yes [ ]
CO3	Collision-Jam Propagation delay	41.2.1.4.3	SOP + SOJ ≤ 976 BT	M	Yes [ ]
CO4	Cessation of Collision Propagation delay	41.2.1.4.4	EOJ ≤ SOP	M	Yes [ ]

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41.6.4.7 Error-Handling function

Item	Feature	Subclause	Value/Comment	Status	Support
EH1	Carrier Integrity function implementation	41.2.1.5.1	Self-interrupt of data reception	M	Yes [ ]
EH2	False Carrier Event count for Link Unstable detection	41.2.1.5.1	False Carrier Event count equals FCELimit	M	Yes [ ]
EH3	False carrier count reset	41.2.1.5.1	Count reset on valid carrier	M	Yes [ ]
EH4	False carrier timer for Link Unstable detection	41.2.1.5.1	False carrier of length in excess of false_carrier_timer	M	Yes [ ]
EH5	Jam message duration	41.2.1.5.1	Equals duration of false carrier event, but not greater than duration of false_carrier_timer	M	Yes [ ]
EH6	Link Unstable detection	41.2.1.5.1	False Carrier Event count equals FCELimit or False carrier exceeds the false_carrier_timer or power-up reset	M	Yes [ ]
EH7	Messages sent to repeater unit in Link Unstable state	41.2.1.5.1	Inhibited sending messages to repeater unit	M	Yes [ ]
EH8	Messages sent from repeater unit in Link Unstable state	41.2.1.5.1	Inhibited sending output messages	M	Yes [ ]
EH9	Monitoring activity on a port in Link Unstable state	41.2.1.5.1	Continue monitoring activity at that port	M	Yes [ ]
EH10	Reset of Link Unstable state	41.2.1.5.1	No activity for more than ipg_-timer plus idle_timer or Valid carrier event of duration greater than valid_carrier_-timer preceded by Idle of duration greater than ipg_timer	M	Yes [ ]
EH11	Block flow of non-1000 Mb/s signals	41.2.1.5.2		M	Yes [ ]

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41.6.4.8 Partition function

Item	Feature	Subclause	Value/Comment	Status	Support
PA1	Partition function implementation	41.2.1.6	Self-interrupt of data reception	M	Yes [ ]
PA2	Consecutive Collision Event count for entry into partition state	41.2.1.6	Consecutive Collision Event count equals or exceeds CELimit	M	Yes [ ]
PA3	Excessive receive duration with collision for entry into partition state.	41.2.1.6	Reception duration in excess of jabber_timer with collision	M	Yes [ ]
PA4	Consecutive Collision Event counter incrementing	41.2.1.6	Count incremented on each transmission that suffers a collision	M	Yes [ ]
PA5	Consecutive Collision Event counter reset	41.2.1.6	Count reset on successful transmission or reception	M	Yes [ ]
PA6	Messages sent to repeater unit in Partition state	41.2.1.6	Inhibited sending messages to repeater unit	M	Yes [ ]
PA7	Messages sent from repeater unit in Partition state	41.2.1.6	Continue sending output messages	M	Yes [ ]
PA8	Monitoring activity on a port in Partition state	41.2.1.6	Continue monitoring activity at that port	M	Yes [ ]
PA9	Reset of Partition state	41.2.1.6	Power-up reset or transmitting or detecting activity for greater than duration no_collision_-timer without a collision	M	Yes [ ]

41.6.4.9 Receive Jabber function

Item	Feature	Subclause	Value/Comment	Status	Support
RJ1	Receive Jabber function implementation	41.2.1.7	Self-interrupt of data reception	M	Yes [ ]
RJ2	Excessive receive duration timer for Receive Jabber detection	41.2.1.7	Reception duration in excess of jabber_timer	M	Yes [ ]
RJ3	Messages sent to repeater unit in Receive Jabber state	41.2.1.7	Inhibit sending input messages to repeater unit	M	Yes [ ]
RJ4	Messages sent from repeater unit in Receive Jabber state	41.2.1.7	Inhibit sending output mes-sages	M	Yes [ ]
RJ5	Reset of Receive Jabber state	41.2.1.7	Power-up reset or Carrier no longer detected	M	Yes [ ]

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41.6.4.10 Repeater state diagrams

Item	Feature	Subclause	Value/Comment	Status	Support
SD1	Repeater unit state diagram	41.2.2.2	Meets the requirements of Figure 41–2	M	Yes [ ]
SD2	Receive timer for port X state diagram	41.2.2.2	Meets the requirements of Figure 41–3	M	Yes [ ]
SD3	Repeater partition state diagram for port X	41.2.2.2	Meets the requirements of Figure 41–4	M	Yes [ ]
SD4	Carrier integrity monitor for port X state diagram	41.2.2.2	Meets the requirements of Figure 41–5	M	Yes [ ]

41.6.4.11 Repeater electrical

Item	Feature	Subclause	Value/Comment	Status	Support
EL1	Port-to-port isolation	41.3.1	Satisfies isolation and grounding requirements for attached network segments	M	Yes [ ]
EL2	Safety	41.4.1	IEC 60950:1991	M	Yes [ ]
EL3	Installation practices	41.4.2.1	Sound, as defined by local code and regulations	M	Yes [ ]
EL4	Grounding	41.4.2.2	Chassis ground provided through ac mains cord	M	Yes [ ]
EL5	Two-port repeater set MTBF	41.4.4	At least 50 000 hours	M	Yes [ ]
EL6	Additional port effect on MTBF	41.4.4	No more than 3.46×10^{-6} increase in failures per hour	M	Yes [ ]
EL7	Electromagnetic interference	41.4.5.1	Comply with local or national codes	M	Yes [ ]

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41.6.4.12 Repeater labeling

Item	Feature	Subclause	Value/Comment	Status	Support
LB1	Crossover ports	41.5	Marked with an X	M	Yes [ ]
LB2	Data Rate	41.5	1000 Mb/s	O	Yes [ ] No [ ]
LB3	Safety warnings	41.5	Any applicable	O	Yes [ ] No [ ]
LB4	Port Types	41.5	1000BASE-SX, 1000BASE-LX, 1000BASE-CX, or 1000BASE-T	O	Yes [ ] No [ ]
LB5	Worse-case start-of-packet propagation delay	41.5	Value in bit times (BT)	O	Yes [ ] No [ ]
LB6	Worse-case start-of-collision-Jam propagation delay	41.5	Value in BT	O	Yes [ ] No [ ]
LB7	Worse-case Cessation-of-Collision Jam propagation delay	41.5	Value in BT	O	Yes [ ] No [ ]

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42. System considerations for multisegment 1000 Mb/s networks

42.1 Overview

This clause provides information on building 1000 Mb/s networks. The 1000 Mb/s technology is designed to be deployed in both homogenous 1000 Mb/s networks and 10/100/1000 Mb/s mixed networks using bridges and/or routers. Network topologies can be developed within a single 1000 Mb/s collision domain, but maximum flexibility is achieved by designing multiple collision domain networks that are joined by bridges and/or routers configured to provide a range of service levels to DTEs. For example, a combined 1000BASE-T/100BASE-T/10BASE-T system built with repeaters and bridges can deliver dedicated or shared service to DTEs at 1000 Mb/s, 100 Mb/s, or 10 Mb/s.

Linking multiple collision domains with bridges maximizes flexibility. Bridged topology designs can provide single data rate (Figure 42–1) or multiple data rate (Figure 42–2) services.

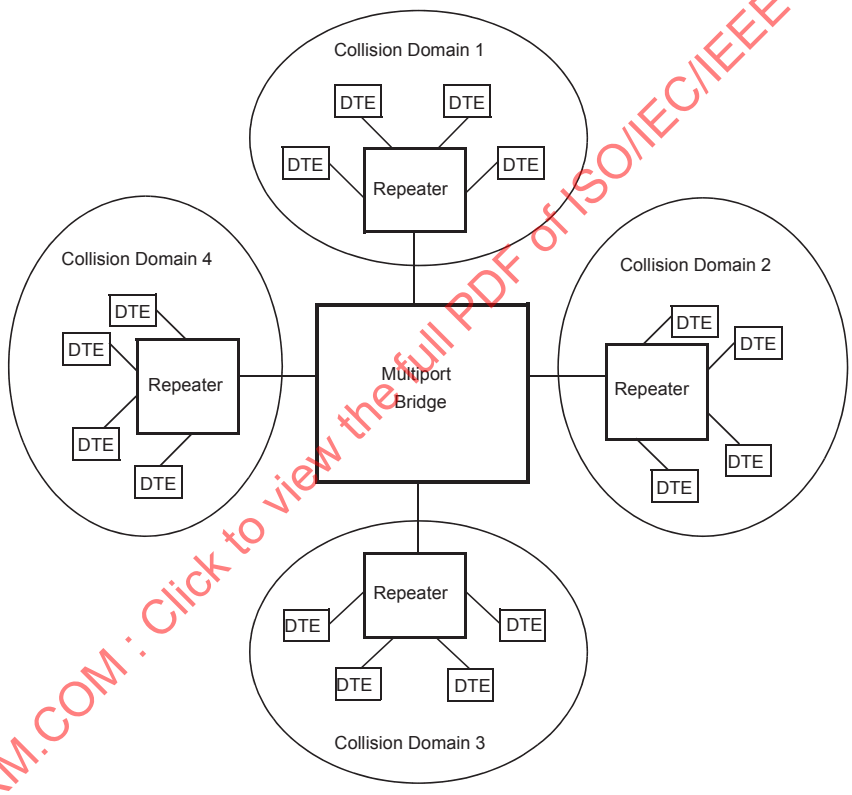

Figure 42–1—1000 Mb/s multiple collision domain topology using multiport bridge

Individual collision domains can be linked by single devices (as shown in Figure 42–1 and Figure 42–2) or by multiple devices from any of several transmission systems. The design of multiple-collision-domain networks is governed by the rules defining each of the transmission systems incorporated into the design.

The design of shared bandwidth 10 Mb/s collision domains is defined in Clause 13; the design of shared bandwidth 100 Mb/s CSMA/CD collision domains is defined in Clause 29; the design of shared bandwidth 1000 Mb/s CSMA/CD collision domains is defined in the following subclauses.

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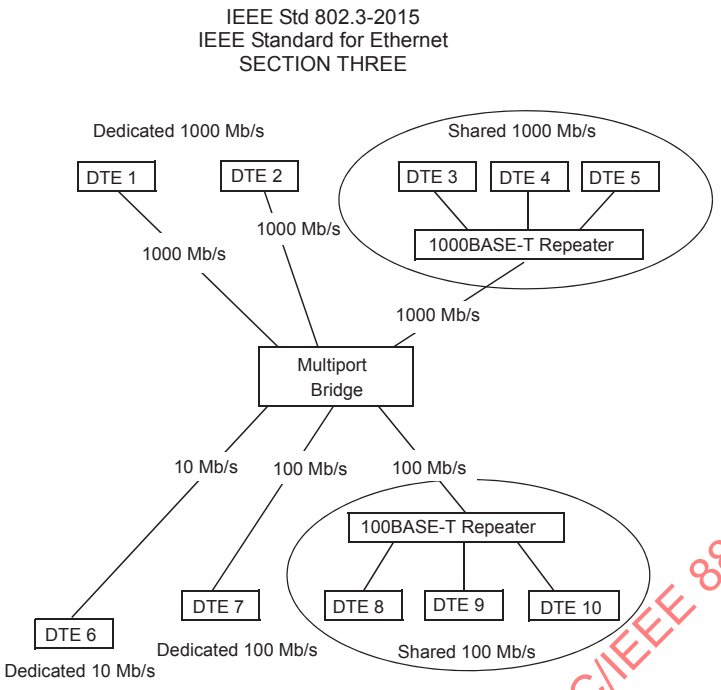

Figure 42–2—Multiple data rate, multiple collision domain topology using multiport bridge

42.1.1 Single collision domain multisegment networks

This clause provides information on building 1000 Mb/s CSMA/CD multisegment networks within a single collision domain. The proper operation of a CSMA/CD network requires the physical size of the collision domain to be limited in order to meet the round-trip propagation delay requirements of 4.2.3.2.3 and 4.4.2, and requires the number of repeaters to be limited to one so as not to exceed the InterFrameGap shrinkage noted in 4.4.2.

This clause provides two network models. Transmission System Model 1 is a set of configurations that have been validated under conservative rules and have been qualified as meeting the requirements set forth above. Transmission System Model 2 is a set of calculation aids that allow those configuring a network to test a proposed configuration against a simple set of criteria that allows it to be qualified. Transmission System Model 2 validates an additional broad set of topologies that are fully functional and do not fit within the simpler, but more restrictive rules of Model 1.

The physical size of a CSMA/CD network is limited by the characteristics of individual network components. These characteristics include the following:

a) Media lengths and their associated propagation time delay.
b) Delay of repeater units (start-up, steady-state, and end of event).
c) Delay of MAUs and PHYs (start-up, steady-state, and end of event).
d) Interpacket gap shrinkage due to repeater units.
e) Delays within the DTE associated with the CSMA/CD access method.
f) Collision detect and deassertion times associated with the MAUs and PHYs.

Table 42–1 summarizes the delays, measured in Bit Times (BTs), for 1000 Mb/s media segments.

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Table 42–1—Delays for network media segments Model 1

Media type	Maximum number of PHYs per segment	Maximum segment length (m)	Maximum medium round-trip delay per segment (BT)
Category 5 Link Segment (1000BASE-T)	2	100	1112
Shielded Jumper Cable Link Segment (1000BASE-CX)	2	25	253
Optical Fiber Link Segment (1000BASE-SX, 1000BASE-LX)	2	316[a]	3192

[a]May be limited by the maximum transmission distance of the link.

42.1.2 Repeater usage

Repeaters are the means used to connect segments of a network medium together into a single collision domain. Different physical signaling systems (e.g., 1000BASE-CX, 1000BASE-SX, 1000BASE-LX, 1000BASE-T) can be joined into a common collision domain using a repeater. Bridges can also be used to connect different signaling systems; however, if a bridge is so used, each LAN connected to the bridge will comprise a separate collision domain.

42.2 Transmission System Model 1

The following network topology constraints apply to networks using Transmission System Model 1.

a) Single repeater topology maximum.
b) Link distances not to exceed the lesser of 316 m or the segment lengths as shown in Table 42–1.

42.3 Transmission System Model 2

Transmission System Model 2 is a single repeater topology with the physical size limited primarily by round-trip collision delay. A network configuration must be validated against collision delay using a network model for a 1000 Mb/s collision domain. The modeling process is quite straightforward and can easily be done either manually or with a spreadsheet.

The model proposed here is derived from the one presented in 13.4. Modifications have been made to accommodate adjustments for DTE, repeater, and cable speeds.

For a network consisting of two 1000BASE-T DTEs as shown in Figure 42–3, a crossover connection may be required if the auto-crossover function is not implemented. See 40.4 and 40.8.

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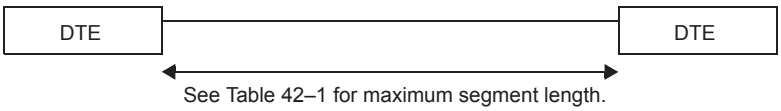

Figure 42–3—Model 1: Two DTEs, no repeater

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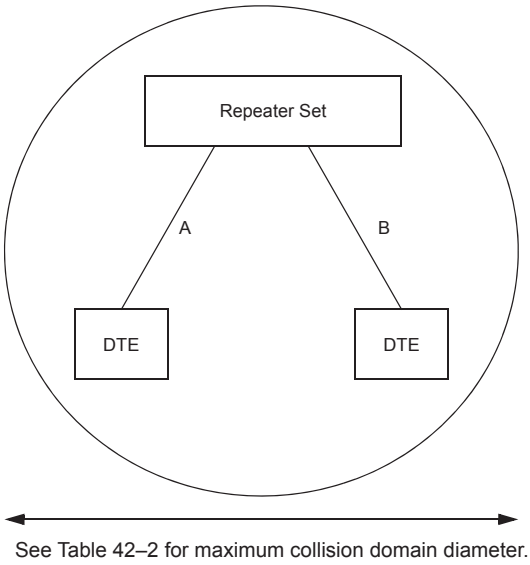

Figure 42–4—Model 1: Single repeater

Table 42–2—Maximum Model 1 collision domain diameter[a]

Configuration	Category 5 Twisted-Pair (T)	Shielded Jumper Cable (CX)	Optical Fiber (SX/LX)	Mixed Category 5 and Fiber (T and SX/LX)	Mixed Shielded Jumper and Fiber (CX and SX/LX)
DTE-DTE (see Figure 42–3)	100	25	316[b]	NA	NA
One repeater (see Figure 42–4)	200	50	220	210[c]	220[d]

[a]In meters.
[b]May be limited by the maximum transmission distance of the link.
[c]Assumes 100 m of Category 5 twisted-pair and one Optical Fiber link of 110 m.
[d]Assumes 25 m of Shielded Jumper Cable and one Optical Fiber link of 195 m.

42.3.1 Round-trip collision delay

For a network configuration to be valid, it must be possible for any two DTEs on the network to properly arbitrate for the network. When two or more stations attempt to transmit within a slot time interval, each station must be notified of the contention by the returned "collision" signal within the "collision window" (see 4.1.2.2). Additionally, the maximum length fragment created on a 1000 Mb/s network must contain less than 512 bytes after the Start Frame Delimiter (SFD). These requirements limit the physical diameter (maximum distance between DTEs) of a network. The maximum round-trip delay must be qualified between all pairs of DTEs in the network. In practice this means that the qualification must be done between those that, by inspection of the topology, are candidates for the longest delay. The following network modeling methodology is provided to assist that calculation.

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42.3.1.1 Worst-case path delay value (PDV) selection

The worst-case path through a network to be validated is identified by examination of aggregate DTE delays, cable delays, and repeater delay. The worst case consists of the path between the two DTEs at opposite ends of the network that have the longest round-trip time. Figure 42–5 shows a schematic representation of a one-repeater path.

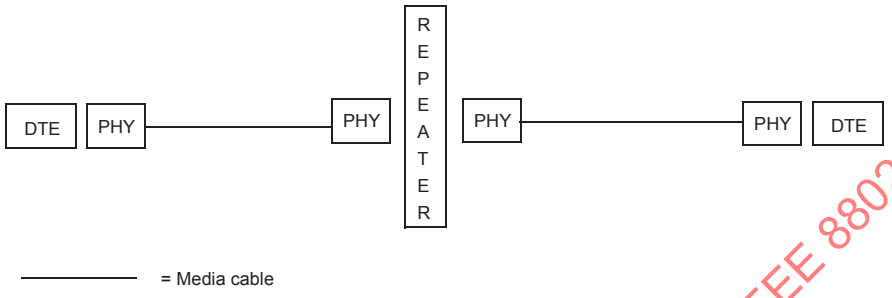

Figure 42–5—System Model 2: Single repeater

42.3.1.2 Worst-case PDV calculation

Once a set of paths is chosen for calculation, each is checked for validity against the following formula:

PDV = ∑link delays (LSDV) + repeater delay + DTE delays + safety margin

Values for the formula variables are determined by the following method:

a) Determine the delay for each link segment (Link Segment Delay Value, or LSDV), using the formula

LSDV=2 (for round-trip delay) × segment length × cable delay for this segment

NOTE 1—Length is the sum of the cable lengths between the PHY interfaces at the repeater and PHY interfaces at the farthest DTE. All measurements are in meters.

NOTE 2—Cable delay is the delay specified by the manufacturer or the maximum value for the type of cable used as shown in Table 42–3. For this calculation, cable delay must be specified in bit times per meter (BT/m). Table 42–4 can be used to convert values specified relative to the speed of light (%c) or nanoseconds per meter (ns/m).

NOTE 3—When actual cable lengths or propagation delays are not known, use the Max delay in bit times as specified in Table 42–3 for copper cables. Delays for fiber should be calculated, as the value found in Table 42–3 will be too large for most applications.

NOTE 4—The value found in Table 42–3 for Shielded Jumper Cable is the maximum delay for cable with solid dielectric. Cables with foam dielectric may have a significantly smaller delay.

b) Sum together the LSDVs for all segments in the path.
c) Determine the delay for the repeater. If model-specific data is not available from the manufacturer, enter the appropriate default value from Table 42–3.
d) Use the DTE delay value shown in Table 42–3 unless your equipment manufacturer defines a different value. If the manufacturer's supplied values are used, the DTE delays of both ends of the worst- case path should be summed together.
e) Decide on appropriate safety margin—0 to 40 bit times—for the PDV calculation. Safety margin is used to provide additional margin to accommodate unanticipated delay elements, such as extra-long connecting cable runs between wall jacks and DTEs. (A safety margin of 32 BT is recommended.)

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f) Insert the values obtained through the calculations above into the following formula to calculate the PDV. (Some configurations may not use all the elements of the formula.)

PDV = ∑link delays (LSDV) + repeater delay + DTE delay + safety margin

g) If the PDV is less than 4096, the path is qualified in terms of worst-case delay.
h) Late collisions and/or CRC errors may be indications that path delays exceed 4096 BT.

Table 42–3—Network component delays, Transmission System Model 2

Component	Round-trip delay in bit times per meter (BT/m)	Maximum round-trip delay in bit times (BT)
Two DTEs		864
Category 5 Cable segment	11.12	1112 (100 m)
Shielded Jumper Cable segment	10.10	253 (25 m)
Optical Fiber Cable segment	10.10	1111 (110 m)
Repeater		976

Table 42–4—Conversion table for cable delays

Speed relative to c	ns/m	BT/m
0.4	8.34	8.34
0.5	6.67	6.67
0.51	6.54	6.54
0.52	6.41	6.41
0.53	6.29	6.29
0.54	6.18	6.18
0.55	6.06	6.06
0.56	5.96	5.96
0.57	5.85	5.85
0.58	5.75	5.75
0.5852	5.70	5.70
0.59	5.65	5.65
0.6	5.56	5.56
0.61	5.47	5.47

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Table 42–4—Conversion table for cable delays *(continued)*

Speed relative to c	ns/m	BT/m
0.62	5.38	5.38
0.63	5.29	5.29
0.64	5.21	5.21
0.65	5.13	5.13
0.654	5.10	5.10
0.66	5.05	5.05
0.666	5.01	5.01
0.67	4.98	4.98
0.68	4.91	4.91
0.69	4.83	4.83
0.7	4.77	4.77
0.8	4.17	4.17
0.9	3.71	3.71

42.4 Full duplex 1000 Mb/s topology limitations

Unlike half duplex CSMA/CD networks, the physical size of full duplex 1000 Mb/s networks is not limited by the round-trip collision propagation delay. Instead, the maximum link length between DTEs is limited only by the signal transmission characteristics of the specific link.

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43. Content moved to IEEE Std 802.1AX-2008

NOTE—The Link Aggregation specification was moved to IEEE Std 802.1AX™-2008 during the IEEE Std 802.3-2008 revision.

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Annex 36A

(informative)

Jitter test patterns

This annex defines test patterns for 1000BASE-X PMDs. The applicability of these patterns is specified in the relevant PMD clauses. The patterns may be implemented at a bit, code-group, or frame level and may be used for transmitter testing. The receiver may not have the capability to accept these diagnostic sequences; however, system debug can be improved if a receiver is able to test for one or more of these patterns and report bit errors (e.g., 8B/10B decoder errors) back to the user.

36A.1 High-frequency test pattern

The intent of this test pattern is to test random jitter (RJ) at a BER of 10^{-12}, and also to test the asymmetry of transition times. This high-frequency test pattern generates a one, or light on, for a duration of 1 bit time, followed by a zero, or light off, for a duration of 1 bit time. This pattern repeats continuously for the duration of the test. For example: 10101010101010101010101010101010101010...

NOTE—This pattern can be generated by the repeated transmission of the D21.5 code-group. Disparity rules are followed.

36A.2 Low-frequency test pattern

The intent of this test pattern is to test low-frequency RJ and also to test PLL tracking error. This low frequency test pattern generates a one, or light on, for a duration of 5 bit times, followed by a zero, or light off, for a duration of 5 bit times. This pattern repeats continuously for the duration of the test. For example: 11111000001111100000111110000011111100000...

NOTE—This pattern can be generated by the repeated transmission of the K28.7 code-group. Disparity rules are followed.

36A.3 Mixed frequency test pattern

The intent of this test pattern is to test the combination of RJ and deterministic jitter (DJ). This mixed frequency test pattern generates a one, or light on, for a duration of 5 bit times, followed by a zero, or light off, for a duration of 1 bit times, followed by a one for 1 bit time followed by a zero for 1 bit time followed by a one for 2 bit times followed by a zero for 5 bit times followed by a one for 1 bit time followed by a zero for 1 bit time followed by a one for 1 bit time followed by a zero for 2 bit times. This pattern repeats continuously for the duration of the test. For example: 11111010110000010100111110101100000101000...

NOTE—This pattern can be generated by the repeated transmission of the K28.5 code-group. Disparity rules are followed.

36A.4 Long continuous random test pattern

The long continuous random test pattern is a random test pattern intended to provide broad spectral content and minimal peaking that can be used for the measurement of jitter at either a component or system level.

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NOTE—The derivation of this pattern may be found in *Fibre Channel Jitter Working Group Technical Report* [B30]. This technical report modified the original RPAT as defined by Fibre Channel so that it would maintain its intended qualities but fit into a Fibre Channel frame. This annex uses similar modifications to fit the same RPAT into an IEEE 802.3 frame.

The long continuous random test pattern consists of a continuous stream of identical packets, separated by a minimum IPG. Each packet is encapsulated within SPD and EPD delimiters as specified in Clause 36 in the ordinary way. The contents of each packet is composed of the following octet sequences, as observed at the GMII, before 8B/10B coding.

Each packet in the long continuous random test pattern consists of 8 octets of PREAMBLE/SFD, followed by 1512 data octets (126 repetitions of the 12-octet modified RPAT sequence), plus 4 CRC octets, followed by a minimum IPG of 12 octets of IDLE.

PREAMBLE/SFD:

55 55 55 55 55 55 55 D5

MODIFIED RPAT SEQUENCE (LOOP 126 TIMES)

BE D7 23 47 6B 8F B3 14 5E FB 35 59

CRC

94 D2 54 AC

IPG (TX_EN and TX_ER low)

00 00 00 00 00 00 00 00 00 00 00 00

END

36A.5 Short continuous random test pattern

The short continuous random test pattern is a random test pattern intended to provide broad spectral content and minimal peaking that can be used for the measurement of jitter at either a component or system level.

NOTE—The derivation of this pattern may be found in *Fibre Channel Jitter Working Group Technical Report* [B30]. This technical report modified the original RPAT as defined by Fibre Channel so that it would maintain its intended qualities but fit into a Fibre Channel frame. This annex uses similar modifications to fit the same RPAT into an IEEE 802.3 frame.

The short continuous random test pattern consists of a continuous stream of identical packets, separated by a minimum IPG. Each packet is encapsulated within SPD and EPD delimiters as specified in Clause 36 in the ordinary way. The contents of each packet is composed of the following octet sequences, as observed at the GMII, before 8B/10B coding.

Each packet in the short continuous random test pattern consists of 8 octets of PREAMBLE/SFD, followed by 348 data octets (29 repetitions of the 12-octet modified RPAT sequence), plus 4 CRC octets, followed by a minimum IPG of 12 octets of IDLE.

The format of this packet is such that the PCS will generate the following ordered sets for the IPG: /T/ /R/ /I1/ /I2/ /I2/ /I2/ /I2/

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PREAMBLE/SFD:

55 55 55 55 55 55 55 D5

MODIFIED RPAT SEQUENCE (LOOP 29 TIMES)

BE D7 23 47 6B 8F B3 14 5E FB 35 59

CRC

2F E0 AA EF

IPG (TX_EN and TX_ER low)

00 00 00 00 00 00 00 00 00 00 00 00

END

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Annex 36B

(informative)

8B/10B transmission code running disparity calculation examples

Detection of a invalid code-group in the 8B/10B transmission code does not necessarily indicate that the code-group in which the error was detected was the one in which the error occurred. Invalid code-groups may result from a prior error that altered the running disparity of the bit stream but that did not result in a detectable error at the code-group in which the error occurred. The examples shown in Tables 36B–1 and 36B–2 exhibit this behavior. The example shown in Table 36B–3 exhibits the case where a bit error in a received code-group is detected in that code-group, affects the next code group, and error propagation is halted upon detection of the running disparity error.

Table 36B–1—RD error detected two code-groups following error

Stream	Code-group			Code-group			Code-group		
	RD	RD	RD	RD	RD	RD	RD	RD	RD
Transmitted code-group	–	D21.1	–	D10.2	–	D23.5	+		
Transmitted bit stream	–	101010 - 1001	–	010101	–	0101	–	111010 + 1010	+
Received bit stream	–	101010 - 1011[a]	+	010101	+	0101	+	111010 +[b] 1010	+
Received code-group	–	D21.0	+	D10.2	+	invalid code-group[b]		+[c]	

[a]Bit error introduced (1001 ⇒ 1011)
[b]Nonzero disparity blocks must alternate in polarity (+ ⇒ –). In this case, RD does not alternate (+ ⇒ +), the received code group is not found in the Current RD+ column in either Table 36–1a or Table 36–2, and an invalid code-group is recognized.
[c]Running disparity is calculated on the received code-group regardless of the validity of the received code-group. Nonzero disparity blocks prevent the propagation of errors and normalize running disparity to the transmitted bit stream (i.e., equivalent to the received bit stream had an error not occurred).

Table 36B–2—RD error detected in next code-group following error

Stream	Code-group			Code-group			Code-group		
	RD	RD	RD	RD	RD	RD	RD	RD	RD
Transmitted code-group	–	D21.1	–	D23.4	–	D23.5	+		
Transmitted bit stream	–	101010 – 1001	–	111010	+	0010 –	111010	+ 1010	+
Received bit stream	–	101010 – 1011[a]	+	111010	+[b]	0010 –	111010	+ 1010	+
Received code-group	–	D21.0	+	invalid code-group[b]		–	D23.5	+	

[a]Bit error introduced (1001 ⇒ 1011)
[b]Nonzero disparity blocks must alternate in polarity (+ ⇒ –).

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Table 36B–3—A single bit error affects two received code-groups

Stream	Code-group			Code-group			Code-group		
	RD	RD	RD	RD	RD	RD	RD	RD	RD
Transmitted code-group	–	D3.6 (FCS3)		–	K29.7 (/T/)		–	K23.7 (/R/)	–
Transmitted bit stream	–	110001 - 0110		–	101110 + 1000		–	111010 + 1000	–
Received bit stream	–	110001 - 0111[a]	+[b]	101110	+[c]	1000	–	111010 + 1000	–
Received code-group	–	invalid code-group[d]	+	invalid code-group[e]		–	K23.7 (/R/)		–

[a]Bit error introduced (0110 ⇒ 0111).
[b]Nonzero disparity blocks must alternate in polarity (– ⇒ +). Received RD differs from transmitted RD.
[c]Nonzero disparity blocks must alternate in polarity (+ ⇒ –). Invalid code-group due to RD error since RD remains at +.
[d]Received code-group is not found in either Table 36–1a or Table 36–2.
[e]Nonzero disparity blocks prevent the propagation of errors and normalize running disparity to the transmitted bit stream (i.e. equivalent to the received bit stream had an error not occurred). All code-groups contained in PCS End_of_Packet delimiters (/T/R/R or /T/R/K28.5/) include nonzero disparity blocks.

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Annex 38A

(informative)

Fiber launch conditions

38A.1 Overfilled Launch

Overfilled Launch (OFL), as described in IEC 60793-1-4 [B38], is the standard launch used to define optical fiber bandwidth. This launch uniformly overfills the fiber both angularly and spatially. It excites both radial and azimuthal modes of the fiber equally, thus providing a reproducible bandwidth which is insensitive to small misalignments of the input fiber. It is also relatively insensitive to microbending and macrobending when they are not sufficient to affect power distribution carried by the fiber. A restricted launch gives a less reproducible bandwidth number and is dependent on an exact definition of the launch. Overfilled launch is commonly used to measure the bandwidth of LED-based links.

38A.2 Radial Overfilled Launch (ROFL)

A Radial Overfilled Launch is created when a multimode optical fiber is illuminated by the coherent optical output of a source operating in its lowest order transverse mode in a manner that excites predominantly the radial modes of the multimode fiber. This contrasts with the OFL, which is intended to excite both radial and azimuthal modes of the fiber equally. In practice an ROFL is obtained when

a) A spot of laser light is projected onto the core of the multimode fiber,
b) The laser spot is approximately symmetrical about the optical center of the multimode fiber,
c) The optical axis of both the fiber and the laser beam are approximately aligned,
d) The angle of divergence of the laser beam is less than the numerical aperture of the multimode fiber,
e) The laser spot is larger than the core of the multimode fiber.

An ROFL cannot be created using a multi-transverse mode laser or by simply projecting a speckle pattern through an aperture.

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Annex 40A

(informative)

Additional cabling design guidelines

This annex provides additional cabling guidelines when installing a new Category 5/Class D balanced cabling system or using an existing Category 5/Class D balanced cabling system. These guidelines are intended to supplement those in Clause 40. 1000BASE-T is designed to operate over 4-pair twisted-pair cabling systems that meet the requirements described in ANSI/TIA/EIA-568-A-1995 (Category 5) and ISO/IEC 11801:1995 (Class D), and the additional transmission parameters of return loss, ELFEXT loss, and MDELFEXT loss specified in 40.7. There are additional steps that may be taken by network designers that provide additional operating margins and ensure the objective BER of 10^{-10} is achieved. Cabling systems that meet or exceed the specifications in 40.7 for a worst case 4-connector topology are recommended for new installations. Whether installing a new Category 5/Class D balanced cabling system or reusing one that is already installed, it is highly recommended that the cabling system be measured/certified before connecting 1000BASE-T equipment following the guidelines in ANSI/EIA/TIA 568-B1 Annex D.

40A.1 Alien crosstalk

40A.1.1 Multipair cabling (i.e., greater than 4-pair)

Multiple Gigabit Ethernet links [(n*4-Pair) with n greater than 1] should not share a common sheath as in a 25-pair binder group in a multipair cable. When the multipair cable is terminated into compliant connecting hardware (TIA does not specify 25 position connecting hardware), the NEXT loss contributions between the adjacent 4-pair Gigabit Ethernet link, from connecting hardware and the cable combined, cannot be completely cancelled.

40A.1.2 Bundled or hybrid cable configurations

Another source of alien crosstalk can occur in a bundled or hybrid cable configuration where two or more 4-pair cables are assembled together.

In order to limit the noise coupled between adjacent 1000BASE-T link segments in a bundled or hybrid cable configuration, the PSNEXT loss between a 1000BASE-T duplex channel in a link segment and all duplex channels in adjacent 1000BASE-T link segments should be greater than 35 – 15*log(*f*/100) (dB) at all frequencies from 1 MHz to 100 MHz.

40A.2 Cabling configurations

The primary application for the Clause 40 specification is expected to be between a workstation and the local telecommunications closet. In commercial buildings this application is generally referred to as the horizontal cabling subsystem. As specified in ISO/IEC 11801:1995 the maximum length of a horizontal subsystem building wiring channel is 100 m. The channel consists of cords, cables, and connecting hardware. The maximum configuration for this channel is shown in Figure 40A–1.

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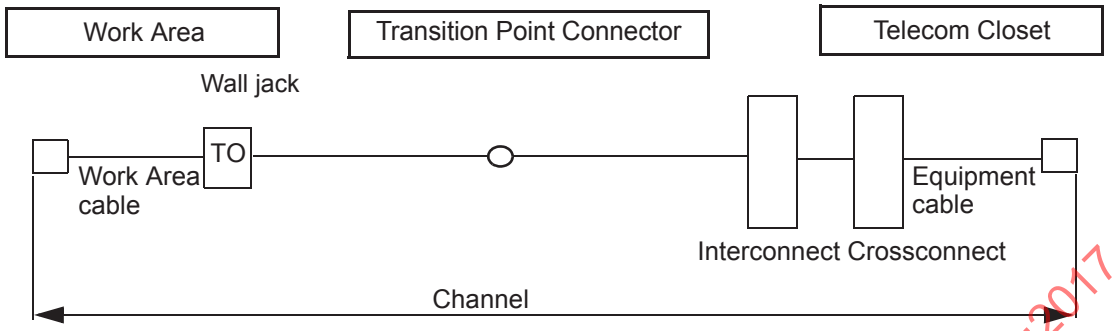

Figure 40A–1—Maximum horizontal subsystem configuration

On the other hand, a minimum configuration can be achieved by removing the patch cord and transition point, which is shown in Figure 40A–2.

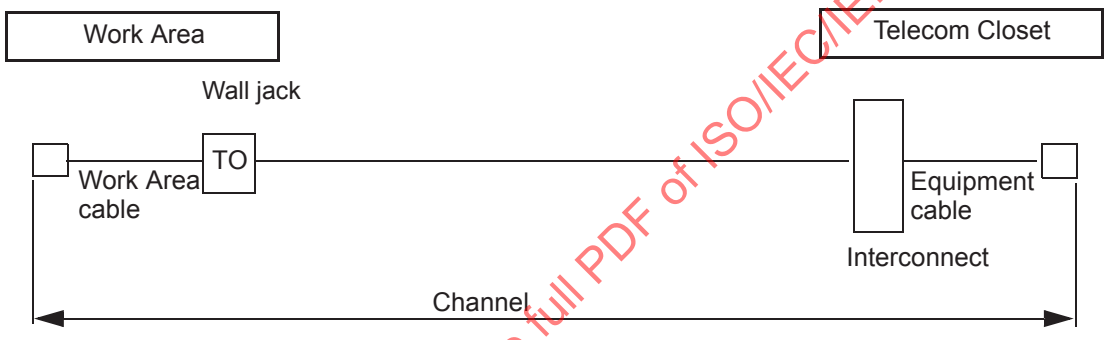

Figure 40A–2—Minimum horizontal subsystem configuration

1000BASE-T is designed to operate over a channel that meets the specifications of 40.7 and the channel configuration shown in Figure 40A–1. However, if the channel specifications of 40.8 cannot be met when using the channel configuration shown in Figure 40A–1, the configuration shown in Figure 40A–2 is recommended. This optimized channel for a 1000BASE-T link segment deletes the transition point and runs an equipment patch cord directly between the LAN equipment and the connector termination of the permanent link. This reduces the number of connectors and their associated crosstalk in the link. The minimum link configuration:

a) Minimizes crosstalk, both near-end and far-end, which maximizes the BER margin; and
b) Minimizes link insertion loss.

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Annex 40B

(informative)

Description of cable clamp

This annex describes the cable clamp used in the common-mode noise rejection test of 40.6.1.3.3, which is used to determine the sensitivity of the 1000BASE-T receiver to common-mode noise from the link segment. As shown in Figure 40B–1, the clamp is 300 mm long, 58 mm wide, 54 mm high with a center opening of 6.35 mm (0.25 in). The clamp consists of two halves that permit the insertion of a cable into the clamp.

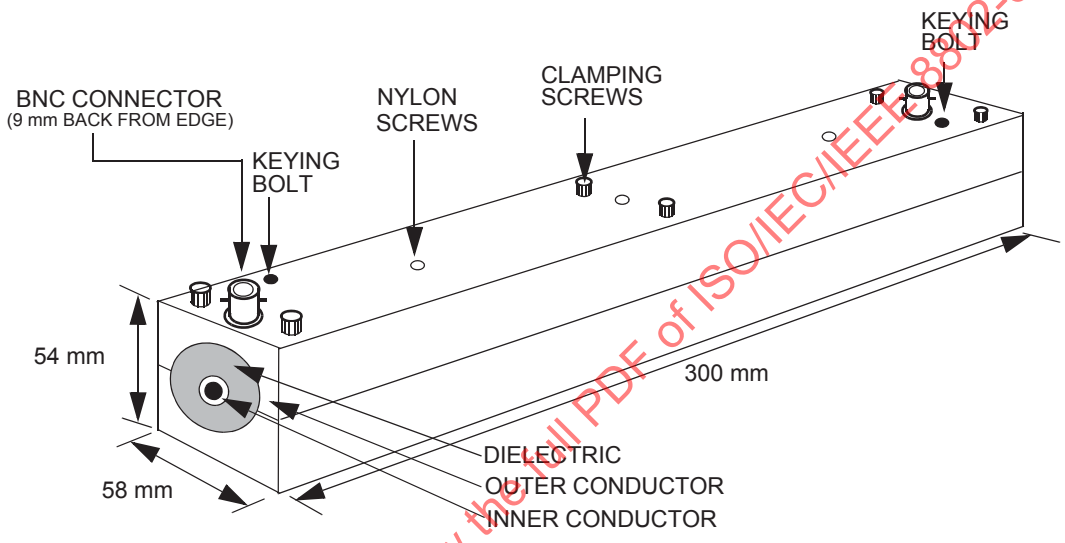

Figure 40B–1—Cable clamp

The clamp has a copper center conductor and an aluminum outer conductor with a high density polyethylene dielectric. The following is a review of the construction and materials of the clamp:

a) *Inner conductor*—Copper tubing with an inner diameter of 6.35 mm (0.25 in) and an outer diameter of 9.4 mm (0.37 in).
b) *Outer conductor*—Aluminum bar that is 300 mm long and approximately 54 mm by 58 mm. The bar is milled to accept the outer diameter of the dielectric material.
c) *Dielectric*—High Density Polyethylene (Residual, TypeF) with dielectric constant of 2.32. An outside diameter of 33.5 mm and an inner diameter that accepts the outside diameter of the copper inner conductor.
d) *Connectors*—BNC connectors are located 9 mm (0.39 in) from each end of the clamp and are recessed into the outer conductor. The center conductor of the connector is connected to the inter conductor as shown in Figure 40B–2.
e) *Clamping screws*—Six screws are used to connect the two halves of the clamp together after the cable has been inserted. Although clamping screws are shown in Figure 40B–1, any clamping method may be used that ensures the two halves are connected electrically and permits quick assembly and disassembly.
f) *Nylon screws*—Used to align and secure the inner conductor and dielectric to the outer conductor. The use and location of the screws is left to the manufacturer.
g) *Keying bolts*—Two studs used to align the two halves of the clamp.

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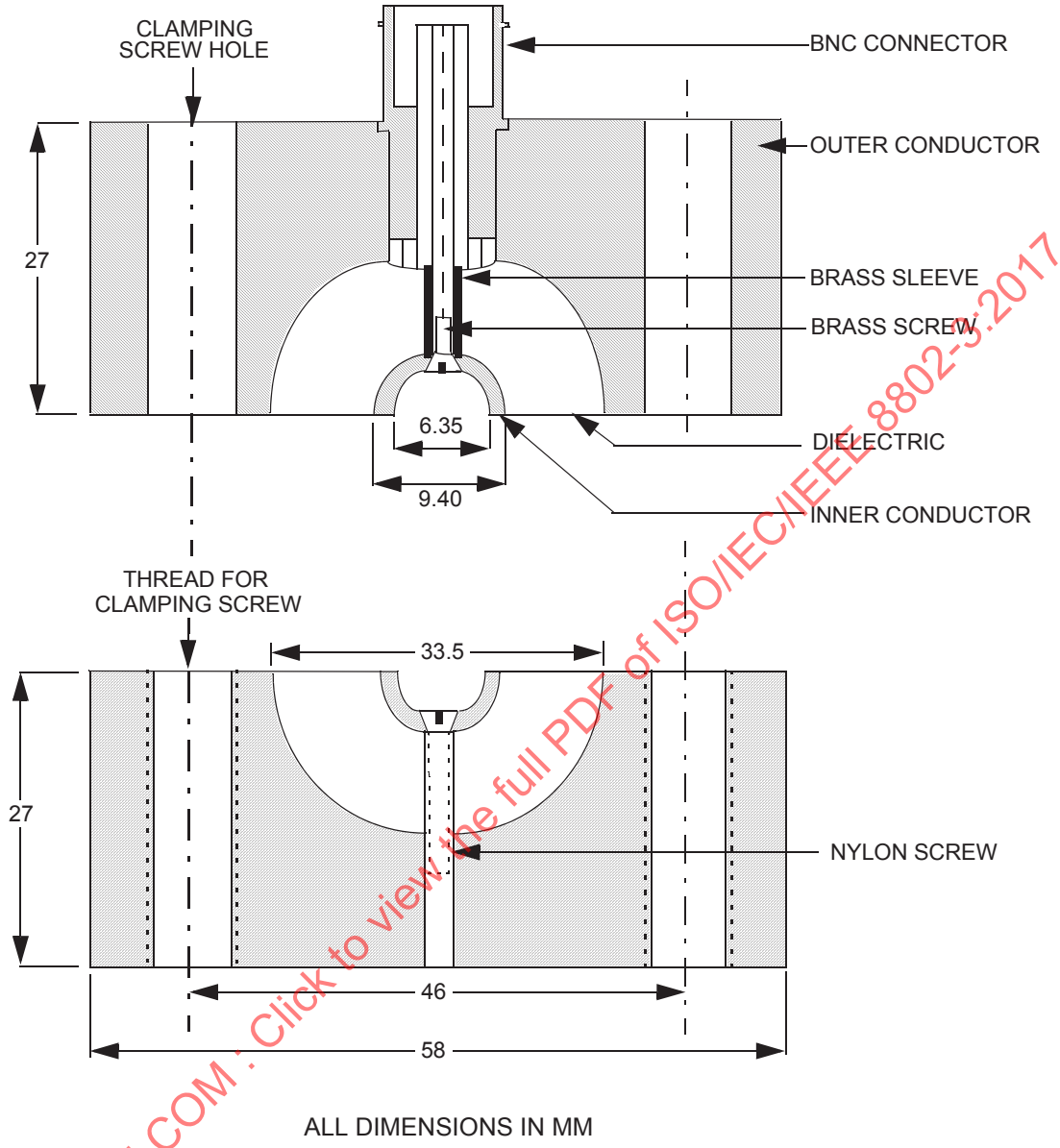

Figure 40B–2—Cross-section of cable clamp

As shown in Figure 40B–2 the inner conductor on the bottom half of the clamp extends slightly (~ 0.1mm) above the dielectric to ensure there is good electrical connection with the inner conductor of the top half of the clamp along the full length of the conductor when the two halves are clamped together.

The electrical parameters of the clamp between 1MHz and 250 MHz are as follows:

a) Insertion loss: < 0.2 dB
b) Return loss: > 20.0 dB

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40B.1 Cable clamp validation

In order to ensure the cable clamp described above is operating correctly, the following test procedure is provided. Prior to conducting the following test shown in Figure 40B–3, the clamp should be tested to ensure the insertion loss and return loss are as specified above. The cable clamp validation test procedure uses a well-balanced 4-pair Category 5 unshielded test cable or better that meets the specifications of 40.7. The test hardware consists of the following:

a) *Resistor network*—Network consists of three 50 ±0.1% Ω resistors; two resistors are connected in series as a differential termination for cable pairs and the other resistor is connected between the two and the ground plane as a common-mode termination.
b) *Balun*—3 ports, laboratory quality with a 100 Ω differential input, 50 Ω differential output, and a 50 Ω common-mode output:
   Insertion Loss (100 Ω balanced <->50 Ω unbalanced): <1.2 dB (1-350MHz)
   Return Loss: >20 dB (1-350 MHz)
   Longitudinal Balance: >50 dB (1-350 MHz)
c) *Test cable*—4-pair 100 Ω UTP category 5 balanced cable at least 30 m long.
d) *Chokes (2)*—Wideband Ferrite Material:
   Inter-diameter: 6.35 to 6.86 mm
   Impedance: 250 Ω @ 100 MHz
e) *Ground plane*—Copper sheet or equivalent.
f) *Signal generator*
g) *Oscilloscope*
h) *Receiver*

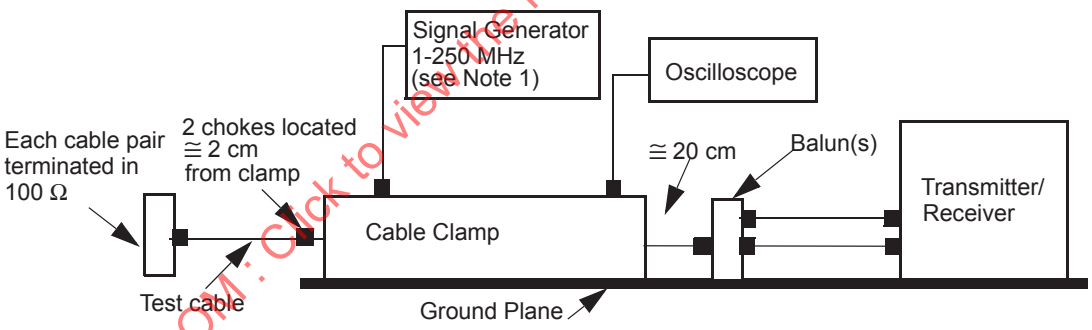

Figure 40B–3—Cable clamp validation test configuration

With the test cable inserted in the cable clamp, a signal generator with a 50 Ω output impedance is connected to one end of the cable clamp and an oscilloscope with a 50 Ω input impedance is connected to the other end. The signal generator shall be capable of providing a sine wave signal of 1 MHz to 250 MHz. The output of the signal generator is adjusted for a voltage of 1.0 Vrms (2.83 Vpp) at 20 MHz on the oscilloscope. The remainder of the test is conducted without changing the signal generator voltage. The cable pairs not connected to the balun are terminated in a resistor network, although when possible it is recommended that each cable pair be terminated in a balun. It very important that the cable clamp, balun, receiver, and resistor networks have good contact with the ground plane. The two chokes, which are located next to each other, are located approximately 2.0 cm from the clamp. The cable between the clamp and the balun should be straight and not in contact with the ground plane.

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The differential-mode and common-mode voltage outputs of the balun should meet the limits shown in Table 40B–1 over the frequency range 1 MHz to 250 MHz for each cable pair. The differential mode voltage at the output of the balun must be increased by 3 dB to take into account the 100-to-50 impedance matching loss of the balun.

Table 40B–1—Common- and differential-mode output voltages

Frequency (*f*)	Common-mode voltage	Differential-mode voltage
1-30 MHz	<0.1+0.97(f/30) Vpp	<2.4 + 19.68 (f/30) mVpp
30-80 MHz	<1.07 Vpp	<22 mVpp
80-250 MHz	<1.07 – 0.6 (f-80)/170 Vpp	<22 mVpp

NOTE—Prior to conducting the validation test the cable clamp should be tested without the cable inserted to determine the variation of the signal generator voltage with frequency at the output of the clamp. The signal generator voltage should be adjusted to 1 Vrms (2.83 Vpp) at 20 MHz on the oscilloscope. When the frequency is varied from 20 MHz to 250 MHz, the voltage on the oscilloscope should not vary more than ±7.5%. If the voltage varies more than ±7.5%, then a correction factor must be applied at each measurement frequency.

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Annex 40C

(informative)

Add-on interface for additional Next Pages

This annex describes a technique for implementing Auto-Negotiation for 1000BASE-T when the implementer wishes to send additional Next Pages (other than those required to configure for 1000BASE-T operation). To accomplish this mode of Auto-Negotiation, the implementer must ensure that the three Next Pages required for 1000BASE-T configuration are sent first.

The add-on interface described in this annex shows one technique for supporting the transmission of additional Next Pages. This mechanism utilizes the existing Clause 28 Auto-Negotiation mechanism and variables defined in Clause 28. Its purpose is merely to provide optional NEXT PAGE WAIT responses to the Auto-Negotiation Arbitration state diagram (see Figure 28–18).

The add-on interface for Auto-Negotiation is intended to interface directly between the defined registers and the Auto-Negotiation mechanism defined in Clause 28. The mechanism described includes five main blocks (see Figure 40C–1).

The first three blocks are used by the MASTER-SLAVE resolution function. They are used to generate and store random seeds and to resolve the status of the MASTER-SLAVE relationship. Their operation is described later in this annex. The final two blocks, the transmit state diagram for the 1000BASE-T Next Page exchange and the receive state diagram for the 1000BASE-T Next Page exchange, are described in this annex.

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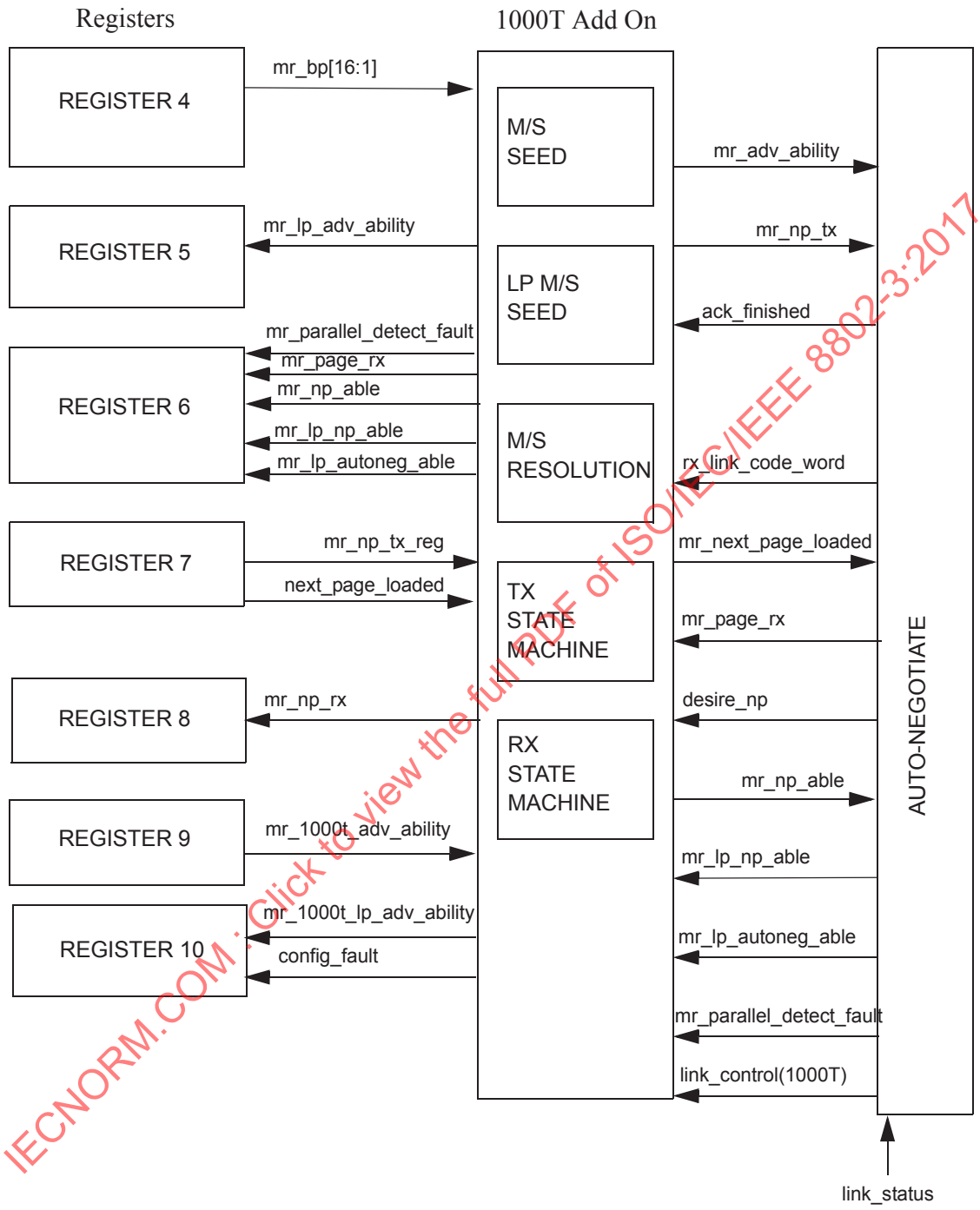

Figure 40C–1—Auto-Negotiate add-on diagram for 1000BASE-T

NOTE—When the exchange of Next Pages is complete, the MASTER-SLAVE relationship can be determined using Table 40–5 with the 1000BASE-T Technology Ability Next Page bit values specified in Table 40–4 and information received from the link partner. This process is conducted at the entrance to the FLP LINK GOOD CHECK state shown in the Auto-Negotiation Arbitration state diagram (Figure 28–18).

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40C.1 State variables

ATMP_CNT
: This variable is used to count the number of failed MASTER-SLAVE resolutions. It has a maximum value of 7.

config_fault
: This variable indicates the result of the MASTER-SLAVE resolution function.

desire_1000T_adv
: The local device desires a 1000BASE-T link.
Values: true; bits 9.8 or 9.9 do not contain a logic zero.
false; bits 9.8 and 9.9 both contain a logic zero.

mr_bp
: This variable is used as an intermediate signal from register 4. Normally register 4 would directly source the mr_adv_ability information. This information is now sourced from the transmit state machine.

mr_1000t_adv_ability
: A 16-bit array used to store and indicate the contents of register 9.

mr_1000t_lp_adv_ability
: A 16-bit array used to write information to register 10.

mr_np_tx_reg
: This variable is an intermediate signal from register 7. Normally register 7 would directly source the information to the Auto-Negotiation function via mr_np_tx. This information is now sourced from the transmit state diagram.

mr_np_rx
: A 16-bit array used to write information to register 8.
Values: Zeros; data bit is logical zero.
One; data bit is logical one.

next_page_loaded
: This variable is an intermediate signal from register 7. Normally register 7 would directly source the information to the Auto-Negotiation function via mr_next_page_loaded. This information is now sourced from the transmit state diagram.

reg_random
: An 11-bit array used to store the received random seed from the link partner. It is used by the MASTER-SLAVE resolution function.

All other signals are defined in Clause 28.

40C.2 State diagrams

40C.2.1 Auto-Negotiation Transmit state diagram add-on for 1000BASE-T

The Auto-Negotiation transmit state diagram add-on (see Figure 40C–2) is responsible for sending the Base Page, 1000BASE-T Next Pages, as well as additional Next Pages as specified by the management interface.

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1000BASE-T Next Pages will automatically be sent by the PHY whenever there are no additional Next Pages to be sent. If the user desires to send additional Next Pages, then the user must first send three pages of any format. Management will automatically replace these three pages with the appropriate 1000BASE-T Message Page and the two following unformatted pages and then will send the additional Next Pages as specified by the user. All other steps are performed by the management interface. The management interface is now required to complete the Next Page exchange by sourcing its own NULL page. This is shown in Figure 40C–2 for illustration only.

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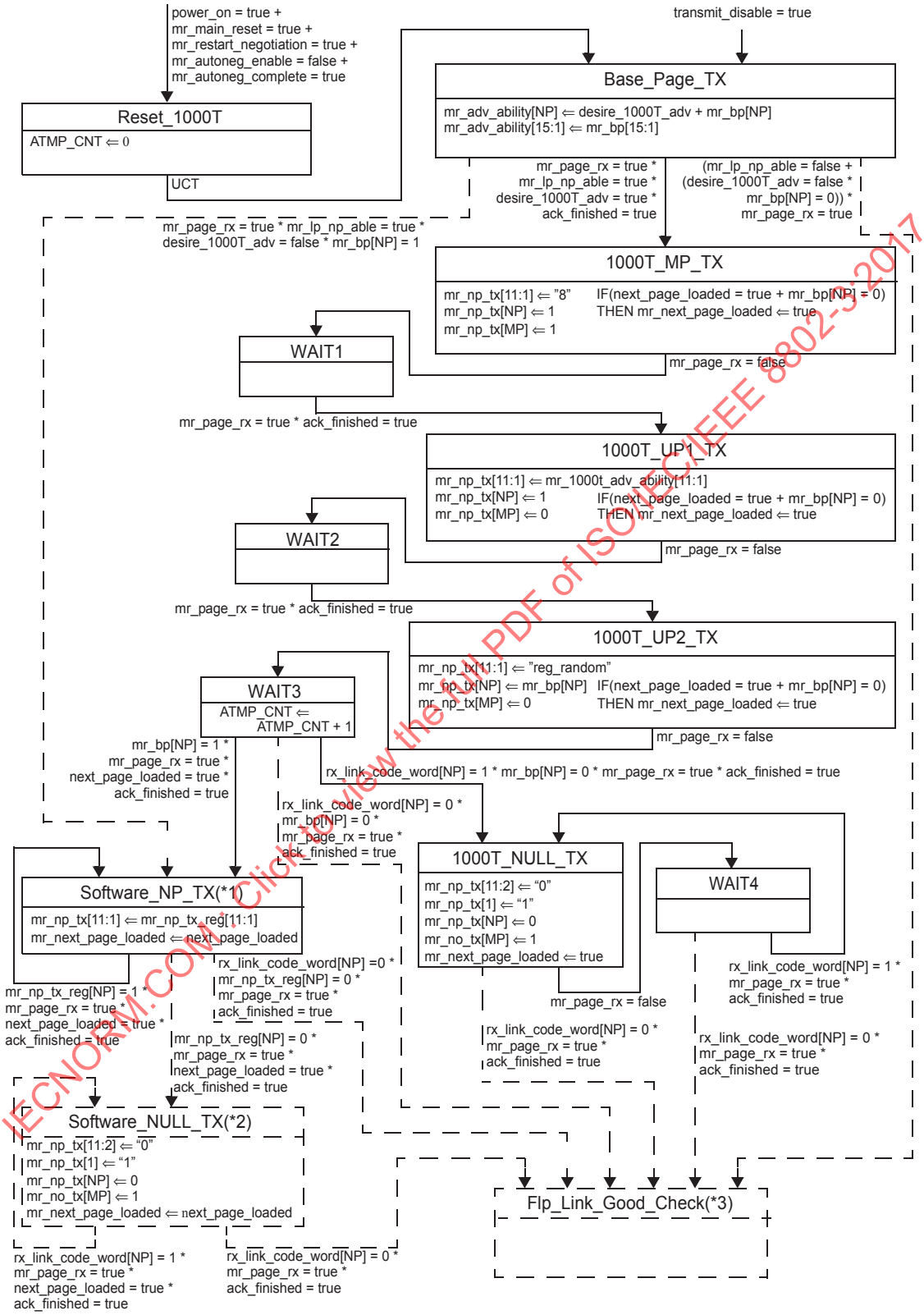

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Figure 40C–2—Auto-Negotiation Transmit state diagram add-on for 1000BASE-T

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NOTES for Figure 40C–2

1—(Software_NP_TX) If the user desires to send additional Next Pages, then the contents of the first three Next Pages will be overwritten by the three 1000BASE-T Next Pages. In this case, the user is responsible for stepping through the Next Page sequence (by creating the initial three Next Pages to be overwritten by the three 1000BASE-T Next Pages); otherwise the process is automatic. (next_page_loaded signals clear operation as per Clause 28.)

2—(Software_NULL_TX) This is shown for illustration only. This is done in software and is required.

3—(Flp_Link_Good_Check) This is shown for illustration only. This state is from the Auto-Negotiation Arbitration state diagram and indicates the conclusion of pages being sent. (The transition desire_1000T_adv = false is to show sequence for non 1000BASE-T implementations.)

40C.2.2 Auto-Negotiation Receive state diagram add-on for 1000BASE-T

The Auto-Negotiation receive state diagram add-on for 1000BASE-T Next Pages (see Figure 40C–3) is responsible for receiving the Base Page, 1000BASE-T Next Pages, and any additional Next Pages received. 1000BASE-T Next Pages will automatically be received whenever the user does not wish to participate in Next Page exchanges. In this case, the appropriate 1000BASE-T message page and its two unformatted pages will automatically be received and stored in their appropriate registers. Any additional Next Pages received will still be placed in register 8, but will be overwritten automatically when a new page is received. The net result is that the management interface does not need to poll registers 6 and 8. The information in register 8 will be meaningless in this case. If the user desires to participate in additional Next Page exchanges via setting the appropriate bit in register 4, the user now becomes responsible (as was previously the case) for defining how this will be accomplished. In this situation, the first three Next Pages received may be 1000BASE-T and should be discarded. This information will automatically be stored internally in the appropriate register 10 and reg_random. The management interface/user can ignore the information received for the 1000BASE-T Next Pages.

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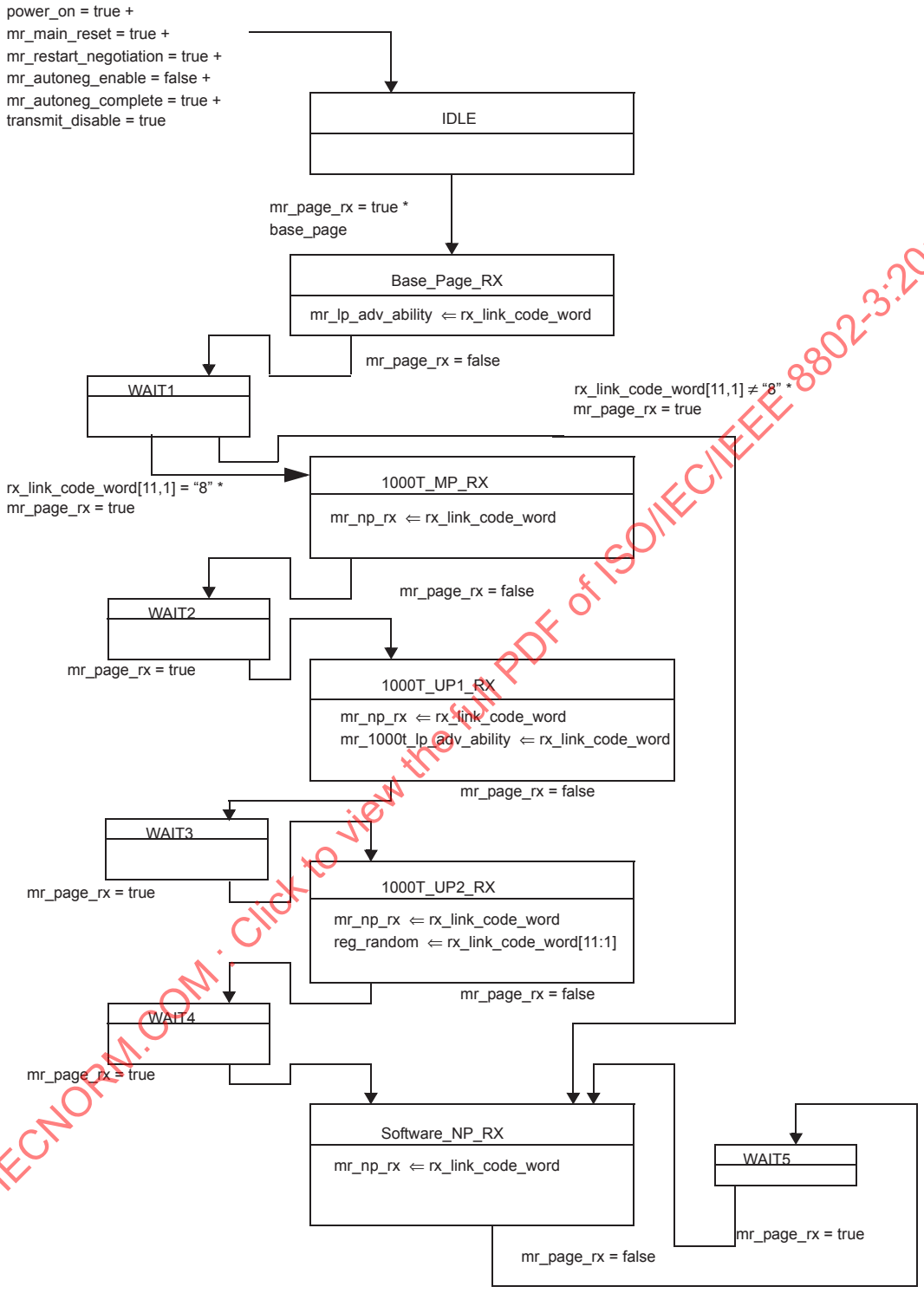

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Figure 40C–3—Auto-Negotiation Receive state diagram add-on for 1000BASE-T

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Annex 43A

Annex 43A is no longer in use.

NOTE—The Link Aggregation specification, including Annex 43, *Collection and Distribution functions*, was moved to IEEE Std 802.1AX-2008 during the IEEE Std 802.3-2008 revision.

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Annex 43B

Annex 43B is no longer in use.

NOTE—When the Link Aggregation specification contained in Clause 43, Annex 43A, and Annex 43 C were moved to IEEE Std 802.1AX-2008 during the IEEE Std 802.3-2008 revision the content of Annex 43B was moved to become Annex 57A.

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Annex 43C

Annex 43C is no longer in use.

NOTE—The Link Aggregation specification, including Annex 43C ‘LACP standby link selection and dynamic Key management’ was moved to IEEE Std 802.1AX-2008 during the IEEE Std 802.3-2008 revision.

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SECTION FOUR

This section includes Clause 44 through Clause 55 and Annex 44A through Annex 55B.

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44. Introduction to 10 Gb/s baseband network

44.1 Overview

44.1.1 Scope

10 Gigabit Ethernet uses the IEEE 802.3 MAC sublayer, connected through a 10 Gigabit Media Independent Interface (XGMII) to Physical Layer entities such as 10GBASE-SR, 10GBASE-LX4, 10GBASE-CX4, 10GBASE-LRM, 10GBASE-LR, 10GBASE-ER, 10GBASE-SW, 10GBASE-LW, 10GBASE-EW, and 10GBASE-T.

10 Gigabit Ethernet extends the IEEE 802.3 MAC beyond 1000 Mb/s to 10 Gb/s. The bit rate is faster and the bit times are shorter—both in proportion to the change in bandwidth. The minimum packet transmission time has been reduced by a factor of ten. A rate control mode (see 4.2.3.2.2) is added to the MAC to adapt the average MAC data rate to the SONET/SDH data rate for WAN-compatible applications of this standard. Achievable topologies for 10 Gb/s operation are comparable to those found in 1000BASE-X full duplex mode and equivalent to those found in WAN applications.

10 Gigabit Ethernet is defined for full duplex mode of operation only.

44.1.2 Objectives

The following are the objectives of 10 Gigabit Ethernet:

a) Support the full duplex Ethernet MAC.
b) Provide 10 Gb/s data rate at the XGMII.
c) Support LAN PMDs operating at 10 Gb/s, and WAN PMDs operating at SONET STS-192c/SDH VC-4-64c rate.
d) Support cable plants using cabled optical fiber compliant with ISO/IEC 11801:1995.
e) Allow for a nominal network extent of up to 40 km.
f) Support operation over a twinaxial cable assembly for wiring closet and data center applications.
g) Support operation over selected copper media from ISO/IEC 11801:2002.
h) Support a BER objective of 10^{-12}.

44.1.3 Relationship of 10 Gigabit Ethernet to the ISO OSI reference model

10 Gigabit Ethernet couples the IEEE 802.3 MAC to a family of 10 Gb/s Physical Layers. The relationships among 10 Gigabit Ethernet, the IEEE 802.3 MAC, and the ISO Open System Interconnection (OSI) reference model are shown in Figure 44–1.

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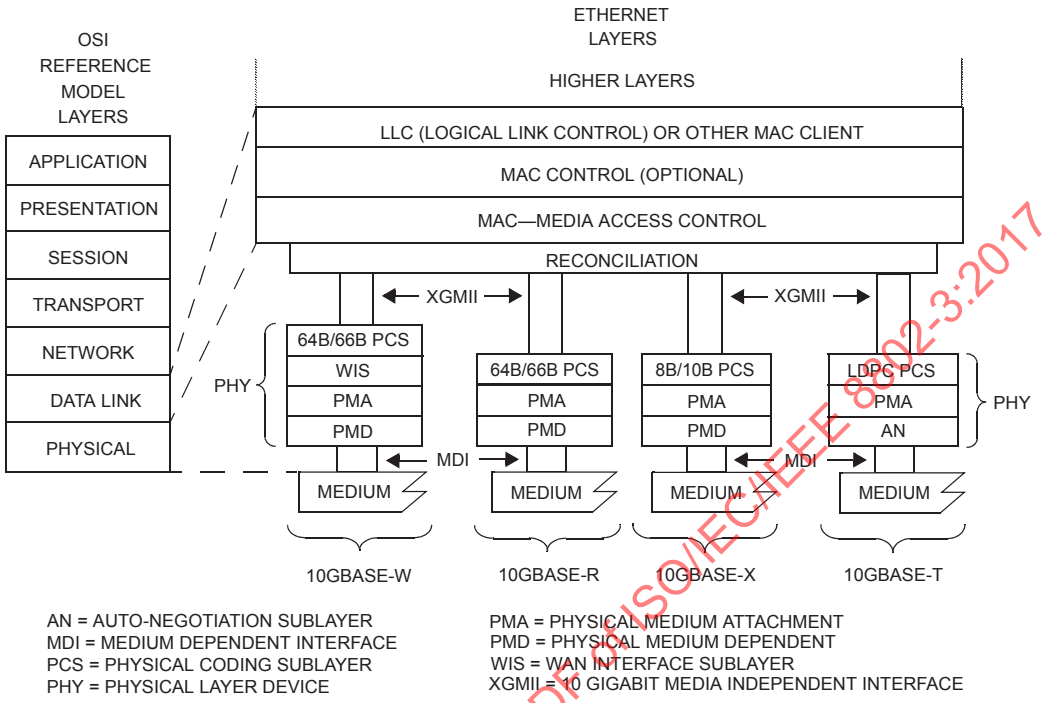

Figure 44–1—Architectural positioning of 10 Gigabit Ethernet

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It is important to note that, while this specification defines interfaces in terms of bits, octets, and frames, implementations may choose other data-path widths for implementation convenience. The only exceptions are as follows:

a) The XGMII, which, when implemented at an observable interconnection port, uses a four octet-wide data path as specified in Clause 46.
b) The management interface, which, when physically implemented as the MDIO/MDC (Management Data Input/Output and Management Data Clock) at an observable interconnection port, uses a bit-wide data path as specified in Clause 45.
c) The PMA Service Interface, which, when physically implemented as the XSBI (10 Gigabit Sixteen Bit Interface) at an observable interconnection port, uses a 16-bit-wide data path as specified in Clause 51.
d) The MDI as specified in Clause 53 for 10GBASE-LX4, in Clause 54 for 10GBASE-CX4, in Clause 55 for 10GBASE-T, in Clause 68 for 10GBASE-LRM, and in Clause 52 for other PMD types.

44.1.4 Summary of 10 Gigabit Ethernet sublayers

44.1.4.1 Reconciliation Sublayer (RS) and 10 Gigabit Media Independent Interface (XGMII)

The 10 Gigabit Media Independent Interface (Clause 46) provides an interconnection between the Media Access Control (MAC) sublayer and Physical Layer entities (PHY). This XGMII supports 10 Gb/s operation through its 32-bit-wide transmit and receive data paths. The Reconciliation Sublayer provides a mapping between the signals provided at the XGMII and the MAC/PLS service definition.

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While the XGMII is an optional interface, it is used extensively in this standard as a basis for functional specification and provides a common service interface for Clause 47, Clause 48, Clause 49, and Clause 55.

44.1.4.2 XGMII Extender Sublayer (XGXS) and 10 Gigabit Attachment Unit Interface (XAUI)

The 10 Gigabit Attachment Unit Interface (Clause 47) provides an interconnection between two XGMII Extender sublayers to increase the reach of the XGMII. This XAUI supports 10 Gb/s operation through its four-lane, differential-pair transmit and receive paths. The XGXS provides a mapping between the signals provided at the XGMII and the XAUI.

44.1.4.3 Management interface (MDIO/MDC)

The MDIO/MDC management interface (Clause 45) provides an interconnection between MDIO Manageable Devices (MMD) and Station Management (STA) entities.

44.1.4.4 Physical Layer signaling systems

This standard specifies a family of Physical Layer implementations. The generic term 10 Gigabit Ethernet refers to any use of the 10 Gb/s IEEE 802.3 MAC (the 10 Gigabit Ethernet MAC) coupled with any IEEE 802.3 10GBASE Physical Layer implementation. Table 44–1 specifies the correlation between nomenclature and clauses. Implementations conforming to one or more nomenclatures shall meet the requirements of the corresponding clauses.

Table 44–1—Nomenclature and clause correlation

Nomenclature	Clause										
	48	49	50	51	52			53	54	55	68
	8B/10B PCS & PMA	64B/66B PCS	WIS	Serial PMA	850 nm Serial PMD	1310 nm Serial PMD	1550 nm Serial PMD	1310 nm WDM PMD	4-Lane electrical PMD	Twisted-pair PCS & PMA	1310 nm Serial MMF PMD
10GBASE-SR		M[a]		M	M						
10GBASE-SW		M	M	M	M						
10GBASE-LX4	M							M			
10GBASE-CX4	M								M		
10GBASE-LR		M		M		M					
10GBASE-LW		M	M	M		M					
10GBASE-ER		M		M			M				
10GBASE-EW		M	M	M			M				
10GBASE-T										M	
10GBASE-LRM		M		M							M

[a]M = Mandatory

The term 10GBASE-X, specified in Clause 48, Clause 53, and Clause 54, refers to a specific family of Physical Layer implementations based upon 8B/10B data coding method. The 10GBASE-X family of Physical Layer implementations is composed of 10GBASE-LX4 and 10GBASE-CX4.

The term 10GBASE-R refers to a specific family of Physical Layer implementations. The 10GBASE-R family of Physical Layer implementations based upon 64B/66B data coding method is composed of 10GBASE-SR, 10GBASE-LR, 10GBASE-ER, and 10GBASE-LRM.

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The term 10GBASE-W, specified in Clause 49 through Clause 52, refers to a specific family of Physical Layer implementations based upon STS-192c/SDH VC-4-64c encapsulation of 64B/66B encoded data. The 10GBASE-W family of Physical Layer standards has been adapted from the ATIS-0600416.1999(R2010) (SONET STS-192c/SDH VC-4-64c) Physical Layer specifications. The 10GBASE-W family of Physical Layer implementations is composed of 10GBASE-SW, 10GBASE-LW, and 10GBASE-EW.

All 10GBASE-R and 10GBASE-W PHY devices share a common PCS specification (see Clause 49). The 10GBASE-W PHY devices also require the use of the WAN Interface Sublayer, (WIS) (Clause 50).

The term 10GBASE-T, specified in Clause 55, refers to a specific Physical Layer implementation based upon 64B/65B data coding placed in a low density parity check (LDPC) frame that is mapped to a 128 double-square (DSQ128) constellation for transmission on 4-pair, twisted-pair copper cabling.

Physical Layer device specifications are contained in Clause 52, Clause 53, Clause 54, Clause 55, and Clause 68.

Annex 44A contains diagrams of the data flow between the MAC and the MDI, as well as information on the relation between data valid signals and loopback.

44.1.4.5 WAN Interface Sublayer (WIS), type 10GBASE-W

The WIS provides a 10GBASE-W device with the capability to transmit and receive IEEE 802.3 MAC frames within the payload envelope of a SONET STS-192c/SDH VC-4-64c frame.

44.1.5 Management

Managed objects, attributes, and actions are defined for all 10 Gigabit Ethernet components. These items are defined in Clause 30.

44.2 State diagrams

State diagrams take precedence over text.

The conventions of 1.2 are adopted, along with the extensions listed in 21.5.

44.3 Delay constraints

Predictable operation of the MAC Control PAUSE operation (Clause 31, Annex 31B) demands that there be an upper bound on the propagation delays through the network. This implies that MAC, MAC Control sublayer, and PHY implementers must conform to certain delay maxima, and that network planners and administrators conform to constraints regarding the cable topology and concatenation of devices. Table 44–2 contains the values of maximum sublayer round-trip (sum of transmit and receive) delay in bit time as specified in 1.4 and pause_quanta as specified in 31B.2.

Equation (44–1) specifies the calculation of bit time per meter of fiber or electrical cable based upon the parameter n, which represents the ratio of the speed of electromagnetic propagation in the fiber or electrical cable to the speed of light in a vacuum. The value of n should be available from the fiber or electrical cable manufacturer, but if no value is known then a conservative delay estimate can be calculated using a default value of $n = 0.66$. The speed of light in a vacuum is $c = 3 \times 10^8$ m/s. Table 44–3 can be used to convert fiber or electrical cable delay values specified relative to the speed of light or in nanoseconds per meter.

$$\text{cable delay} = \frac{10^{10}}{nc} \text{ BT/m} \qquad (44\text{–}1)$$

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Table 44–2—Round-trip delay constraints (informative)

Sublayer	Maximum (bit time)	Maximum (pause_quanta)	Notes
MAC, RS, and MAC Control	8192	16	See 46.1.4.
XGXS and XAUI	4096	8	Round-trip of 2 XGXS and trace for both directions. See 47.2.2.
10GBASE-X PCS and PMA	2048	4	See 48.5
10GBASE-R PCS	3584	7	See 49.2.15.
WIS	14336	28	See 50.3.7.
LX4 PMD	512	1	Includes 2 m of fiber. See 53.2.
CX4 PMD	512	1	See 54.3.
Serial PMA and PMD (except LRM)	512	1	Includes 2 m of fiber. See 52.2.
LRM PMA and PMD	9216	18	Includes 2 m of fiber. See 68.2.
10GBASE-T PHY	25 600	50	See 55.11.

Table 44–3—Conversion table for cable delays

Speed relative to *c*	ns/m	BT/m
0.40	8.33	83.3
0.50	6.67	66.7
0.51	6.54	65.4
0.52	6.41	64.1
0.53	6.29	62.9
0.54	6.17	61.7
0.55	6.06	60.6
0.56	5.95	59.5
0.57	5.85	58.5
0.58	5.75	57.5
0.5852	5.70	57.0
0.59	5.65	56.5
0.60	5.56	55.6
0.61	5.46	54.6

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Table 44–3—Conversion table for cable delays *(continued)*

Speed relative to *c*	ns/m	BT/m
0.62	5.38	53.8
0.63	5.29	52.9
0.64	5.21	52.1
0.65	5.13	51.3
0.654	5.10	51.0
0.66	5.05	50.5
0.666	5.01	50.1
0.67	4.98	49.8
0.68	4.90	49.0
0.69	4.83	48.3
0.7	4.76	47.6
0.8	4.17	41.7
0.9	3.70	37.0

44.4 Protocol implementation conformance statement (PICS) proforma

The supplier of a protocol implementation that is claimed to conform to any part of IEEE Std 802.3, Clause 45 through Clause 55 and Clause 68, demonstrates compliance by completing a protocol implementation conformance statement (PICS) proforma.

A completed PICS proforma is the PICS for the implementation in question. The PICS is a statement of which capabilities and options of the protocol have been implemented. A PICS is included at the end of each clause as appropriate. Each of the 10 Gigabit Ethernet PICS conforms to the same notation and conventions used in 100BASE-T (see 21.6).

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45. Management Data Input/Output (MDIO) Interface

45.1 Overview

This clause defines the logical and electrical characteristics of an extension to the two signal Management Data Input/Output (MDIO) Interface specified in Clause 22.

The purpose of this extension is to provide the ability to access more device registers while still retaining logical compatibility with the MDIO interface defined in Clause 22. Clause 22 specifies the MDIO frame format and uses an ST code of 01 to access registers. In this clause, additional registers are added to the address space by defining MDIO frames that use an ST code of 00.

This extension to the MDIO interface is applicable to the following:

— Implementations that operate at speeds of 10 Gb/s and above.
— Implementations of 10PASS-TS and 2BASE-TL subscriber network Physical Layer devices.
— Implementations of 10, 100, or 1000 Mb/s with additional management functions beyond those defined in Clause 22.

The MDIO electrical interface is optional. Where no physical embodiment of the MDIO exists, provision of an equivalent mechanism to access the registers is recommended.

Throughout this clause, an “a.b.c” format is used to identify register bits, where “a” is the device address, “b” is the register address, and “c” is the bit number within the register.

45.1.1 Summary of major concepts

The following are major concepts of the MDIO Interface:

a) Preserve the management frame structure defined in 22.2.4.5.
b) Define a mechanism to address more registers than specified in 22.2.4.5.
c) Define ST and OP codes to identify and control the extended access functions.
d) Provide an electrical interface specification that is compatible with common digital CMOS ASIC processes.

45.1.2 Application

This clause defines a management interface between Station Management (STA) and the sublayers that form a Physical Layer device (PHY) entity. Where a sublayer, or grouping of sublayers, is an individually manageable entity, it is known as an MDIO Manageable Device (MMD). This clause allows a single STA, through a single MDIO interface, to access up to 32 PHYs (defined as PRTAD in the frame format defined in 45.3) consisting of up to 32 MMDs as shown in Figure 45–1. The MDIO interface can support up to a maximum of 65 536 registers in each MMD.

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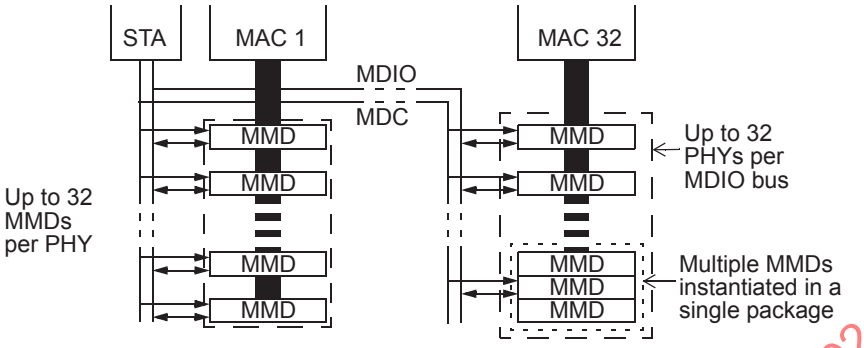

Figure 45–1—DTE and MMD devices

45.2 MDIO Interface Registers

The management interface specified in Clause 22 provides a simple, two signal, serial interface to connect a Station Management entity and a managed PHY for providing access to management parameters and services. The interface is referred to as the MII management interface.

The MDIO interface is based on the MII management interface, but differs from it in several ways. The MDIO interface uses indirect addressing to create an extended address space allowing a much larger number of registers to be accessed within each MMD. The MDIO address space is orthogonal to the MII management interface address space. The mechanism for the addressing is defined in 45.3. The MDIO electrical interface operates at lower voltages than those specified for the MII management interface. The electrical interface is specified in 45.4. For cases where a single entity combines Clause 45 MMDs with Clause 22 registers, then the Clause 22 registers may be accessed using the Clause 45 electrical interface and the Clause 22 management frame structure. The list of possible MMDs is shown in Table 45–1. The PHY XS and DTE XS devices are the two partner devices used to extend the interface that sits immediately below the Reconciliation Sublayer. For 10 Gigabit Ethernet, the interface extenders are defined as the XGXS devices. For 10PASS-TS and 2BASE-TL, control and monitoring of the TC sublayer is defined in the TC MMD. For 10, 100 and 1000 Mb/s PHYs, further management capability is defined in the Clause 22 extension MMD.

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Table 45–1—MDIO Manageable Device addresses

Device address	MMD name
0	Reserved
1	PMA/PMD
2	WIS
3	PCS
4	PHY XS
5	DTE XS
6	TC

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Table 45–1—MDIO Manageable Device addresses *(continued)*

Device address	MMD name
7	Auto-Negotiation
8	Separated PMA (1)
9	Separated PMA (2)
10	Separated PMA (3)
11	Separated PMA (4)
12 through 28	Reserved
29	Clause 22 extension
30	Vendor specific 1
31	Vendor specific 2

10PASS-TS and 2BASE-TL each have two port subtypes, 10PASS-TS-O, 10PASS-TS-R, 2BASE-TL-O and 2BASE-TL-R. Hereafter, referred to generically as -O and -R. The -O subtype corresponds to the port located at the service provider end of a subscriber link (the central office end). The -R subtype corresponds to the port located at the subscriber end of a subscriber link (the remote end). See 61.1 for more information.

Some register behavior may differ based on the port subtype. In the case where a register's behavior or definition differs between port subtypes, it is noted in the register description and in the bit definition tables (denoted by "O:" and "R:" in the R/W column).

The Clause 22 extension MMD allows new features to be added to 10, 100, and 1000 Mb/s PHYs beyond those already defined in Clause 22.

If a device supports the MDIO interface it shall respond to all possible register addresses for the device and return a value of zero for undefined and unsupported registers. Writes to undefined registers and read-only registers shall have no effect. The operation of an MMD shall not be affected by writes to reserved and unsupported register bits, and such register bits shall return a value of zero when read.

In the case of two registers that together form a 32-bit counter, whenever the most significant 16-bit register of the counter is read, the 32-bit counter value is latched into the register pair, the value being latched before the contents of the most significant 16 bits are driven on the MDIO interface and the contents of both registers is cleared to all zeros. A subsequent read from the least significant 16-bit register will return the least significant 16 bits of the latched value, but will not change the contents of the register pair. Writing to these registers has no effect. Counters that adhere to this behavior are marked in their bit definition tables with the tag "MW = Multi-word".

To ensure compatibility with future use of reserved bits and registers, the Management Entity should write to reserved bits with a value of zero and ignore reserved bits on read.

Some of the bits within MMD registers are defined as latching low (LL) or latching high (LH). When a bit is defined as latching low and the condition for the bit to be low has occurred, the bit shall remain low until after it has been read via the management interface. Once such a read has occurred, the bit shall assume a value based on the current state of the condition it monitors. When a bit is defined as latching high and the condition for the bit to be high has occurred, the bit shall remain high until after it has been read via the management interface. Once such a read has occurred, the bit shall assume a value based on the current state of the condition it monitors.

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For multi-bit fields, the lowest numbered bit of the field in the register corresponds to the least significant bit of the field.

Figure 45–2 describes the signal terminology used for the MMDs.

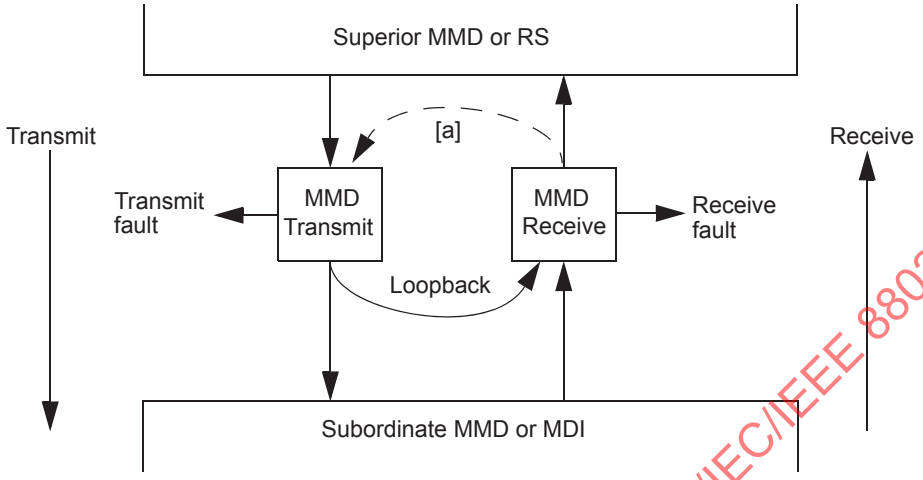

Figure 45–2—MMD signal terminology

[a] Direction of the optional PHY XS loopback

Each MMD contains registers 5 and 6, as defined in Table 45–2. Bits read as a one in this register indicate which MMDs are instantiated within the same package as the MMD being accessed. Bit 5.0 is used to indicate that Clause 22 functionality has been implemented within a Clause 45 electrical interface device. Bit 6.13 indicates that Clause 22 functionality is extended using the Clause 45 electrical interface through MMD 29. The definition of the term package is vendor specific and could be a chip, module, or other similar entity.

Table 45–2—Devices in package registers bit definitions

Bit(s)[a]	Name	Description	R/W[b]
m.6.15	Vendor-specific device 2 present	1 = Vendor-specific device 2 present in package 0 = Vendor-specific device 2 not present in package	RO
m.6.14	Vendor-specific device 1 present	1 = Vendor-specific device 1 present in package 0 = Vendor-specific device 1 not present in package	RO
m.6.13	Clause 22 extension present	1 = Clause 22 extension present in package 0 = Clause 22 extension not present in package	RO
m.6.12:0	Reserved	Value always 0	RO
m.5.15:12	Reserved	Value always 0	RO
m.5.11	Separated PMA (4) present	1 = Separated PMA[c] (4) present in package 0 = Separated PMA (4) not present in package	RO
m.5.10	Separated PMA (3) present	1 = Separated PMA (3) present in package 0 = Separated PMA (3) not present in package	RO

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Table 45–2—Devices in package registers bit definitions *(continued)*

Bit(s)[a]	Name	Description	R/W[b]
m.5.9	Separated PMA (2) present	1 = Separated PMA (2) present in package 0 = Separated PMA (2) not present in package	RO
m.5.8	Separated PMA (1) present	1 = Separated PMA (1) present in package 0 = Separated PMA (1) not present in package	RO
m.5.7	Auto-Negotiation present	1 = Auto-Negotiation present in package 0 = Auto-Negotiation not present in package	RO
m.5.6	TC present	1 = TC present in package 0 = TC not present in package	RO
m.5.5	DTE XS present	1 = DTE XS present in package 0 = DTE XS not present in package	RO
m.5.4	PHY XS present	1 = PHY XS present in package 0 = PHY XS not present in package	RO
m.5.3	PCS present	1 = PCS present in package 0 = PCS not present in package	RO
m.5.2	WIS present	1 = WIS present in package 0 = WIS not present in package	RO
m.5.1	PMD/PMA present	1 = PMA/PMD present in package 0 = PMA/PMD not present in package	RO
m.5.0	Clause 22 registers present	1 = Clause 22 registers present in package 0 = Clause 22 registers not present in package	RO

[a]m = address of MMD accessed (see Table 45–1)
[b]RO = Read only
[c]Separated PMAs are defined in 45.2.1

45.2.1 PMA/PMD registers

For devices operating at 40 Gb/s or higher speeds, the PMA may be instantiated as multiple sublayers (see 83.1.4 for how MMD addresses are allocated to multiple PMA sublayers). A PMA sublayer that is packaged with the PMD is addressed as MMD 1. More addressable instances of PMA sublayers, each one separated from lower addressable instances, may be implemented and addressed as MMD 8, 9, 10, and 11 where MMD 8 is the closest to the PMD and MMD 11 is the furthest from the PMD. The addresses and functions of all registers in MMD 8, 9, 10 and 11 are defined identically to MMD 1, except registers m.5 and m.6 as defined in Table 45–2.

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The assignment of registers in the PMA/PMD is shown in Table 45–3.

Table 45–3—PMA/PMD registers

Register address	Register name	Subclause
1.0	PMA/PMD control 1	45.2.1.1
1.1	PMA/PMD status 1	45.2.1.2
1.2, 1.3	PMA/PMD device identifier	45.2.1.3
1.4	PMA/PMD speed ability	45.2.1.4
1.5, 1.6	PMA/PMD devices in package	45.2.1.5
1.7	PMA/PMD control 2	45.2.1.6
1.8	PMA/PMD status 2	45.2.1.7
1.9	PMA/PMD transmit disable	45.2.1.8
1.10	PMD receive signal detect	45.2.1.9
1.11	PMA/PMD extended ability	45.2.1.10
1.12	10G-EPON PMA/PMD ability	45.2.1.11
1.13	40G/100G PMA/PMD extended ability	45.2.1.12
1.14, 1.15	PMA/PMD package identifier	45.2.1.13
1.16	EEE capability	45.2.1.14
1.17 through 1.29	Reserved	
1.30	10P/2B PMA/PMD control	45.2.1.15
1.31	10P/2B PMA/PMD status	45.2.1.16
1.32	10P/2B link partner PMA/PMD control[a]	45.2.1.17
1.33	10P/2B link partner PMA/PMD status[a]	45.2.1.18
1.34, 1.35	Reserved	
1.36	10P/2B link loss counter	45.2.1.19
1.37	10P/2B RX SNR margin	45.2.1.20
1.38	10P/2B link partner RX SNR margin[a]	45.2.1.21
1.39	10P/2B line attenuation	45.2.1.22
1.40	10P/2B link partner line attenuation[a]	45.2.1.23
1.41	10P/2B line quality thresholds	45.2.1.24
1.42	2B link partner line quality thresholds[a]	45.2.1.25
1.43	10P FEC correctable errors counter	45.2.1.26
1.44	10P FEC uncorrectable errors counter	45.2.1.27
1.45	10P link partner FEC correctable errors[a]	45.2.1.28
1.46	10P link partner FEC uncorrectable errors[a]	45.2.1.29
1.47	10P electrical length	45.2.1.30
1.48	10P link partner electrical length[a]	45.2.1.31
1.49	10P PMA/PMD general configuration[a]	45.2.1.32
1.50	10P PSD configuration[a]	45.2.1.33
1.51, 1.52	10P downstream data rate configuration[a]	45.2.1.34

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Table 45–3—PMA/PMD registers *(continued)*

Register address	Register name	Subclause
1.53	10P downstream Reed-Solomon configuration[a]	45.2.1.35
1.54, 1.55	10P upstream data rate[a]	45.2.1.36
1.56	10P upstream Reed-Solomon configuration[a]	45.2.1.37
1.57, 1.58	10P tone group	45.2.1.38
1.59, 1.60, 1.61, 1.62, 1.63	10P tone control parameters[a]	45.2.1.39
1.64	10P tone control action[a]	45.2.1.40
1.65, 1.66, 1.67	10P tone status	45.2.1.41
1.68	10P outgoing indicator bits	45.2.1.42
1.69	10P incoming indicator bits	45.2.1.43
1.70	10P cyclic extension configuration	45.2.1.44
1.71	10P attainable downstream data rate	45.2.1.45
1.72 through 1.79	Reserved	
1.80	2B general parameter	45.2.1.46
1.81 through 1.88	2B PMD parameters	45.2.1.47
1.89	2B code violation errors counter	45.2.1.48
1.90	2B link partner code violation errors[a]	45.2.1.49
1.91	2B errored seconds counter	45.2.1.50
1.92	2B link partner errored seconds[a]	45.2.1.51
1.93	2B severely errored seconds counter	45.2.1.52
1.94	2B link partner severely errored seconds[a]	45.2.1.53
1.95	2B LOSW counter	45.2.1.54
1.96	2B link partner LOSW[a]	45.2.1.55
1.97	2B unavailable seconds counter	45.2.1.56
1.98	2B link partner unavailable seconds[a]	45.2.1.57
1.99	2B state defects	45.2.1.58
1.100	2B link partner state defects[a]	45.2.1.59
1.101	2B negotiated constellation	45.2.1.60
1.102 through 1.109	2B extended PMD parameters	45.2.1.61
1.110 through 1.128	Reserved	
1.129	10GBASE-T status	45.2.1.62
1.130	10GBASE-T pair swap and polarity	45.2.1.63
1.131	10GBASE-T TX power backoff and PHY short reach setting	45.2.1.64
1.132	10GBASE-T test mode	45.2.1.65
1.133	10GBASE-T SNR operating margin channel A	45.2.1.66
1.134	10GBASE-T SNR operating margin channel B	45.2.1.67
1.135	10GBASE-T SNR operating margin channel C	45.2.1.68
1.136	10GBASE-T SNR operating margin channel D	45.2.1.69

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Table 45–3—PMA/PMD registers *(continued)*

Register address	Register name	Subclause
1.137	10GBASE-T minimum margin channel A	45.2.1.70
1.138	10GBASE-T minimum margin channel B	45.2.1.71
1.139	10GBASE-T minimum margin channel C	45.2.1.72
1.140	10GBASE-T minimum margin channel D	45.2.1.73
1.141	10GBASE-T RX signal power channel A	45.2.1.74
1.142	10GBASE-T RX signal power channel B	45.2.1.75
1.143	10GBASE-T RX signal power channel C	45.2.1.76
1.144	10GBASE-T RX signal power channel D	45.2.1.77
1.145 through 1.146	10GBASE-T skew delay	45.2.1.78
1.147	10GBASE-T fast retrain status and control register	45.2.1.79
1.148 through 1.149	Reserved	
1.150	BASE-R PMD control	45.2.1.80
1.151	BASE-R PMD status	45.2.1.81
1.152	BASE-R LP coefficient update, lane 0	45.2.1.82
1.153	BASE-R LP status report, lane 0	45.2.1.83
1.154	BASE-R LD coefficient update, lane 0	45.2.1.84
1.155	BASE-R LD status report, lane 0	45.2.1.85
1.156	BASE-R PMD status 2	45.2.1.86
1.157	BASE-R PMD status 3	45.2.1.87
1.158 through 1.159	Reserved	
1.160	1000BASE-KX control	45.2.1.88
1.161	1000BASE-KX status	45.2.1.89
1.162 through 1.164	PMA overhead control 1, 2, and 3 registers	45.2.1.90
1.165, 1.166	PMA overhead status 1 and 2 registers	45.2.1.91
1.167 through 1.169	Reserved	
1.170	BASE-R FEC ability	45.2.1.92
1.171	BASE-R FEC control	45.2.1.93
1.172 through 1.173	10GBASE-R FEC corrected blocks counter	45.2.1.94
1.174 through 1.175	10GBASE-R FEC uncorrected blocks counter	45.2.1.95
1.176 through 1.178	Reserved	
1.179	CAUI-4 chip-to-module recommended CTLE	45.2.1.96
1.180 through 1.183	CAUI-4 chip-to-chip transmitter equalization, receive direction, lane 0 through lane 3	45.2.1.97, 45.2.1.98
1.184 through 1.187	CAUI-4 chip-to-chip transmitter equalization, transmit direction, lane 0 through lane 3	45.2.1.99, 45.2.1.100
1.188 through 1.199	Reserved	
1.200	RS-FEC control register	45.2.1.101

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Table 45–3—PMA/PMD registers *(continued)*

Register address	Register name	Subclause
1.201	RS-FEC status register	45.2.1.102
1.202, 1.203	RS-FEC corrected codewords counter	45.2.1.103
1.204, 1.205	RS-FEC uncorrected codewords counter	45.2.1.104
1.206	RS-FEC lane mapping register	45.2.1.105
1.207 through 1.209	Reserved	
1.210 through 1.217	RS-FEC symbol error counter, lane 0 to 3	45.2.1.106, 45.2.1.107
1.218 through 1.229	Reserved	
1.230 through 1.249	RS-FEC BIP error counter, lane 0 to 19	45.2.1.108, 45.2.1.109
1.250 through 1.269	RS-FEC PCS lane mapping, lane 0 to 19	45.2.1.110, 45.2.1.111
1.270 through 1.279	Reserved	
1.280 through 1.283	RS-FEC PCS alignment status 1 through 4	45.2.1.112 to 45.2.1.115
1.284 through 1.299	Reserved	
1.300 through 1.339	BASE-R FEC corrected blocks counter, lanes 0 through 19	45.2.1.116
1.340 through 1.699	Reserved	
1.700 through 1.739	BASE-R FEC uncorrected blocks counter, lanes 0 through 19	45.2.1.117
1.740 through 1.1099	Reserved	
1.1100	BASE-R LP coefficient update, lane 0 (copy)	45.2.1.82
1.1101 through 1.1109	BASE-R LP coefficient update, lanes 1 through 9	45.2.1.118
1.1110 through 1.1199	Reserved	
1.1200	BASE-R LP status report, lane 0 (copy)	45.2.1.83
1.1201 through 1.1209	BASE-R LP status report, lanes 1 through 9	45.2.1.119
1.1210 through 1.1299	Reserved	
1.1300	BASE-R LD coefficient update, lane 0 (copy)	45.2.1.84
1.1301 through 1.1309	BASE-R LD coefficient update, lanes 1 through 9	45.2.1.120
1.1310 through 1.1399	Reserved	
1.1400	BASE-R LD status report, lane 0 (copy)	45.2.1.85
1.1401 through 1.1409	BASE-R LD status report, lanes 1 through 9	45.2.1.121
1.1410 through 1.1449	Reserved	
1.1450 through 1.1453	PMD training pattern, lanes 0 to 3	45.2.1.122
1.1454 through 1.1499	Reserved	
1.1500	Test-pattern ability	45.2.1.123
1.1501	PRBS pattern testing control	45.2.1.124
1.1502 through 1.1509	Reserved	
1.1510	Square wave testing control	45.2.1.125

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Table 45–3—PMA/PMD registers *(continued)*

Register address	Register name	Subclause
1.1511 through 1.1599	Reserved	
1.1600 through 1.1609	PRBS Tx error counters, lane 0 through lane 9	45.2.1.126
1.1610 through 1.1699	Reserved	
1.1700 through 1.1709	PRBS Rx error counters, lane 0 through lane 9	45.2.1.127
1.1710 through 1.1799	Reserved	
1.1800	TimeSync PMA/PMD capability	45.2.1.128
1.1801 through 1.1804	TimeSync PMA/PMD transmit path data delay	45.2.1.129
1.1805 through 1.1808	TimeSync PMA/PMD receive path data delay	45.2.1.130
1.1809 through 1.32767	Reserved	
1.32 768 through 1.65 535	Vendor specific	

[a]Register is defined only for -O port types and is reserved for -R ports.

45.2.1.1 PMA/PMD control 1 register (Register 1.0)

The assignment of bits in the PMA/PMD control 1 register is shown in Table 45–4. The default value for each bit of the PMA/PMD control 1 register has been chosen so that the initial state of the device upon power up or completion of reset is a normal operational state without management intervention.

Table 45–4—PMA/PMD control 1 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.0.15	Reset	1 = PMA/PMD reset 0 = Normal operation	R/W SC
1.0.14	Reserved	Value always 0	RO
1.0.13	Speed selection (LSB)	1.0.6 1.0.13 1 1 = bits 5:2 select speed 1 0 = 1000 Mb/s 0 1 = 100 Mb/s 0 0 = 10 Mb/s	R/W
1.0.12	Reserved	Value always 0	RO
1.0.11	Low power	1 = Low-power mode 0 = Normal operation	R/W
1.0.10:7	Reserved	Value always 0	RO
1.0.6	Speed selection (MSB)	1.0.6 1.0.13 1 1 = bits 5:2 select speed 1 0 = 1000 Mb/s 0 1 = 100 Mb/s 0 0 = 10 Mb/s	R/W

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Table 45–4—PMA/PMD control 1 register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
1.0.5:2	Speed selection	5 4 3 2 1 x x x = Reserved x 1 x x = Reserved 0 0 1 1 = 100 Gb/s 0 0 1 0 = 40 Gb/s 0 0 0 1 = 10PASS-TS/2BASE-TL 0 0 0 0 = 10 Gb/s	R/W
1.0.1	PMA remote loopback	1 = Enable PMA remote loopback mode 0 = Disable PMA remote loopback mode	R/W
1.0.0	PMA local loopback	1 = Enable PMA local loopback mode 0 = Disable PMA local loopback mode	R/W

[a]R/W = Read/Write, SC = Self-clearing, RO = Read only

45.2.1.1.1 Reset (1.0.15)

Resetting a PMA/PMD is accomplished by setting bit 1.0.15 to a one. This action shall set all PMA/PMD registers to their default states. As a consequence, this action may change the internal state of the PMA/PMD and the state of the physical link. This action may also initiate a reset in any other MMDs that are instantiated in the same package. This bit is self-clearing, and a PMA/PMD shall return a value of one in bit 1.0.15 when a reset is in progress; otherwise, it shall return a value of zero. A PMA/PMD is not required to accept a write transaction to any of its registers until the reset process is completed. The control and management interface shall be restored to operation within 0.5 s from the setting of bit 1.0.15. During a reset, a PMD/PMA shall respond to reads from register bits 1.0.15 and 1.8.15:14. All other register bits should be ignored.

NOTE—This operation may interrupt data communication. The data path of a PMD, depending on type and temperature, may take many seconds to run at optimum error ratio after exiting from reset or low-power mode.

45.2.1.1.2 Low power (1.0.11)

A PMA/PMD may be placed into a low-power mode by setting bit 1.0.11 to a one. This action may also initiate a low-power mode in any other MMDs that are instantiated in the same package. The low-power mode is exited by resetting the PMA/PMD. The behavior of the PMA/PMD in transition to and from the low-power mode is implementation specific and any interface signals should not be relied upon. While in the low-power mode, the device shall, as a minimum, respond to management transactions necessary to exit the low-power mode. The default value of bit 1.0.11 is zero.

NOTE—This operation will interrupt data communication. The data path of a PMD, depending on type and temperature, may take many seconds to run at optimum error ratio after exiting from reset or low-power mode.

45.2.1.1.3 Speed selection (1.0.13, 1.0.6, 1.0.5:2)

For devices operating at 10 Mb/s, 100 Mb/s, or 1000 Mb/s the speed of the PMA/PMD may be selected using bits 13 and 6. The speed abilities of the PMA/PMD are advertised in the PMA/PMD speed ability register. These two bits use the same definition as the speed selection bits defined in Clause 22.

For devices not operating at 10 Mb/s, 100 Mb/s, or 1000 Mb/s, the speed of the PMA/PMD may be selected using bits 5 through 2. When bits 5 through 2 are set to 0000 the use of a 10G PMA/PMD is selected. More specific selection is performed using the PMA/PMD control 2 register (Register 1.7) (see 45.2.1.6). The

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speed abilities of the PMA/PMD are advertised in the PMA/PMD speed ability register. A PMA/PMD may ignore writes to the PMA/PMD speed selection bits that select speeds it has not advertised in the PMA/PMD speed ability register. It is the responsibility of the STA entity to ensure that mutually acceptable speeds are applied consistently across all the MMDs on a particular PHY.

The PMA/PMD speed selection defaults to a supported ability.

When set to 0001, bits 5:2 select the use of the 10PASS-TS or 2BASE-TL PMA/PMD. More specific mode selection is performed using the 10P/2B PMA control register (45.2.1.15).

When bits 5 through 2 are set to 0010 the use of a 40G PMA/PMD is selected; when set to 0011 the use of a 100G PMA/PMD is selected. More specific selection is performed using the PMA/PMD control 2 register (Register 1.7) (see 45.2.1.6.3).

45.2.1.1.4 PMA remote loopback (1.0.1)

The PMA shall be placed in a remote loopback mode of operation when bit 1.0.1 is set to a one. When bit 1.0.1 is set to a one, the PMA shall accept data on the receive path and return it on the transmit path.

The remote loopback function is optional for all port types, except 2BASE-TL and 10PASS-TS, which do not support loopback. A device's ability to perform the remote loopback function is advertised in the remote loopback ability bit of the related speed-dependent status register. A PMA that is unable to perform the remote loopback function shall ignore writes to this bit and shall return a value of zero when read. For 40/100 Gb/s operation, the remote loopback functionality is detailed in 83.5.9. For 40/100 Gb/s operation, the remote loopback ability bit is specified in the 40G/100G PMA/PMD extended ability register.

The default value of bit 1.0.1 is zero.

45.2.1.1.5 PMA local loopback (1.0.0)

The PMA shall be placed in a local loopback mode of operation when bit 1.0.0 is set to a one. When bit 1.0.0 is set to a one, the PMA shall accept data on the transmit path and return it on the receive path.

The local loopback function is mandatory for the 1000BASE-KX, 10GBASE-KR, 10GBASE-X, 40GBASE-KR4, 40GBASE-CR4, and 100GBASE-CR10 port type and optional for all other port types, except 2BASE-TL, 10PASS-TS, and 10/1GBASE-PRX, which do not support loopback. A device's ability to perform the local loopback function is advertised in the local loopback ability bit of the related speed-dependent status register. A PMA that is unable to perform the local loopback function shall ignore writes to this bit and shall return a value of zero when read. For 10 Gb/s operation, the local loopback functionality is detailed in 48.3.3 and 51.8. For 40/100 Gb/s operation, the local loopback functionality is detailed in 83.5.8. For 10/40/100 Gb/s operation, the local loopback ability bit is specified in the PMA/PMD status 2 register.

The default value of bit 1.0.0 is zero.

NOTE—The signal path through the PMA that is exercised in the loopback mode of operation is implementation specific, but it is recommended that the signal path encompass as much of the PMA circuitry as is practical. The intention of providing this loopback mode of operation is to permit a diagnostic or self-test function to perform the transmission and reception of a PDU, thus testing the transmit and receive data paths. Other loopback signal paths may be enabled using loopback controls within other MMDs.

45.2.1.2 PMA/PMD status 1 register (Register 1.1)

The assignment of bits in the PMA/PMD status 1 register is shown in Table 45–5. All the bits in the PMA/PMD status 1 register are read only; therefore, a write to the PMA/PMD status 1 register shall have no effect.

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Table 45–5—PMA/PMD status 1 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1.15:10	Reserved	Value always 0	RO
1.1.9	PIASA	PMA ingress AUI stop ability	RO
1.1.8	PEASA	PMA egress AUI stop ability	RO
1.1.7	Fault	1 = Fault condition detected 0 = Fault condition not detected	RO
1.1.6:3	Reserved	Value always 0	RO
1.1.2	Receive link status	1 = PMA/PMD receive link up 0 = PMA/PMD receive link down	RO/LL
1.1.1	Low-power ability	1 = PMA/PMD supports low-power mode 0 = PMA/PMD does not support low-power mode	RO
1.1.0	Reserved	Value always 0	RO

[a]RO = Read only, LL = Latching low

45.2.1.2.1 PMA ingress AUI stop ability (1.1.9)

If bit 1.1.9 is set to one, then the PMA is indicating that the PMA sublayer attached by the ingress AUI is permitted to stop signaling during LPI. If the bit is set to zero, then the PMA is indicating that the PMA sublayer attached by the ingress AUI is not permitted to stop signaling during LPI. If the PMA sublayer attached by the ingress AUI does not support EEE capability or is not capable to stop signaling, then this bit has no effect.

45.2.1.2.2 PMA egress AUI stop ability (1.1.8)

If bit 1.1.8 is set to one, then the PMA is indicating that the PMA sublayer attached by the egress AUI is permitted to stop signaling during LPI. If the bit is set to zero, then the PMA is indicating that the PMA sublayer attached by the egress AUI is not permitted to stop signaling during LPI. If the PMA sublayer attached by the egress AUI does not support EEE capability or is not capable to stop signaling, then this bit has no effect.

45.2.1.2.3 Fault (1.1.7)

Fault is a global PMA/PMD variable. When read as a one, bit 1.1.7 indicates that either (or both) the PMA or the PMD has detected a fault condition on either the transmit or receive paths. When read as a zero, bit 1.1.7 indicates that neither the PMA nor the PMD has detected a fault condition. For 10/40/100 Gb/s operation, bit 1.1.7 is set to a one when either of the fault bits (1.8.11, 1.8.10) located in register 1.8 are set to a one. For 10PASS-TS or 2BASE-TL operations, when read as a one, a fault has been detected and more detailed information is conveyed in 45.2.1.19, 45.2.1.42, 45.2.1.43, and 45.2.1.58.

45.2.1.2.4 Receive link status (1.1.2)

When read as a one, bit 1.1.2 indicates that the PMA/PMD receive link is up. When read as a zero, bit 1.1.2 indicates that the PMA/PMD receive link is down. The receive link status bit shall be implemented with latching low behavior.

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While a 10PASS-TS or 2BASE-TL PMA/PMD is initializing, this bit shall indicate receive link down (see 45.2.1.16).

45.2.1.2.5 Low-power ability (1.1.1)

When read as a one, bit 1.1.1 indicates that the PMA/PMD supports the low-power feature. When read as a zero, bit 1.1.1 indicates that the PMA/PMD does not support the low-power feature. If a PMA/PMD supports the low-power feature, then it is controlled using the low-power bit 1.0.11.

45.2.1.3 PMA/PMD device identifier (Registers 1.2 and 1.3)

Registers 1.2 and 1.3 provide a 32-bit value, which may constitute a unique identifier for a particular type of PMA/PMD. The identifier shall be composed of the 3rd through 24th bits of the Organizationally Unique Identifier (OUI) assigned to the device manufacturer by the IEEE, plus a six-bit model number, plus a four-bit revision number.

A PMA/PMD may return a value of zero in each of the 32 bits of the PMA/PMD device identifier to indicate that a unique identifier as described above is not provided.

The format of the PMA/PMD device identifier is specified in 22.2.4.3.1.

NOTE—The use of only 22 bits of the OUI as described here has been deprecated by the IEEE Registration Authority. The definition of vendor-specific device identifiers for other applications is expected to use the full 24 bits to accommodate the use of either an OUI or Company ID.

45.2.1.4 PMA/PMD speed ability (Register 1.4)

The assignment of bits in the PMA/PMD speed ability register is shown in Table 45–6.

Table 45–6—PMA/PMD speed ability register bit definitions

Bit(s)	Name	Description	R/W[a]
1.4.15:10	Reserved for future speeds	Value always 0	RO
1.4.9	100G capable	1 = PMA/PMD is capable of operating at 100 Gb/s 0 = PMA/PMD is not capable of operating as 100 Gb/s	RO
1.4.8	40G capable	1 = PMA/PMD is capable of operating at 40 Gb/s 0 = PMA/PMD is not capable of operating as 40 Gb/s	RO
1.4.7	10/1G capable	1 = PMA/PMD is capable of operating at 10 Gb/s downstream and 1 Gb/s upstream 0 = PMA/PMD is not capable of operating at 10 Gb/s downstream and 1 Gb/s upstream.	RO
1.4.6	10M capable	1 = PMA/PMD is capable of operating at 10 Mb/s 0 = PMA/PMD is not capable of operating as 10 Mb/s	RO
1.4.5	100M capable	1 = PMA/PMD is capable of operating at 100 Mb/s 0 = PMA/PMD is not capable of operating at 100 Mb/s	RO
1.4.4	1000M capable	1 = PMA/PMD is capable of operating at 1000 Mb/s 0 = PMA/PMD is not capable of operating at 1000 Mb/s	RO
1.4.3	Reserved	Value always 0	RO
1.4.2	10PASS-TS capable	1 = PMA/PMD is capable of operating as 10PASS-TS 0 = PMA/PMD is not capable of operating as 10PASS-TS	RO

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Table 45–6—PMA/PMD speed ability register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
1.4.1	2BASE-TL capable	1 = PMA/PMD is capable of operating as 2BASE-TL 0 = PMA/PMD is not capable of operating as 2BASE-TL	RO
1.4.0	10G capable	1 = PMA/PMD is capable of operating at 10 Gb/s 0 = PMA/PMD is not capable of operating at 10 Gb/s	RO

[a]RO = Read only

45.2.1.4.1 100G capable (1.4.9)

When read as a one, bit 1.4.9 indicates that the PMA/PMD is able to operate at a data rate of 100 Gb/s. When read as a zero, bit 1.4.9 indicates that the PMA/PMD is not able to operate at a data rate of 100 Gb/s.

45.2.1.4.2 40G capable (1.4.8)

When read as a one, bit 1.4.8 indicates that the PMA/PMD is able to operate at a data rate of 40 Gb/s. When read as a zero, bit 1.4.8 indicates that the PMA/PMD is not able to operate at a data rate of 40 Gb/s.

45.2.1.4.3 10/1G capable (1.4.7)

When read as a one, bit 1.4.7 indicates that the PMA/PMD is able to operate at a data rate of 10 Gb/s in the downstream direction and 1 Gb/s in the upstream direction. When read as a zero, bit 1.4.7 indicates that the PMA/PMD is not able to operate at a data rate of 10 Gb/s in the downstream direction and 1 Gb/s in the upstream direction.

45.2.1.4.4 10M capable (1.4.6)

When read as a one, bit 1.4.6 indicates that the PMA/PMD is able to operate at a data rate of 10 Mb/s. When read as a zero, bit 1.4.6 indicates that the PMA/PMD is not able to operate at a data rate of 10 Mb/s.

45.2.1.4.5 100M capable (1.4.5)

When read as a one, bit 1.4.5 indicates that the PMA/PMD is able to operate at a data rate of 100 Mb/s. When read as a zero, bit 1.4.5 indicates that the PMA/PMD is not able to operate at a data rate of 100 Mb/s.

45.2.1.4.6 1000M capable (1.4.4)

When read as a one, bit 1.4.4 indicates that the PMA/PMD is able to operate at a data rate of 1000 Mb/s. When read as a zero, bit 1.4.4 indicates that the PMA/PMD is not able to operate at a data rate of 1000 Mb/s.

45.2.1.4.7 10PASS-TS capable (1.4.2)

When read as a one, bit 1.4.2 indicates that the PMA/PMD is able to operate as 10PASS-TS. When read as a zero, bit 1.4.2 indicates that the PMA/PMD is not able to operate as 10PASS-TS.

45.2.1.4.8 2BASE-TL capable (1.4.1)

When read as a one, bit 1.4.1 indicates that the PMA/PMD is able to operate as 2BASE-TL. When read as a zero, bit 1.4.1 indicates that the PMA/PMD is not able to operate as 2BASE-TL.

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45.2.1.4.9 10G capable (1.4.0)

When read as a one, bit 1.4.0 indicates that the PMA/PMD is able to operate at a data rate of 10 Gb/s. When read as a zero, bit 1.4.0 indicates that the PMA/PMD is not able to operate at a data rate of 10 Gb/s.

45.2.1.5 PMA/PMD devices in package (Registers 1.5 and 1.6)

The PMA/PMD devices in package registers are defined in Table 45–2.

45.2.1.6 PMA/PMD control 2 register (Register 1.7)

The assignment of bits in the PMA/PMD control 2 register is shown in Table 45–7.

45.2.1.6.1 PMA ingress AUI stop enable (1.7.9)

If bit 1.7.9 is set to 1 then the PMA may stop the ingress direction AUI signaling during LPI otherwise it shall keep active signaling on that AUI. If the PMA does not support EEE capability or is not able to stop the ingress direction AUI signaling (see 45.2.1.2.1) then this bit has no effect.

45.2.1.6.2 PMA egress AUI stop enable (1.7.8)

If bit 1.7.8 is set to 1 then the PMA may stop the egress direction AUI signaling during LPI otherwise it shall keep active signaling on that AUI. If the PMA does not support EEE capability or is not able to stop the egress direction AUI signaling (see 45.2.1.2.2) then this bit has no effect.

45.2.1.6.3 PMA/PMD type selection (1.7.5:0)

The PMA/PMD type of the PMA/PMD shall be selected using bits 5 to 0. The PMA/PMD type abilities of the PMA/PMD are advertised in bits 9 and 7 through 0 of the PMA/PMD status 2 register; the PMA/PMD extended ability register; and the 40G/100G PMA/PMD extended ability register. A PMA/PMD shall ignore writes to the PMA/PMD type selection bits that select PMA/PMD types it has not advertised. It is the responsibility of the STA entity to ensure that mutually acceptable MMD types are applied consistently across all the MMDs on a particular PHY.

The PMA/PMD type selection defaults to a supported ability.

45.2.1.7 PMA/PMD status 2 register (Register 1.8)

The assignment of bits in the PMA/PMD status 2 register is shown in Table 45–8. All the bits in the PMA/PMD status 2 register are read only; a write to the PMA/PMD status 2 register shall have no effect.

45.2.1.7.1 Device present (1.8.15:14)

When read as <10>, bits 1.8.15:14 indicate that a device is present and responding at this register address. When read as anything other than <10>, bits 1.8.15:14 indicate that no device is present at this register address or that the device is not functioning properly.

45.2.1.7.2 Transmit fault ability (1.8.13)

When read as a one, bit 1.8.13 indicates that the PMA/PMD has the ability to detect a fault condition on the transmit path. When read as a zero, bit 1.8.13 indicates that the PMA/PMD does not have the ability to detect a fault condition on the transmit path.

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Table 45–7—PMA/PMD control 2 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.7.15:10	Reserved	Value always 0	RO
1.7.9	PIASE	PMA ingress AUI stop enable	R/W
1.7.8	PEASE	PMA egress AUI stop enable	R/W
1.7.7:6	Reserved	Value always 0	RO
1.7.5:0	PMA/PMD type selection	5 4 3 2 1 0 1 1 x x x x = reserved 1 0 1 1 1 1 = 100GBASE-SR4 PMA/PMD 1 0 1 1 1 0 = 100GBASE-CR4 PMA/PMD 1 0 1 1 0 1 = 100GBASE-KR4 PMA/PMD 1 0 1 1 0 0 = 100GBASE-KP4 PMA/PMD 1 0 1 0 1 1 = 100GBASE-ER4 PMA/PMD 1 0 1 0 1 0 = 100GBASE-LR4 PMA/PMD 1 0 1 0 0 1 = 100GBASE-SR10 PMA/PMD 1 0 1 0 0 0 = 100GBASE-CR10 PMA/PMD 1 0 0 1 1 x = reserved 1 0 0 1 0 1 = 40GBASE-ER4 PMA/PMD 1 0 0 1 0 0 = 40GBASE-LR PMA/PMD 1 0 0 0 1 1 = 40GBASE-FR PMA/PMD 1 0 0 0 1 0 = 40GBASE-SR4 PMA/PMD 1 0 0 0 0 1 = 40GBASE-CR4 PMA/PMD 1 0 0 0 0 0 = 40GBASE-KR4 PMA/PMD 0 1 1 1 1 1 = 10/1GBASE-PRX-U4 0 1 1 1 1 0 = 10GBASE-PR-U4 0 1 1 1 0 1 = 10/1GBASE-PRX-D4 0 1 1 1 0 0 = 10GBASE-PR-D4 0 1 1 0 1 1 = reserved 0 1 1 0 1 0 = 10GBASE-PR-U3 0 1 1 0 0 1 = 10GBASE-PR-U1 0 1 1 0 0 0 = 10/1GBASE-PRX-U3 0 1 0 1 1 1 = 10/1GBASE-PRX-U2 0 1 0 1 1 0 = 10/1GBASE-PRX-U1 0 1 0 1 0 1 = 10GBASE-PR-D3 0 1 0 1 0 0 = 10GBASE-PR-D2 0 1 0 0 1 1 = 10GBASE-PR-D1 0 1 0 0 1 0 = 10/1GBASE-PRX-D3 0 1 0 0 0 1 = 10/1GBASE-PRX-D2 0 1 0 0 0 0 = 10/1GBASE-PRX-D1 0 0 1 1 1 1 = 10BASE-T PMA/PMD 0 0 1 1 1 0 = 100BASE-TX PMA/PMD 0 0 1 1 0 1 = 1000BASE-KX PMA/PMD 0 0 1 1 0 0 = 1000BASE-T PMA/PMD 0 0 1 0 1 1 = 10GBASE-KR PMA/PMD 0 0 1 0 1 0 = 10GBASE-KX4 PMA/PMD 0 0 1 0 0 1 = 10GBASE-T PMA 0 0 1 0 0 0 = 10GBASE-LRM PMA/PMD 0 0 0 1 1 1 = 10GBASE-SR PMA/PMD 0 0 0 1 1 0 = 10GBASE-LR PMA/PMD 0 0 0 1 0 1 = 10GBASE-ER PMA/PMD 0 0 0 1 0 0 = 10GBASE-LX4 PMA/PMD 0 0 0 0 1 1 = 10GBASE-SW PMA/PMD 0 0 0 0 1 0 = 10GBASE-LW PMA/PMD 0 0 0 0 0 1 = 10GBASE-EW PMA/PMD 0 0 0 0 0 0 = 10GBASE-CX4 PMA/PMD	R/W

[a]R/W = Read/Write, RO = Read only

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Table 45–8—PMA/PMD status 2 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.8.15:14	Device present	15 14 1 0 = Device responding at this address 1 1 = No device responding at this address 0 1 = No device responding at this address 0 0 = No device responding at this address	RO
1.8.13	Transmit fault ability	1 = PMA/PMD has the ability to detect a fault condition on the transmit path 0 = PMA/PMD does not have the ability to detect a fault condition on the transmit path	RO
1.8.12	Receive fault ability	1 = PMA/PMD has the ability to detect a fault condition on the receive path 0 = PMA/PMD does not have the ability to detect a fault condition on the receive path	RO
1.8.11	Transmit fault	1 = Fault condition on transmit path 0 = No fault condition on transmit path	RO/LH
1.8.10	Receive fault	1 = Fault condition on receive path 0 = No fault condition on receive path	RO/LH
1.8.9	Extended abilities	1 = PMA/PMD has extended abilities listed in register 1.11 0 = PMA/PMD does not have extended abilities	RO
1.8.8	PMD transmit disable ability	1 = PMD has the ability to disable the transmit path 0 = PMD does not have the ability to disable the transmit path	RO
1.8.7	10GBASE-SR ability	1 = PMA/PMD is able to perform 10GBASE-SR 0 = PMA/PMD is not able to perform 10GBASE-SR	RO
1.8.6	10GBASE-LR ability	1 = PMA/PMD is able to perform 10GBASE-LR 0 = PMA/PMD is not able to perform 10GBASE-LR	RO
1.8.5	10GBASE-ER ability	1 = PMA/PMD is able to perform 10GBASE-ER 0 = PMA/PMD is not able to perform 10GBASE-ER	RO
1.8.4	10GBASE-LX4 ability	1 = PMA/PMD is able to perform 10GBASE-LX4 0 = PMA/PMD is not able to perform 10GBASE-LX4	RO
1.8.3	10GBASE-SW ability	1 = PMA/PMD is able to perform 10GBASE-SW 0 = PMA/PMD is not able to perform 10GBASE-SW	RO
1.8.2	10GBASE-LW ability	1 = PMA/PMD is able to perform 10GBASE-LW 0 = PMA/PMD is not able to perform 10GBASE-LW	RO
1.8.1	10GBASE-EW ability	1 = PMA/PMD is able to perform 10GBASE-EW 0 = PMA/PMD is not able to perform 10GBASE-EW	RO
1.8.0	PMA local loopback ability	1 = PMA has the ability to perform a local loopback function 0 = PMA does not have the ability to perform a local loopback function	RO

[a]RO = Read only, LH = Latching high

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45.2.1.7.3 Receive fault ability (1.8.12)

When read as a one, bit 1.8.12 indicates that the PMA/PMD has the ability to detect a fault condition on the receive path. When read as a zero, bit 1.8.12 indicates that the PMA/PMD does not have the ability to detect a fault condition on the receive path.

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45.2.1.7.4 Transmit fault (1.8.11)

When read as a one, bit 1.8.11 indicates that the PMA/PMD has detected a fault condition on the transmit path. When read as a zero, bit 1.8.11 indicates that the PMA/PMD has not detected a fault condition on the transmit path. Detection of a fault condition on the transmit path is optional and the ability to detect such a condition is advertised by bit 1.8.13. A PMA/PMD that is unable to detect a fault condition on the transmit path shall return a value of zero for this bit. The description of the transmit fault function for the various PMA/PMDs is given in Table 45–9.

Table 45–9—Transmit fault description location

PMA/PMD	Description location
10GBASE-KR	72.6.8
10GBASE-LRM	68.4.8
10GBASE-S, 10GBASE-L, 10GBASE-E	52.4.8
10GBASE-LX4	53.4.10
10GBASE-CX4	54.5.10
10GBASE-T	55.4.2.2
10GBASE-KX4	71.6.10
40GBASE-KR4	84.7.10
40GBASE-CR4, 100GBASE-CR10	85.7.10
40GBASE-SR4, 100GBASE-SR10	86.5.10
40GBASE-LR4, 40GBASE-ER4	87.5.10
40GBASE-FR	89.5.8
100GBASE-KP4	94.3.8
100GBASE-KR4	93.7.10
100GBASE-CR4	92.7.10
100GBASE-SR4	95.5.10
100GBASE-LR4, 100GBASE-ER4	88.5.10

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The transmit fault bit shall be implemented with latching high behavior.

The default value of bit 1.8.11 is zero.

45.2.1.7.5 Receive fault (1.8.10)

When read as a one, bit 1.8.10 indicates that the PMA/PMD has detected a fault condition on the receive path. When read as a zero, bit 1.8.10 indicates that the PMA/PMD has not detected a fault condition on the

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receive path. Detection of a fault condition on the receive path is optional and the ability to detect such a condition is advertised by bit 1.8.12. A PMA/PMD that is unable to detect a fault condition on the receive path shall return a value of zero for this bit. The description of the receive fault function for the various PMA/PMDs is given in Table 45–10.

Table 45–10—Receive fault description location

PMA/PMD	Description location
10GBASE-KR	72.6.9
10GBASE-LRM	68.4.9
10GBASE-S, 10GBASE-L, 10GBASE-E	52.4.9
10GBASE-LX4	53.4.11
10GBASE-CX4	54.5.11
10GBASE-T	55.4.2.4
10GBASE-KX4	71.6.11
40GBASE-KR4	84.7.11
40GBASE-CR4, 100GBASE-CR10	85.7.11
40GBASE-SR4, 100GBASE-SR10	86.5.11
40GBASE-LR4, 40GBASE-ER4	87.5.11
40GBASE-FR	89.5.9
100GBASE-KP4	94.3.9
100GBASE-KR4	93.7.11
100GBASE-CR4	92.7.11
100GBASE-SR4	95.5.11
100GBASE-LR4, 100GBASE-ER4	88.5.11

The receive fault bit shall be implemented with latching high behavior.

45.2.1.7.6 PMA/PMD extended abilities (1.8.9)

When read as a one, bit 1.8.9 indicates that the PMA/PMD has extended abilities listed in register 1.11. When read as a zero, bit 1.8.9 indicates that the PMA/PMD does not have extended abilities.

45.2.1.7.7 PMD transmit disable ability (1.8.8)

When read as a one, bit 1.8.8 indicates that the PMD is able to perform the transmit disable function. When read as a zero, bit 1.8.8 indicates that the PMD is not able to perform the transmit disable function. If a PMD is able to perform the transmit disable function, then it is controlled using the PMD transmit disable register.

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45.2.1.7.8 10GBASE-SR ability (1.8.7)

When read as a one, bit 1.8.7 indicates that the PMA/PMD is able to support a 10GBASE-SR PMA/PMD type. When read as a zero, bit 1.8.7 indicates that the PMA/PMD is not able to support a 10GBASE-SR PMA/PMD type.

45.2.1.7.9 10GBASE-LR ability (1.8.6)

When read as a one, bit 1.8.6 indicates that the PMA/PMD is able to support a 10GBASE-LR PMA/PMD type. When read as a zero, bit 1.8.6 indicates that the PMA/PMD is not able to support a 10GBASE-LR PMA/PMD type.

45.2.1.7.10 10GBASE-ER ability (1.8.5)

When read as a one, bit 1.8.5 indicates that the PMA/PMD is able to support a 10GBASE-ER PMA/PMD type. When read as a zero, bit 1.8.5 indicates that the PMA/PMD is not able to support a 10GBASE-ER PMA/PMD type.

45.2.1.7.11 10GBASE-LX4 ability (1.8.4)

When read as a one, bit 1.8.4 indicates that the PMA/PMD is able to support a 10GBASE-LX4 PMA/PMD type. When read as a zero, bit 1.8.4 indicates that the PMA/PMD is not able to support a 10GBASE-LX4 PMA/PMD type.

45.2.1.7.12 10GBASE-SW ability (1.8.3)

When read as a one, bit 1.8.3 indicates that the PMA/PMD is able to support a 10GBASE-SW PMA/PMD type. When read as a zero, bit 1.8.3 indicates that the PMA/PMD is not able to support a 10GBASE-SW PMA/PMD type.

45.2.1.7.13 10GBASE-LW ability (1.8.2)

When read as a one, bit 1.8.2 indicates that the PMA/PMD is able to support a 10GBASE-LW PMA/PMD type. When read as a zero, bit 1.8.2 indicates that the PMA/PMD is not able to support a 10GBASE-LW PMA/PMD type.

45.2.1.7.14 10GBASE-EW ability (1.8.1)

When read as a one, bit 1.8.1 indicates that the PMA/PMD is able to support a 10GBASE-EW PMA/PMD type. When read as a zero, bit 1.8.1 indicates that the PMA/PMD is not able to support a 10GBASE-EW PMA/PMD type.

45.2.1.7.15 PMA local loopback ability (1.8.0)

When read as a one, bit 1.8.0 indicates that the PMA is able to perform the local loopback function. When read as a zero, bit 1.8.0 indicates that the PMA is not able to perform the local loopback function. If a PMA is able to perform the local loopback function, then it is controlled using the PMA local loopback bit 1.0.0.

45.2.1.8 PMD transmit disable register (Register 1.9)

The assignment of bits in the PMD transmit disable register is shown in Table 45–11. The transmit disable functionality is optional and a PMD's ability to perform the transmit disable functionality is advertised in the PMD transmit disable ability bit 1.8.8. A PMD that does not implement the transmit disable functionality shall ignore writes to the PMD transmit disable register and may return a value of zero for all bits. A PMD

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device that operates using a single lane and has implemented the transmit disable function shall use bit 1.9.0 to control the function. Such devices shall ignore writes to bits 1.9.10:1 and return a value of zero for those bits when they are read. The description of the transmit disable function for the various PMA/PMDs is given in Table 45–12.

NOTE—Disabling the transmitter on one or more lanes stops the entire link from carrying data.

Table 45–11—PMD transmit disable register bit definitions

Bit(s)	Name	Description	R/W[a]
1.9.15:11	Reserved	Value always 0	RO
1.9.10	PMD transmit disable 9	1 = Disable output on transmit lane 9 0 = Enable output on transmit lane 9	R/W
1.9.9	PMD transmit disable 8	1 = Disable output on transmit lane 8 0 = Enable output on transmit lane 8	R/W
1.9.8	PMD transmit disable 7	1 = Disable output on transmit lane 7 0 = Enable output on transmit lane 7	R/W
1.9.7	PMD transmit disable 6	1 = Disable output on transmit lane 6 0 = Enable output on transmit lane 6	R/W
1.9.6	PMD transmit disable 5	1 = Disable output on transmit lane 5 0 = Enable output on transmit lane 5	R/W
1.9.5	PMD transmit disable 4	1 = Disable output on transmit lane 4 0 = Enable output on transmit lane 4	R/W
1.9.4	PMD transmit disable 3	1 = Disable output on transmit lane 3 0 = Enable output on transmit lane 3	R/W
1.9.3	PMD transmit disable 2	1 = Disable output on transmit lane 2 0 = Enable output on transmit lane 2	R/W
1.9.2	PMD transmit disable 1	1 = Disable output on transmit lane 1 0 = Enable output on transmit lane 1	R/W
1.9.1	PMD transmit disable 0	1 = Disable output on transmit lane 0 0 = Enable output on transmit lane 0	R/W
1.9.0	Global PMD transmit disable	1 = Disable transmitter output 0 = Enable transmitter output	R/W

[a]RO = Read only, R/W = Read/Write

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45.2.1.8.1 PMD transmit disable 9 (1.9.10)

When bit 1.9.10 is set to a one, the PMD shall disable output on lane 9 of the transmit path. When bit 1.9.10 is set to zero, the PMD shall enable output on lane 9 of the transmit path.

The default value for bit 1.9.10 is zero.

NOTE—Transmission will not be enabled when this bit is set to zero unless the global PMD transmit disable bit is also zero.

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Table 45–12—Transmit disable description location

PMA/PMD	Description location
10GBASE-KR	72.6.5
10GBASE-LRM	68.4.7
Other 10GBASE-R	52.4.7
10GBASE-LX4	53.4.7
10GBASE-CX4	54.5.6
10GBASE-T	55.4.2.3
10GBASE-KX4	71.6.6
40GBASE-KR4	84.7.6
40GBASE-CR4 and 100GBASE-CR10	85.7.6
40GBASE-SR4 and 100GBASE-SR10	86.5.7
40GBASE-LR4 and 40GBASE-ER4	87.5.7
40GBASE-FR	89.5.6
100GBASE-KP4	94.3.6.6
100GBASE-KR4	93.7.6
100GBASE-CR4	92.7.6
100GBASE-SR4	95.5.7
100GBASE-LR4 and 100GBASE-ER4	88.5.7

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45.2.1.8.2 PMD transmit disable 4, 5, 6, 7, 8 (1.9.5, 1.9.6, 1.9.7, 1.9.8, 1.9.9)

These bits are defined similarly to bit 1.9.10 for lanes 4, 5, 6, 7, and 8, respectively.

45.2.1.8.3 PMD transmit disable 3 (1.9.4)

When bit 1.9.4 is set to a one, the PMD shall disable output on lane 3 of the transmit path. When bit 1.9.4 is set to a zero, the PMD shall enable output on lane 3 of the transmit path.

The default value for bit 1.9.4 is zero.

NOTE—Transmission will not be enabled when this bit is set to a zero unless the global PMD transmit disable bit is also zero.

45.2.1.8.4 PMD transmit disable 2 (1.9.3)

When bit 1.9.3 is set to a one, the PMD shall disable output on lane 2 of the transmit path. When bit 1.9.3 is set to a zero, the PMD shall enable output on lane 2 of the transmit path.

The default value for bit 1.9.3 is zero.

NOTE—Transmission will not be enabled when this bit is set to a zero unless the global PMD transmit disable bit is also zero.

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45.2.1.8.5 PMD transmit disable 1 (1.9.2)

When bit 1.9.2 is set to a one, the PMD shall disable output on lane 1 of the transmit path. When bit 1.9.2 is set to a zero, the PMD shall enable output on lane 1 of the transmit path.

The default value for bit 1.9.2 is zero.

NOTE—Transmission will not be enabled when this bit is set to a zero unless the global PMD transmit disable bit is also zero.

45.2.1.8.6 PMD transmit disable 0 (1.9.1)

When bit 1.9.1 is set to a one, the PMD shall disable output on lane 0 of the transmit path. When bit 1.9.1 is set to a zero, the PMD shall enable output on lane 0 of the transmit path.

The default value for bit 1.9.1 is zero.

NOTE—Transmission will not be enabled when this bit is set to a zero unless the global PMD transmit disable bit is also zero.

45.2.1.8.7 Global PMD transmit disable (1.9.0)

When bit 1.9.0 is set to a one, the PMD shall disable output on the transmit path. When bit 1.9.0 is set to a zero, the PMD shall enable output on the transmit path.

For single wavelength PMD types, transmission will be disabled when this bit is set to one. When this bit is set to zero, transmission is enabled.

For multiple wavelength or lane PMD types, transmission will be disabled on all lanes when this bit is set to one. When this bit is set to zero, the lanes are individually controlled by their corresponding transmit disable bits 1.9.4:1.

The default value for bit 1.9.0 is zero.

45.2.1.9 PMD receive signal detect register (Register 1.10)

The assignment of bits in the PMD receive signal detect register is shown in Table 45–13. The 10G PMD receive signal detect register is mandatory. PMD types that use only a single lane indicate the status of the receive signal detect using bit 1.10.0 and return a value of zero for bits 1.10.10:1. PMD types that use multiple wavelengths or lanes indicate the status of each lane in bits 1.10.10:1 and the logical AND of those bits in bit 1.10.0.

Table 45–13—PMD receive signal detect register bit definitions

Bit(s)	Name	Description	R/W[a]
1.10.15:11	Reserved	Value always 0	RO
1.10.10	PMD receive signal detect 9	1 = Signal detected on receive lane 9 0 = Signal not detected on receive lane 9	RO
1.10.9	PMD receive signal detect 8	1 = Signal detected on receive lane 8 0 = Signal not detected on receive lane 8	RO

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Table 45–13—PMD receive signal detect register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
1.10.8	PMD receive signal detect 7	1 = Signal detected on receive lane 7 0 = Signal not detected on receive lane 7	RO
1.10.7	PMD receive signal detect 6	1 = Signal detected on receive lane 6 0 = Signal not detected on receive lane 6	RO
1.10.6	PMD receive signal detect 5	1 = Signal detected on receive lane 5 0 = Signal not detected on receive lane 5	RO
1.10.5	PMD receive signal detect 4	1 = Signal detected on receive lane 4 0 = Signal not detected on receive lane 4	RO
1.10.4	PMD receive signal detect 3	1 = Signal detected on receive lane 3 0 = Signal not detected on receive lane 3	RO
1.10.3	PMD receive signal detect 2	1 = Signal detected on receive lane 2 0 = Signal not detected on receive lane 2	RO
1.10.2	PMD receive signal detect 1	1 = Signal detected on receive lane 1 0 = Signal not detected on receive lane 1	RO
1.10.1	PMD receive signal detect 0	1 = Signal detected on receive lane 0 0 = Signal not detected on receive lane 0	RO
1.10.0	Global PMD receive signal detect	1 = Signal detected on receive 0 = Signal not detected on receive	RO

[a]RO = Read only

45.2.1.9.1 PMD receive signal detect 9 (1.10.10)

When bit 1.10.10 is read as a one, a signal has been detected on lane 9 of the PMD receive path. When bit 1.10.10 is read as a zero, a signal has not been detected on lane 9 of the PMD receive path.

45.2.1.9.2 PMD receive signal detect 4, 5, 6, 7, 8 (1.10.5, 1.10.6, 1.10.7, 1.10.8, 1.10.9)

These bits are defined similarly to bit 1.10.10 for lanes 4, 5, 6, 7, and 8, respectively.

45.2.1.9.3 PMD receive signal detect 3 (1.10.4)

When bit 1.10.4 is read as a one, a signal has been detected on lane 3 of the PMD receive path. When bit 1.10.4 is read as a zero, a signal has not been detected on lane 3 of the PMD receive path.

45.2.1.9.4 PMD receive signal detect 2 (1.10.3)

When bit 1.10.3 is read as a one, a signal has been detected on lane 2 of the PMD receive path. When bit 1.10.3 is read as a zero, a signal has not been detected on lane 2 of the PMD receive path.

45.2.1.9.5 PMD receive signal detect 1 (1.10.2)

When bit 1.10.2 is read as a one, a signal has been detected on lane 1 of the PMD receive path. When bit 1.10.2 is read as a zero, a signal has not been detected on lane 1 of the PMD receive path.

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45.2.1.9.6 PMD receive signal detect 0 (1.10.1)

When bit 1.10.1 is read as a one, a signal has been detected on lane 0 of the PMD receive path. When bit 1.10.1 is read as a zero, a signal has not been detected on lane 0 of the PMD receive path.

45.2.1.9.7 Global PMD receive signal detect (1.10.0)

When bit 1.10.0 is read as a one, a signal has been detected on all the PMD receive paths. When bit 1.10.0 is read as a zero, a signal has not been detected on at least one of the PMD receive paths.

Single wavelength PMD types indicate the status of their receive path signal using this bit.

Multiple wavelength or multiple lane PMD types indicate the global status of the lane-by-lane signal detect indications using this bit. This bit is read as a one when all the lane signal detect indications are one; otherwise, this bit is read as a zero.

45.2.1.10 PMA/PMD extended ability register (Register 1.11)

The assignment of bits in the PMA/PMD extended ability register is shown in Table 45–14. All of the bits in the PMA/PMD extended ability register are read only; a write to the PMA/PMD extended ability register shall have no effect.

Table 45–14—PMA/PMD Extended Ability register bit definitions

Bit(s)	Name	Description	R/W[a]
1.11.15:11	Reserved	Value always 0	RO
1.11.10	40G/100G extended abilities	1 = PMA/PMD has 40G/100G extended abilities listed in register 1.13 0 = PMA/PMD does not have 40G/100G extended abilities	RO
1.11.9	P2MP ability	1 = PMA/PMD has P2MP abilities listed in register 1.12 0 = PMA/PMD does not have P2MP abilities	RO
1.11.8	10BASE-T ability	1 = PMA/PMD is able to perform 10BASE-T 0 = PMA/PMD is not able to perform 10BASE-T	RO
1.11.7	100BASE-TX ability	1 = PMA/PMD is able to perform 100BASE-TX 0 = PMA/PMD is not able to perform 100BASE-TX	RO
1.11.6	1000BASE-KX ability	1 = PMA/PMD is able to perform 1000BASE-KX 0 = PMA/PMD is not able to perform 1000BASE-KX	RO
1.11.5	1000BASE-T ability	1 = PMA/PMD is able to perform 1000BASE-T 0 = PMA/PMD is not able to perform 1000BASE-T	RO
1.11.4	10GBASE-KR ability	1 = PMA/PMD is able to perform 10GBASE-KR 0 = PMA/PMD is not able to perform 10GBASE-KR	RO
1.11.3	10GBASE-KX4 ability	1 = PMA/PMD is able to perform 10GBASE-KX4 0 = PMA/PMD is not able to perform 10GBASE-KX4	RO

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Table 45–14—PMA/PMD Extended Ability register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
1.11.2	10GBASE-T ability	1 = PMA/PMD is able to perform 10GBASE-T 0 = PMA/PMD is not able to perform 10GBASE-T	RO
1.11.1	10GBASE-LRM ability	1 = PMA/PMD is able to perform 10GBASE-LRM 0 = PMA/PMD is not able to perform 10GBASE-LRM	RO
1.11.0	10GBASE-CX4 ability	1 = PMA/PMD is able to perform 10GBASE-CX4 0 = PMA/PMD is not able to perform 10GBASE-CX4	RO

[a]RO = Read only

45.2.1.10.1 40G/100G extended abilities (1.11.10)

When read as a one, bit 1.11.10 indicates that the PMA/PMD has 40G/100G extended abilities listed in register 1.13. When read as a zero, bit 1.11.10 indicates that the PMA/PMD does not have 40G/100G extended abilities.

45.2.1.10.2 P2MP ability (1.11.9)

When read as a one, bit 1.11.9 indicates that the PMA/PMD has P2MP abilities listed in register 1.12. When read as a zero, bit 1.11.9 indicates that the PMA/PMD does not have P2MP abilities.

45.2.1.10.3 10BASE-T ability (1.11.8)

When read as a one, bit 1.11.8 indicates that the PMA/PMD is able to operate as a 10BASE-T PMA/PMD type. When read as a zero, bit 1.11.8 indicates that the PMA/PMD is not able to operate as a 10BASE-T PMA/PMD type.

45.2.1.10.4 100BASE-TX ability (1.11.7)

When read as a one, bit 1.11.7 indicates that the PMA/PMD is able to operate as a 100BASE-TX PMA/PMD type. When read as a zero, bit 1.11.7 indicates that the PMA/PMD is not able to operate as a 100BASE-TX PMA/PMD type.

45.2.1.10.5 1000BASE-KX ability (1.11.6)

When read as a one, bit 1.11.6 indicates that the PMA/PMD is able to operate as 1000BASE-KX. When read as a zero, bit 1.11.6 indicates that the PMA/PMD is not able to operate as 1000BASE-KX.

45.2.1.10.6 1000BASE-T ability (1.11.5)

When read as a one, bit 1.11.5 indicates that the PMA/PMD is able to operate as a 1000BASE-T PMA/PMD type. When read as a zero, bit 1.11.5 indicates that the PMA/PMD is not able to operate as a 1000BASE-T PMA/PMD type.

45.2.1.10.7 10GBASE-KR ability (1.11.4)

When read as a one, bit 1.11.4 indicates that the PMA/PMD is able to operate as 10GBASE-KR. When read as a zero, bit 1.11.4 indicates that the PMA/PMD is not able to operate as 10GBASE-KR.

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45.2.1.10.8 10GBASE-KX4 ability (1.11.3)

When read as a one, bit 1.11.3 indicates that the PMA/PMD is able to operate as 10GBASE-KX4. When read as a zero, bit 1.11.3 indicates that the PMA/PMD is not able to operate as 10GBASE-KX4.

45.2.1.10.9 10GBASE-T ability (1.11.2)

When read as a one, bit 1.11.2 indicates that the PMA/PMD is able to operate as a 10GBASE-T PMA/PMD type. When read as a zero, bit 1.11.2 indicates that the PMA/PMD is not able to operate as a 10GBASE-T PMA/PMD type.

45.2.1.10.10 10GBASE-LRM ability (1.11.1)

When read as a one, bit 1.11.1 indicates that the PMA/PMD is able to operate as 10GBASE-LRM. When read as a zero, bit 1.11.1 indicates that the PMA/PMD is not able to operate as 10GBASE-LRM.

45.2.1.10.11 10GBASE-CX4 ability (1.11.0)

When read as a one, bit 1.11.0 indicates that the PMA/PMD is able to operate as a 10GBASE-CX4 PMA/PMD type. When read as a zero, bit 1.11.0 indicates that the PMA/PMD is not able to operate as a 10GBASE-CX4 PMA/PMD type.

45.2.1.11 10G-EPON PMA/PMD ability register (Register 1.12)

The assignment of bits in the 10G-EPON PMA/PMD ability register is shown in Table 45–15. All of the bits in the 10G-EPON PMA/PMD ability register are read only; a write to the 10G-EPON PMA/PMD ability register shall have no effect.

Table 45–15—10G-EPON PMA/PMD ability register bit definitions

Bit(s)	Name	Description	R/W[a]
1.12.15	Reserved	Value always 0	RO
1.12.14	10GBASE-PR-D4 ability	1 = PMA/PMD is able to perform 10GBASE-PR-D4 0 = PMA/PMD is not able to perform 10GBASE-PR-D4	RO
1.12.13	10GBASE-PR-U4 ability	1 = PMA/PMD is able to perform 10GBASE-PR-U4 0 = PMA/PMD is not able to perform 10GBASE-PR-U4	RO
1.12.12	10/1GBASE-PRX-D4 ability	1 = PMA/PMD is able to perform 10/1GBASE-PRX-D4 0 = PMA/PMD is not able to perform 10/1GBASE-PRX-D4	RO
1.12.11	10/1GBASE-PRX-U4 ability	1 = PMA/PMD is able to perform 10/1GBASE-PRX-U4 0 = PMA/PMD is not able to perform 10/1GBASE-PRX-U4	RO
1.12.10	10/1GBASE-PRX-D1 ability	1 = PMA/PMD is able to perform 10/1GBASE-PRX-D1 0 = PMA/PMD is not able to perform 10/1GBASE-PRX-D1	RO
1.12.9	10/1GBASE-PRX-D2 ability	1 = PMA/PMD is able to perform 10/1GBASE-PRX-D2 0 = PMA/PMD is not able to perform 10/1GBASE-PRX-D2	RO
1.12.8	10/1GBASE-PRX-D3 ability	1 = PMA/PMD is able to perform 10/1GBASE-PRX-D3 0 = PMA/PMD is not able to perform 10/1GBASE-PRX-D3	RO
1.12.7	10GBASE-PR-D1 ability	1 = PMA/PMD is able to perform 10GBASE-PR-D1 0 = PMA/PMD is not able to perform 10GBASE-PR-D1	RO

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Table 45–15—10G-EPON PMA/PMD ability register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
1.12.6	10GBASE-PR-D2 ability	1 = PMA/PMD is able to perform 10GBASE-PR-D2 0 = PMA/PMD is not able to perform 10GBASE-PR-D2	RO
1.12.5	10GBASE-PR-D3 ability	1 = PMA/PMD is able to perform 10GBASE-PR-D3 0 = PMA/PMD is not able to perform 10GBASE-PR-D3	RO
1.12.4	10/1GBASE-PRX-U1 ability	1 = PMA/PMD is able to perform 10/1GBASE-PRX-U1 0 = PMA/PMD is not able to perform 10/1GBASE-PRX-U1	RO
1.12.3	10/1GBASE-PRX-U2 ability	1 = PMA/PMD is able to perform 10/1GBASE-PRX-U2 0 = PMA/PMD is not able to perform 10/1GBASE-PRX-U2	RO
1.12.2	10/1GBASE-PRX-U3 ability	1 = PMA/PMD is able to perform 10/1GBASE-PRX-U3 0 = PMA/PMD is not able to perform 10/1GBASE-PRX-U3	RO
1.12.1	10GBASE-PR-U1 ability	1 = PMA/PMD is able to perform 10GBASE-PR-U1 0 = PMA/PMD is not able to perform 10GBASE-PR-U1	RO
1.12.0	10GBASE-PR-U3 ability	1 = PMA/PMD is able to perform 10GBASE-PR-U3 0 = PMA/PMD is not able to perform 10GBASE-PR-U3	RO

[a]RO = Read only

45.2.1.11.1 10GBASE-PR-D4 ability (1.12.14)

When read as a one, bit 1.12.14 indicates that the PMA/PMD is able to operate as a 10GBASE-PR-D4 PMA/PMD type. When read as a zero, bit 1.12.14 indicates that the PMA/PMD is not able to operate as a 10GBASE-PR-D4 PMA/PMD type.

45.2.1.11.2 10GBASE-PR-U4 ability (1.12.13)

When read as a one, bit 1.12.13 indicates that the PMA/PMD is able to operate as a 10GBASE-PR-U4 PMA/PMD type. When read as a zero, bit 1.12.13 indicates that the PMA/PMD is not able to operate as a 10GBASE-PR-U4 PMA/PMD type.

45.2.1.11.3 10/1GBASE-PRX-D4 ability (1.12.12)

When read as a one, bit 1.12.12 indicates that the PMA/PMD is able to operate as a 10/1GBASE-PRX-D4 PMA/PMD type. When read as a zero, bit 1.12.12 indicates that the PMA/PMD is not able to operate as a 10/1GBASE-PRX-D4 PMA/PMD type.

45.2.1.11.4 10/1GBASE-PRX-U4 ability (1.12.11)

When read as a one, bit 1.12.11 indicates that the PMA/PMD is able to operate as a 10/1GBASE-PRX-U4 PMA/PMD type. When read as a zero, bit 1.12.11 indicates that the PMA/PMD is not able to operate as a 10/1GBASE-PRX-U4 PMA/PMD type.

45.2.1.11.5 10/1GBASE-PRX-D1 ability (1.12.10)

When read as a one, bit 1.12.10 indicates that the PMA/PMD is able to operate as a 10/1GBASE-PRX-D1 PMA/PMD type. When read as a zero, bit 1.12.10 indicates that the PMA/PMD is not able to operate as a 10/1GBASE-PRX-D1 PMA/PMD type.

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45.2.1.11.6 10/1GBASE-PRX-D2 ability (1.12.9)

When read as a one, bit 1.12.9 indicates that the PMA/PMD is able to operate as a 10/1GBASE-PRX-D2 PMA/PMD type. When read as a zero, bit 1.12.9 indicates that the PMA/PMD is not able to operate as a 10/1GBASE-PRX-D2 PMA/PMD type.

45.2.1.11.7 10/1GBASE-PRX-D3 ability (1.12.8)

When read as a one, bit 1.12.8 indicates that the PMA/PMD is able to operate as a 10/1GBASE-PRX-D3 PMA/PMD type. When read as a zero, bit 1.12.8 indicates that the PMA/PMD is not able to operate as a 10/1GBASE-PRX-D3 PMA/PMD type.

45.2.1.11.8 10GBASE-PR-D1 ability (1.12.7)

When read as a one, bit 1.12.7 indicates that the PMA/PMD is able to operate as a 10GBASE-PR-D1 PMA/PMD type. When read as a zero, bit 1.12.7 indicates that the PMA/PMD is not able to operate as a 10GBASE-PR-D1 PMA/PMD type.

45.2.1.11.9 10GBASE-PR-D2 ability (1.12.6)

When read as a one, bit 1.12.6 indicates that the PMA/PMD is able to operate as a 10GBASE-PR-D2 PMA/PMD type. When read as a zero, bit 1.12.6 indicates that the PMA/PMD is not able to operate as a 10GBASE-PR-D2 PMA/PMD type.

45.2.1.11.10 10GBASE-PR-D3 ability (1.12.5)

When read as a one, bit 1.12.5 indicates that the PMA/PMD is able to operate as a 10GBASE-PR-D3 PMA/PMD type. When read as a zero, bit 1.12.5 indicates that the PMA/PMD is not able to operate as a 10GBASE-PR-D3 PMA/PMD type.

45.2.1.11.11 10/1GBASE-PRX-U1 ability (1.12.4)

When read as a one, bit 1.12.4 indicates that the PMA/PMD is able to operate as a 10/1GBASE-PRX-U1 PMA/PMD type. When read as a zero, bit 1.12.4 indicates that the PMA/PMD is not able to operate as a 10/1GBASE-PRX-U1 PMA/PMD type.

45.2.1.11.12 10/1GBASE-PRX-U2 ability (1.12.3)

When read as a one, bit 1.12.3 indicates that the PMA/PMD is able to operate as a 10/1GBASE-PRX-U2 PMA/PMD type. When read as a zero, bit 1.12.3 indicates that the PMA/PMD is not able to operate as a 10/1GBASE-PRX-U2 PMA/PMD type.

45.2.1.11.13 10/1GBASE-PRX-U3 ability (1.12.2)

When read as a one, bit 1.12.2 indicates that the PMA/PMD is able to operate as a 10/1GBASE-PRX-U3 PMA/PMD type. When read as a zero, bit 1.12.2 indicates that the PMA/PMD is not able to operate as a 10/1GBASE-PRX-U3 PMA/PMD type.

45.2.1.11.14 10GBASE-PR-U1 ability (1.12.1)

When read as a one, bit 1.12.1 indicates that the PMA/PMD is able to operate as a 10GBASE-PR-U1 PMA/PMD type. When read as a zero, bit 1.12.1 indicates that the PMA/PMD is not able to operate as a 10GBASE-PR-U1 PMA/PMD type.

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45.2.1.11.15 10GBASE-PR-U3 ability (1.12.0)

When read as a one, bit 1.12.0 indicates that the PMA/PMD is able to operate as a 10GBASE-PR-U3 PMA/PMD type. When read as a zero, bit 1.12.0 indicates that the PMA/PMD is not able to operate as a 10GBASE-PR-U3 PMA/PMD type.

45.2.1.12 40G/100G PMA/PMD extended ability register (Register 1.13)

The assignment of bits in the 40G/100G PMA/PMD extended ability register is shown in Table 45–16. All of the bits in the PMA/PMD extended ability register are read only; a write to the PMA/PMD extended ability register shall have no effect.

Table 45–16—40G/100G PMA/PMD extended ability register bit definitions

Bit(s)	Name	Description	R/W[a]
1.13.15	PMA remote loopback ability	1 = PMA has the ability to perform a remote loopback function 0 = PMA does not have the ability to perform a remote loopback function	RO
1.13.14	100GBASE-CR4 ability	1 = PMA/PMD is able to perform 100GBASE-CR4 0 = PMA/PMD is not able to perform 100GBASE-CR4	RO
1.13.13	100GBASE-KR4 ability	1 = PMA/PMD is able to perform 100GBASE-KR4 0 = PMA/PMD is not able to perform 100GBASE-KR4	RO
1.13.12	100GBASE-KP4 ability	1 = PMA/PMD is able to perform 100GBASE-KP4 0 = PMA/PMD is not able to perform 100GBASE-KP4	RO
1.13.11	100GBASE-ER4 ability	1 = PMA/PMD is able to perform 100GBASE-ER4 0 = PMA/PMD is not able to perform 100GBASE-ER4	RO
1.13.10	100GBASE-LR4 ability	1 = PMA/PMD is able to perform 100GBASE-LR4 0 = PMA/PMD is not able to perform 100GBASE-LR4	RO
1.13.9	100GBASE-SR10 ability	1 = PMA/PMD is able to perform 100GBASE-SR10 0 = PMA/PMD is not able to perform 100GBASE-SR10	RO
1.13.8	100GBASE-CR10 ability	1 = PMA/PMD is able to perform 100GBASE-CR10 0 = PMA/PMD is not able to perform 100GBASE-CR10	RO
1.13.7	100GBASE-SR4 ability	1 = PMA/PMD is able to perform 100GBASE-SR4 0 = PMA/PMD is not able to perform 100GBASE-SR4	RO
1.13.6	Reserved	Value always 0	RO
1.13.5	40GBASE-ER4 ability	1 = PMA/PMD is able to perform 40GBASE-ER4 0 = PMA/PMD is not able to perform 40GBASE-ER4	RO
1.13.4	40GBASE-FR ability	1 = PMA/PMD is able to perform 40GBASE-FR 0 = PMA/PMD is not able to perform 40GBASE-FR	RO
1.13.3	40GBASE-LR4 ability	1 = PMA/PMD is able to perform 40GBASE-LR4 0 = PMA/PMD is not able to perform 40GBASE-LR4	RO
1.13.2	40GBASE-SR4 ability	1 = PMA/PMD is able to perform 40GBASE-SR4 0 = PMA/PMD is not able to perform 40GBASE-SR4	RO
1.13.1	40GBASE-CR4 ability	1 = PMA/PMD is able to perform 40GBASE-CR4 0 = PMA/PMD is not able to perform 40GBASE-CR4	RO
1.13.0	40GBASE-KR4 ability	1 = PMA/PMD is able to perform 40GBASE-KR4 0 = PMA/PMD is not able to perform 40GBASE-KR4	RO

[a]RO = Read only

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45.2.1.12.1 PMA remote loopback ability (1.13.15)

When read as a one, bit 1.13.15 indicates that the PMA is able to perform the remote loopback function. When read as a zero, bit 1.13.15 indicates that the PMA is not able to perform the remote loopback function. If a PMA is able to perform the remote loopback function, then it is controlled using the PMA remote loopback bit 1.0.1 (see 45.2.1.1.4).

45.2.1.12.2 100GBASE-CR4 ability (1.13.14)

When read as a one, bit 1.13.14 indicates that the PMA/PMD is able to operate as a 100GBASE-CR4 PMA/PMD type. When read as a zero, bit 1.13.14 indicates that the PMA/PMD is not able to operate as a 100GBASE-CR4 PMA/PMD type.

45.2.1.12.3 100GBASE-KR4 ability (1.13.13)

When read as a one, bit 1.13.13 indicates that the PMA/PMD is able to operate as a 100GBASE-KR4 PMA/PMD type. When read as a zero, bit 1.13.13 indicates that the PMA/PMD is not able to operate as a 100GBASE-KR4 PMA/PMD type.

45.2.1.12.4 100GBASE-KP4 ability (1.13.12)

When read as a one, bit 1.13.12 indicates that the PMA/PMD is able to operate as a 100GBASE-KP4 PMA/PMD type. When read as a zero, bit 1.13.12 indicates that the PMA/PMD is not able to operate as a 100GBASE-KP4 PMA/PMD type.

45.2.1.12.5 100GBASE-ER4 ability (1.13.11)

When read as a one, bit 1.13.11 indicates that the PMA/PMD is able to operate as a 100GBASE-ER4 PMA/PMD type. When read as a zero, bit 1.13.11 indicates that the PMA/PMD is not able to operate as a 100GBASE-ER4 PMA/PMD type.

45.2.1.12.6 100GBASE-LR4 ability (1.13.10)

When read as a one, bit 1.13.10 indicates that the PMA/PMD is able to operate as a 100GBASE-LR4 PMA/PMD type. When read as a zero, bit 1.13.10 indicates that the PMA/PMD is not able to operate as a 100GBASE-LR4 PMA/PMD type.

45.2.1.12.7 100GBASE-SR10 ability (1.13.9)

When read as a one, bit 1.13.9 indicates that the PMA/PMD is able to operate as a 100GBASE-SR10 PMA/PMD type. When read as a zero, bit 1.13.9 indicates that the PMA/PMD is not able to operate as a 100GBASE-SR10 PMA/PMD type.

45.2.1.12.8 100GBASE-CR10 ability (1.13.8)

When read as a one, bit 1.13.8 indicates that the PMA/PMD is able to operate as a 100GBASE-CR10 PMA/PMD type. When read as a zero, bit 1.13.8 indicates that the PMA/PMD is not able to operate as a 100GBASE-CR10 PMA/PMD type.

45.2.1.12.9 100GBASE-SR4 ability (1.13.7)

When read as a one, bit 1.13.7 indicates that the PMA/PMD is able to operate as a 100GBASE-SR4 PMA/PMD type. When read as a zero, bit 1.13.7 indicates that the PMA/PMD is not able to operate as a 100GBASE-SR4 PMA/PMD type.

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45.2.1.12.10 40GBASE-ER4 ability (1.13.5)

When read as a one, bit 1.13.5 indicates that the PMA/PMD is able to operate as a 40GBASE-ER4 PMA/PMD type. When read as a zero, bit 1.13.5 indicates that the PMA/PMD is not able to operate as a 40GBASE-ER4 PMA/PMD type.

45.2.1.12.11 40GBASE-FR ability (1.13.4)

When read as a one, bit 1.13.4 indicates that the PMA/PMD is able to operate as a 40GBASE-FR PMA/PMD type. When read as a zero, bit 1.13.4 indicates that the PMA/PMD is not able to operate as a 40GBASE-FR PMA/PMD type.

45.2.1.12.12 40GBASE-LR4 ability (1.13.3)

When read as a one, bit 1.13.3 indicates that the PMA/PMD is able to operate as a 40GBASE-LR4 PMA/PMD type. When read as a zero, bit 1.13.3 indicates that the PMA/PMD is not able to operate as a 40GBASE-LR4 PMA/PMD type.

45.2.1.12.13 40GBASE-SR4 ability (1.13.2)

When read as a one, bit 1.13.2 indicates that the PMA/PMD is able to operate as a 40GBASE-SR4 PMA/PMD type. When read as a zero, bit 1.13.2 indicates that the PMA/PMD is not able to operate as a 40GBASE-SR4 PMA/PMD type.

45.2.1.12.14 40GBASE-CR4 ability (1.13.1)

When read as a one, bit 1.13.1 indicates that the PMA/PMD is able to operate as a 40GBASE-CR4 PMA/PMD type. When read as a zero, bit 1.13.1 indicates that the PMA/PMD is not able to operate as a 40GBASE-CR4 PMA/PMD type.

45.2.1.12.15 40GBASE-KR4 ability (1.13.0)

When read as a one, bit 1.13.0 indicates that the PMA/PMD is able to operate as a 40GBASE-KR4 PMA/PMD type. When read as a zero, bit 1.13.0 indicates that the PMA/PMD is not able to operate as a 40GBASE-KR4 PMA/PMD type.

45.2.1.13 PMA/PMD package identifier (Registers 1.14 and 1.15)

Registers 1.14 and 1.15 provide a 32-bit value, which may constitute a unique identifier for a particular type of package that the PMA/PMD is instantiated within. The identifier shall be composed of the 3rd through 24th bits of the Organizationally Unique Identifier (OUI) assigned to the package manufacturer by the IEEE, plus a six-bit model number, plus a four-bit revision number. A PMA/PMD may return a value of zero in each of the 32 bits of the package identifier.

A non-zero package identifier may be returned by one or more MMDs in the same package. The package identifier may be the same as the device identifier.

The format of the package identifier is specified in 22.2.4.3.1.

45.2.1.14 EEE capability (Register 1.16)

This register is used to indicate the capability of the PMA/PMD to support EEE functions for each PHY type. The assignment of bits in the EEE capability register is shown in Table 45–17.

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Table 45–17—EEE capability register bit definitions

Bit(s)	Name	Description	R/W[a]
1.16.15:12	Reserved	Value always 0	RO
1.16.11	100GBASE-CR4 deep sleep	1 = EEE deep sleep is supported for 100GBASE-CR4 0 = EEE deep sleep is not supported for 100GBASE-CR4	RO
1.16.10	100GBASE-KR4 deep sleep	1 = EEE deep sleep is supported for 100GBASE-KR4 0 = EEE deep sleep is not supported for 100GBASE-KR4	RO
1.16.9	100GBASE-KP4 deep sleep	1 = EEE deep sleep is supported for 100GBASE-KP4 0 = EEE deep sleep is not supported for 100GBASE-KP4	RO
1.16.8	100GBASE-CR10 deep sleep	1 = EEE deep sleep is supported for 100GBASE-CR10 0 = EEE deep sleep is not supported for 100GBASE-CR10	RO
1.16.7:2	Reserved	Value always 0	RO
1.16.1	40GBASE-CR4 deep sleep	1 = EEE deep sleep is supported for 40GBASE-CR4 0 = EEE deep sleep is not supported for 40GBASE-CR4	RO
1.16.0	40GBASE-KR4 deep sleep	1 = EEE deep sleep is supported for 40GBASE-KR4 0 = EEE deep sleep is not supported for 40GBASE-KR4	RO

[a] RO = Read only

45.2.1.14.1 100GBASE-CR4 EEE deep sleep supported (1.16.11)

If the device supports EEE deep sleep operation for 100GBASE-CR4 as defined in 92.1, this bit shall be set to a one; otherwise this bit shall be set to a zero.

45.2.1.14.2 100GBASE-KR4 EEE deep sleep supported (1.16.10)

If the device supports EEE deep sleep operation for 100GBASE-KR4 as defined in 93.1, this bit shall be set to a one; otherwise this bit shall be set to a zero.

45.2.1.14.3 100GBASE-KP4 EEE deep sleep supported (1.16.9)

If the device supports EEE deep sleep operation for 100GBASE-KP4 as defined in 94.1, this bit shall be set to a one; otherwise this bit shall be set to a zero.

45.2.1.14.4 100GBASE-CR10 EEE deep sleep supported (1.16.8)

If the device supports EEE deep sleep operation for 100GBASE-CR10 as defined in 85.1, this bit shall be set to a one; otherwise this bit shall be set to a zero.

45.2.1.14.5 40GBASE-CR4 EEE deep sleep supported (1.16.1)

If the device supports EEE deep sleep operation for 40GBASE-CR4 as defined in 85.1, this bit shall be set to a one; otherwise this bit shall be set to a zero.

45.2.1.14.6 40GBASE-KR4 EEE deep sleep supported (1.16.0)

If the device supports EEE deep sleep operation for 40GBASE-KR4 as defined in 84.1, this bit shall be set to a one; otherwise this bit shall be set to a zero.

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45.2.1.15 10P/2B PMA/PMD control register (Register 1.30)

The assignment of bits in the 10P/2B PMA control register is shown in Table 45–18.

Table 45–18—10P/2B PMA control register bit definitions

Bit(s)	Name	Description	R/W[a]
1.30.15	PMA/PMD link control	1 = begin initialization, enable link (-R default) 0 = force link down (-O default)	R/W
1.30.14	STFU	Silence the far unit 1 = send silence command 0 = silence command inactive (default)	R/W
1.30.13:8	Silence time	Silence time = 10 × (value of bits + 1) seconds	R/W
1.30.7	Port subtype select	1 = port operates as an -O subtype 0 = port operates as a -R subtype	R/W
1.30.6	Handshake cleardown	1 = send cleardown command 0 = idle (default)	R/W, SC
1.30.5	Ignore incoming handshake	1 = PMA/PMD does not respond to handshake tones 0 = PMA/PMD responds to handshake tones	R/W
1.30.4:0	PMA/PMD type selection	4 3 2 1 0 0 0 0 0 0 = 10PASS-TS PMA/PMD type 0 0 0 0 1 = 2BASE-TL PMA/PMD type 0 0 0 1 0 = 2BASE-TL or 10PASS-TS (-R only) 0 0 0 1 1 = 2BASE-TL preferred, or 10PASS-TS (-O only) 0 0 1 0 0 = 10PASS-TS preferred, or 2BASE-TL (-O only) all other values are reserved	R/W

[a]R/W = Read/Write, SC = Self-clearing

45.2.1.15.1 PMA/PMD link control (1.30.15)

The STA may enable the PMA/PMD link and initiate link initialization by writing this bit to a one. While link is initializing or up, this bit shall remain a one and writing a one to this bit shall be ignored. The STA may force the link down by writing a zero to this bit. While this bit is set to zero, the PHY shall not send G.994.1 handshake tones. For -O subtypes, upon link drop or MMD reset, the PMA/PMD shall set these bits to zero. For -R subtypes, upon link drop or MMD reset, the PMA/PMD shall set these bits to one.

45.2.1.15.2 STFU (1.30.14)

When this bit is set to a one, the PMA/PMD sends a message to the link partner instructing it to be silent for the silence time (see 45.2.1.15.3). Writing to this bit is valid only when the PMA/PMD link status bits in the PMA/PMD status register (see 45.2.1.16.4) are set to “link is down (ready)”. Writes are otherwise ignored.

This bit clears to zero when the silence command is sent, or upon the execution of an MMD reset.

45.2.1.15.3 Silence time (1.30.13:8)

The value of these bits sets the silence time conveyed in a STFU operation (see 45.2.1.15.2). The silence time is encoded according to Equation (45–1), where *x* is the decimal value of the bits:

$$\text{time} = 10 \times (x + 1) \text{ seconds} \qquad (45–1)$$

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45.2.1.15.4 Port subtype select (1.30.7)

This register bit selects the port subtype for PMA/PMD operation. The bit defaults to a supported mode. The PHY shall ignore writes that select an unsupported mode (see 45.2.1.15).

Changing this bit alters the fundamental operation of the PMA/PMD, therefore, writes to change this bit shall be ignored if the link is up or initializing (see 45.2.1.16.4).

45.2.1.15.5 Handshake cleardown (1.30.6)

Setting this bit to a one shall cause the PMA/PMD to issue a G.994.1 cleardown command to the link partner (see 61.4.3). The PMA/PMD shall clear this bit to zero after the cleardown command has been sent or upon MMD reset. If the PMA/PMD link is not in the "link down (ready)" state (see 45.2.1.16.4), writes to this register shall be ignored.

45.2.1.15.6 Ignore incoming handshake (1.30.5)

When set to a one, the PMA/PMD shall not respond to received handshake tones (see 61.4.3). When set to a zero, the PMA/PMD shall respond to received handshake tones normally, according to 61.4.3 and G.994.1. Upon MMD reset, this bit shall be cleared to zero.

45.2.1.15.7 PMA/PMD type selection (1.30.4:0)

The PMA/PMD type of a 10P/2B PHY may be selected using bits 4 through 0. A PHY shall ignore writes to the type selection bits that select PMA/PMD types it has not advertised in the speed ability register. It is the responsibility of the STA entity to ensure that mutually acceptable port types are applied consistently across all the MMDs on a particular PHY.

A value of 00010 may be set in -R subtype PMA/PMDs that have both 2BASE-TL and 10PASS-TS capability set in the PMA/PMD speed ability register. The PMA/PMD type of the -R is set upon link initialization by the -O.

Values of 00011 and 00100 may be set in -O subtype PMA/PMDs that have both 2BASE-TL and 10PASS-TS capabilities set in the PMA/PMD speed ability register. These values indicate whether the -R is set to 10PASS-TS or 2BASE-TL respectively. If the -R is not capable of the "preferred" mode, the -R is set to 10PASS-TS or 2BASE-TL respectively.

The selection is advertised during link initialization G.994 handshake.

The PMA/PMD type selection defaults to a supported ability.

45.2.1.16 10P/2B PMA/PMD status register (Register 1.31)

The assignment of bits in the 10P/2B PMA/PMD status register is shown in Table 45–19.

45.2.1.16.1 Data rate (1.31.15:5)

These bits indicate the current bit rate of an operational PMA/PMD link. These bits shall be set to all zeros when the link is down or initializing.

45.2.1.16.2 CO supported (1.31.4)

This bit indicates that the PMA/PMD supports operation as a -O subtype. This bit is set to a one when the capability is supported and zero otherwise. This bit reflects the signal PMA_PMD_type in 61.3.2.1.

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Table 45–19—10P/2B PMA/PMD status register bit definitions

Bit(s)	Name	Description	R/W[a]
1.31.15:5	Data rate	Current operating bit rate of the PMD *n* = the value of the bits Data rate = 64*n* kb/s	RO
1.31.4	CO supported	1 = -O subtype operation supported 0 = -O subtype operation not supported	RO
1.31.3	CPE supported	1 = -R subtype operation supported 0 = -R subtype operation not supported	RO
1.31.2:0	PMA/PMD link status	2 1 0 0 0 0 = link is down (not ready) 1 0 0 = link is down (ready) 0 0 1 = link is initializing 0 1 0 = link is up, 10PASS-TS 0 1 1 = link is up, 2BASE-TL all other values reserved	RO

[a]RO = Read only

45.2.1.16.3 CPE supported (1.31.3)

This bit indicates that the PMA/PMD supports operation as a -R subtype. This bit is set to a one when the capability is supported and zero otherwise. This bit reflects the signal PMA_PMD_type in 61.3.2.1.

45.2.1.16.4 PMA/PMD link status (1.31.2:0)

The overall state of the PMA/PMD link is reflected in bits 2:0. After the PMA/PMD is linked to the remote PHY, the PHY shall set these bits to indicate the PMA/PMD port type that is linked (010 for 10PASS-TS and 011 for 2BASE-TL). The corresponding signal, PMA_received_synchronized, is defined in 61.3.2.1.

While the link is initializing, these bits shall be set to 001.

When read as 000, these bits shall indicate that PMA/PMD link is down and the PMA/PMD is not detecting handshake tones from a link partner. This state is known as “not ready”.

When read as 100, these bits shall indicate that the PMA/PMD link is down and the PMA/PMD is detecting handshake tones from a link partner. This state is known as “ready”.

45.2.1.17 Link partner PMA/PMD control register (Register 1.32)

The 10PASS-TS-O and 2BASE-TL-O PMA/PMDs allow access to certain register values of their link partner via the local MDIO interface. A summary of link partner parameters that may be sent or retrieved is provided in Table 45–20.

The Link partner PMA/PMD control register allows the -O STA to control the transmission and retrieval of parameters from its -R link partner.

The -R STA may read values exchanged by the -O STA in the local register counterpart to the link partner register. For example, the -O 10P link partner electrical length register will be populated with the contents of the -R 10P electrical length register upon a successful “Get link partner parameters” command. Similarly, the -R 10P/2B line quality thresholds register will contain the values sent by the -O in the 10P/2B link partner line quality thresholds register, after a successful “Send link partner parameters” command.

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Table 45–20—Link partner PMA/PMD registers and PMA/PMD register duals

	Register type	Link partner register	Local register counterpart	
	PHY subtype	-O	-O	-R
Link partner register name		**Address and access type[a]**		
10P/2B link partner RX SNR margin		1.38 RO	1.37 RO	1.37 RO
10P/2B link partner line attenuation		1.40 RO	1.39 RO	1.39 RO
10P/2B link partner line quality thresholds		1.42 R/W	1.41 R/W	n/a
10P link partner FEC correctable errors		1.45 RO	1.43 RO	1.43 RO
10P link partner FEC uncorrectable errors		1.46 RO	1.44 RO	1.44 RO
10P link partner electrical length		1.48 RO	1.47 RO	1.47 RO
2B link partner code violation errors		1.90 RO	1.89 RO	1.89 RO
2B link partner errored seconds		1.92 RO	1.91 RO	1.91 RO
2B link partner severely errored seconds		1.94 RO	1.93 RO	1.93 RO
2B link partner LOSW		1.96 RO	1.95 RO	1.95 RO
2B link partner unavailable seconds		1.98 RO	1.97 RO	1.97 RO
2B link partner state defects register		1.100 RO	1.99 RO	1.99 RO

[a]R/W = Read/Write, RO = read only, n/a = undefined

The link partner registers listed in Table 45–20 have the same behavior upon being read or reset as their local register counterparts.

This register is defined for -O port subtypes only.

Bit definitions for the Link partner PMA/PMD control register are found in Table 45–21.

Table 45–21—Link partner PMA/PMD control register bit definitions

Bit(s)	Name	Description	R/W[a]
1.32.15	Get link partner parameters	1 = get link partner parameters 0 = operation complete, ready	R/W, SC
1.32.14	Reserved	Value always 0	RO
1.32.13	Send link partner parameters	1 = send link partner parameters 0 = operation complete, ready	R/W, SC
1.32.12:0	Reserved	Value always 0	RO

[a]R/W = Read/Write, SC = Self-clearing, RO = read only

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45.2.1.17.1 Get link partner parameters (1.32.15)

When this bit is set to a one, the -O PHY updates its link partner registers shown in Table 45–20 with values from the link partner. While the operation is in progress, the PHY shall keep the bit set as one. If the "Get link partner parameters" operation does not complete within 10 seconds, its result shall be marked as "failed" (see 45.2.1.18) and the operation marked as "complete". After completion of the operation or upon reset, the PHY shall reset the bit to zero. A write to this bit when link is down shall cause the result to be marked as "failed" and the operation marked as "complete".

45.2.1.17.2 Send link partner parameters (1.32.13)

When this bit is set to a one, the -O PHY sends the contents of the 2B link partner line quality thresholds register (see 45.2.1.24) to the link partner. While the operation is in progress, the PHY shall keep the bit set as one. The "Send link partner parameters" operation must complete within 10 seconds, or its result shall be marked as "failed" (see 45.2.1.17) and the operation marked as "complete". After completion of the operation or upon reset, the PHY shall reset the bit to zero. A write to this bit when link is down shall cause the result to be marked as "failed" and the operation marked as "complete".

45.2.1.18 Link partner PMA/PMD status register (Register 1.33)

The Link partner PMA/PMD status register reflects the result of the operations that are performed using the Link Partner PMA/PMD control register (1.32).

This register is defined for -O port subtypes only.

Bit definitions for the Link partner PMA/PMD status register are found in Table 45–22.

Table 45–22—Link Partner PMA/PMD status register bit definitions

Bit(s)	Name	Description	R/W[a]
1.33.15	Reserved	Value always 0	RO
1.33.14	Get link partner result	1 = operation failed 0 = operation successful	RO, LH
1.33.13	Reserved	Value always 0	RO
1.33.12	Send link partner result	1 = operation failed 0 = operation successful	RO, LH
1.33.11:0	Reserved	Value always 0	RO

[a]RO = Read only, LH = Latching high

45.2.1.18.1 Get link partner result (1.33.14)

After a "Get link partner parameters" operation terminates, this bit reflects the result of the operation. If the operation did not complete successfully, the PHY shall set this bit to a one. Upon being read or a reset, the PHY shall set the bit to zero.

The definition of an unsuccessful "Get link partner parameters" operation is unspecified and left to the implementation.

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45.2.1.18.2 Send link partner result (1.33.12)

After a “Send link partner parameters” operation terminates, this bit reflects the result of the operation. If the operation did not complete successfully, the PHY shall set this bit to a one. Upon being read or a reset, the PHY resets the bit to zero.

The definition of an unsuccessful “Send link partner parameters” operation is unspecified and left to the implementation.

45.2.1.19 10P/2B PMA/PMD link loss register (Register 1.36)

The 10P/2B PMA/PMD link loss register is a 16 bit counter that contains the number of times the PMA/PMD link is lost. Link is considered lost when the PMA_receive_synchronized signal (see 61.3.2.1) transitions from up to down. These bits shall be reset to all zeros when the register is read by the management function or upon execution of the MMD reset. These bits shall be held at all ones in the case of overflow. The assignment of bits in the 10P/2B PMA/PMD link loss register is shown in Table 45–23.

Table 45–23—10P/2B PMA/PMD link loss register bit definitions

Bit(s)	Name	Description	R/W[a]
1.36.15:0	Link lost events	The bytes of the counter	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.1.20 10P/2B RX SNR margin register (Register 1.37)

For further information on 2BASE-TL SNR margin, see 63.3. For 10PASS-TS SNR margin, see 62.3.

The bit definitions for the 10P/2B RX SNR margin register are found in Table 45–24.

Table 45–24—10P/2B RX SNR margin register bit definition

Bit(s)	Name	Description	R/W[a]
1.37.15:8	Reserved	Value always 0	RO
1.37.7:0	RX SNR margin	Value of SNR margin in dB	RO

[a]RO = Read only

45.2.1.21 10P/2B link partner RX SNR margin register (Register 1.38)

The 10P/2B link partner RX SNR margin register provides access to the link partner’s receive SNR margin. The contents of this register are refreshed when the STA activates the “Get link partner parameter” command in the Link partner PMA/PMD control register (see 45.2.1.17) and the command completes successfully (see 45.2.1.18.1).

This register is defined for -O port subtypes only.

The bit definitions for this register are found in Table 45–24.

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45.2.1.22 10P/2B line attenuation register (Register 1.39)

This register reports the line attenuation as measured by the PMA/PMD. For more information, see the reference documents in 63.3 and 62.3.

The bit definitions for the 10P/2B line attenuation register are found in Table 45–25.

Table 45–25—10P/2B line attenuation register bit definitions

Bit(s)	Name	Description	R/W[a]
1.39.15:0	Line attenuation	The value of the line attenuation in dB, as perceived by the local PMD.	RO

[a]RO = Read only

45.2.1.23 10P/2B link partner line attenuation register (Register 1.40)

The 10P/2B link partner line attenuation register provides access to the link partner's perceived line attenuation margin. The contents of this register are refreshed when the STA activates the "Get link partner parameter" command in the Link partner PMA/PMD control register (see 45.2.1.17) and the command completes successfully (see 45.2.1.18.1).

This register is defined for -O port subtypes only.

The bit definitions for this register are found in Table 45–25.

45.2.1.24 10P/2B line quality thresholds register (Register 1.41)

The 10P/2B line quality thresholds register sets the target environment for the 10PASS-TS/2BASE-TL connection. The line quality is defined by the SNR margin and line attenuation values.

Bit definitions for the 10P/2B line quality threshold register are found in Table 45–26.

Table 45–26—10P/2B line quality thresholds register bit definition

Bit(s)	Name	Description	R/W[a]
1.41.15:8	Loop attenuation threshold	Attenuation threshold in dB	O: R/W R: RO
1.41.7:4	SNR margin threshold	SNR margin threshold in dB	O: R/W R: RO
1.41.3:0	Reserved	Value always 0	RO

[a]R/W = Read/Write, RO = Read only

45.2.1.24.1 Loop attenuation threshold (1.41.15:8)

These bits set the loop attenuation threshold for 2BASE-TL PMA/PMDs. Writing to these bits on a 10PASS-TS PMA/PMD shall have no effect. The threshold value is in units of dB. For more information on the loop attenuation threshold, see 63.2.2.3.

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45.2.1.24.2 SNR margin threshold (1.41.7:4)

These bits set the SNR margin threshold for 10PASS-TS and 2BASE-TL PMA/PMDs. The threshold is expressed in units of dB. For more information of the SNR margin threshold, see 63.2.2.3 for 2BASE-TL and Section 10 of the document referenced in 62.1.3 for 10PASS-TS.

45.2.1.25 2B link partner line quality thresholds register (Register 1.42)

The 2B link partner line quality thresholds register allows the -O STA to set its -R link partner's line quality thresholds. The contents of this register are transmitted to the -R when the STA activates the "Send link partner parameter" command in the Link Partner PMA/PMD control register (see 45.2.1.17) and the command completes successfully (see 45.2.1.18.2).

This register is defined for -O port subtypes only.

The bit definitions for this register are found in Table 45–26.

45.2.1.26 10P FEC correctable errors counter (Register 1.43)

The 10P FEC correctable errors counter is a 16 bit counter that contains the number of FEC codewords that have been received and corrected. For more information on 10PASS-TS FEC, see 62.2.4.2. These bits shall be reset to all zeros upon execution of the MMD reset and upon being read. The assignment of bits in the 10P FEC correctable error counter is shown in Table 45–27.

Table 45–27—10P FEC correctable errors counter register bit definitions

Bit(s)	Name	Description	R/W[a]
1.43.15:0	Correctable codewords [15:0]	The bytes of the counter	RO

[a]RO = Read only

45.2.1.27 10P FEC uncorrectable errors counter (Register 1.44)

The 10P FEC uncorrectable errors counter is a 16 bit counter that contains the number of FEC codewords that have been received and are uncorrectable. For more information on 10PASS-TS FEC, see 62.2.4.2. These bits shall be reset to all zeros upon execution of the MMD reset and upon being read. The assignment of bits in the 10P FEC uncorrectable error counter is shown in Table 45–28.

Table 45–28—10P FEC uncorrectable errors counter bit definitions

Bit(s)	Name	Description	R/W[a]
1.44.15:0	Uncorrectable codewords [15:0]	The bytes of the counter	RO

[a]RO = Read only

45.2.1.28 10P link partner FEC correctable errors register (Register 1.45)

The 10P link partner FEC correctable errors register provides the -O STA with a snapshot of the -R link partner's FEC correctable errors counter. Because this register is not a counter, its value will increment only

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when refreshed. The contents of this register are refreshed when the STA activates the "Get link partner parameter" command in the Link Partner PMA/PMD control register (see 45.2.1.17) and the command completes successfully (see 45.2.1.18.1).

This register is defined for -O port subtypes only.

The bit definitions for this register are found in Table 45–27 and 45.2.1.26.

45.2.1.29 10P link partner FEC uncorrectable errors register (Register 1.46)

The 10P link partner FEC uncorrectable errors register provides the -O STA a snapshot of the -R link partner's FEC uncorrectable errors counter. Because this register is not a counter, its value will increment only when refreshed. The contents of this register are refreshed when the STA activates the "Get link partner parameter" command in the Link Partner PMA/PMD control register (see 45.2.1.17) and the command completes successfully (see 45.2.1.18.1).

This register is defined for -O port subtypes only.

The bit definitions for this register are found in Table 45–28 and 45.2.1.27.

45.2.1.30 10P electrical length register (Register 1.47)

The bit definitions for the 10P electrical length register are found in Table 45–29.

Table 45–29—10P electrical length register bit definitions

Bit(s)	Name	Description	R/W[a]
1.47.15:0	Electrical length	The electrical length of the medium (in meters), as perceived at the local PMD	RO

[a]RO = Read only

45.2.1.30.1 Electrical length (1.47.15:0)

After the link is established, these bits contain the measured electrical length (in meters) of the medium as measured by the PMD. If the link is down or the PMD is unable to determine the electrical length, these bits shall be set to all ones (see 62.3.2).

45.2.1.31 10P link partner electrical length register (Register 1.48)

The 10P link partner electrical length register provides access to the link partner's electrical length measurement. The contents of this register are refreshed when the STA activates the "Get link partner parameter" command in the Link Partner PMA/PMD control register (see 45.2.1.17) and the command completes successfully (see 45.2.1.18.1).

This register is defined for -O port subtypes only.

The bit definitions for this register are found in Table 45–29 and 45.2.1.30.1.

45.2.1.32 10P PMA/PMD general configuration register (Register 1.49)

The 10P PMA/PMD general configuration register is defined for -O port types only.

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The 10P PMA/PMD general configuration register bit definitions are found in Table 45–30.

Table 45–30—10P PMA/PMD general configuration register bit definitions

Bit(s)	Name	Description	R/W[a]
1.49.15:8	Reserved	Value always 0	RO
1.49.7:0	TX window length	Transmit window length	O: R/W R: undefined

[a]RO = Read only, R/W = Read/Write

45.2.1.32.1 TX window length (1.49.7:0)

Bits 7:0 control the PMD transmit window length within the cyclic prefix and suffix in units of number of samples, as defined in 62.3.2.

45.2.1.33 10P PSD configuration register (Register 1.50)

This register is defined for -O port subtypes only.

The 10P PSD configuration register bit definitions may be found in Table 45–31.

Table 45–31—10P PSD configuration register bit definitions

Bit(s)	Name	Description	R/W[a]
1.50.15:9	Reserved	Value always 0	RO
1.50.8	PBO disable	1 = PBO disabled 0 = PBO normal operation	O: R/W R: undefined
1.50.7:0	Reserved	Value always 0	RO

[a]RO = Read only, R/W = Read/Write

45.2.1.33.1 PBO disable (1.50.8)

Setting this bit to a one disables UPBO for performance testing purposes. Refer to 62.3.4.4.

45.2.1.34 10P downstream data rate configuration (Registers 1.51, 1.52)

These registers are defined for -O port subtypes only.

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The bit definitions for the 10P downstream data rate configuration registers are found in Table 45–32.

Table 45–32—10P downstream data rate configuration register bit definitions

Bit(s)	Name	Description	R/W[a]
1.51.15:0	Minimum downstream data rate	Sets the minimum required downstream payload data rate *M* = value of bits Data rate = *M* × 64000 b/s	O: R/W R: undefined
1.52.15:0	Maximum downstream data rate	Sets the maximum downstream payload data rate *M* = value of bits Data rate = *M* × 64000 b/s	O: R/W R: undefined

[a]R/W = Read/Write

45.2.1.35 10P downstream Reed-Solomon configuration (Register 1.53)

This register is defined for -O port subtypes only.

The bit definitions for 10P downstream Reed-Solomon configuration are found in Table 45–33.

Table 45–33—10P downstream Reed-Solomon configuration register bit definitions

Bit(s)	Name	Description	R/W[a]
1.53.15:1	Reserved	Value always 0	RO
1.53.0	RS codeword length	1 = codeword length of 144 0 = codeword length of 240	O: R/W R: undefined

[a]RO = Read only, R/W = Read/Write

45.2.1.35.1 RS codeword length (1.53.0)

This bit selects the Reed-Solomon forward error correction codeword length used in the downstream direction. For more information, see 62.2.4.2.

45.2.1.36 10P upstream data rate configuration (Registers 1.54, 1.55)

These registers are defined for -O port subtypes only.

The bit definitions for 10P upstream data rate configuration are found in Table 45–34.

45.2.1.37 10P upstream 10P upstream Reed-Solomon configuration register (Register 1.56)

This register is defined for -O port subtypes only.

The bit definitions for the 10P upstream Reed-Solomon configuration are found in Table 45–35.

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Table 45–34—10P upstream data rate configuration register bit definitions

Bit(s)	Name	Description	R/W[a]
1.54.15:0	Minimum upstream data rate	Sets the required upstream payload data rate *M* = value of bits Data rate = *M* × 64000 b/s	O: R/W R: undefined
1.55.15:0	Maximum upstream data rate	Sets the maximum upstream payload data rate *M* = value of bits Data rate = *M* × 64000 b/s	O: R/W R: undefined

[a]R/W = Read/Write

Table 45–35—10P upstream Reed-Solomon configuration register bit definitions

Bit(s)	Name	Description	R/W[a]
1.56.15:1	Reserved	Value always 0	RO
1.56.0	RS codeword length	1 = codeword length = 144 0 = codeword length = 240	O: R/W R: undefined

[a]RO = Read only, R/W = Read/Write

45.2.1.37.1 RS codeword length (1.56.0)

This bit selects the Reed-Solomon forward error correction codeword length used in the upstream direction. For more information, see 62.2.4.2.

45.2.1.38 10P tone group registers (Registers 1.57, 1.58)

10PASS-TS operates by modulating 4096 individual tones across the transmission spectrum. Each tone can be assigned a PSD level, desired SNR margin and transmission direction (downstream or upstream). To reduce the complexity of addressing individual tones, tones are addressed by group. The STA sets the lower and upper tones in a group, sets the parameters for that group, and issues a command to activate those parameters for that group. See 62.3.4.7 for details on the mechanism that transfers tone information across the link to and from the -R link partner.

This register allows the STA to specify the range of tones to control. The bit definitions for the 10P tone group register are defined in Table 45–36.

Table 45–36—10P tone group register bit definitions

Bit(s)	Name	Description	R/W[a]
1.57.15:0	Lower tone	The number of the lower frequency tone in the group. Valid when ≤ the Upper tone.	R/W
1.58.15:0	Upper tone	The number of the higher frequency tone in the group. Valid when ≥ the Lower tone.	R/W

[a]R/W = Read/Write

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45.2.1.39 10P tone control parameters (Registers 1.59, 1.60, 1.61, 1.62, 1.63)

These registers allow the STA to specify parameters for the tones selected in the 10P tone group registers. These values do not take effect until the corresponding activation commands are issued in the 10P tone control action register. The bit definitions for the 10P tone control parameters are shown in Table 45–37.

These registers are defined for -O port subtypes only.

Table 45–37—10P tone control parameters register bit definitions

Bit(s)	Name	Description	R/W[a]
1.59.15	Tone active	1 = selected tones are active 0 = selected tones are disabled	R/W
1.59.14	Tone direction	1 = selected tones assigned to upstream communication 0 = selected tones assigned to downstream communication	R/W
1.59.13:5	Max SNR margin	Assigns the maximum SNR margin the PMD may achieve *M* = value of bits Max SNR margin = *M*/4 dB	R/W
1.59.4:0	Reserved	Value always 0	RO
1.60:15:9	Reserved	Value always 0	RO
1.60.8:0	Target SNR margin	Assigns the target SNR margin for the selected tones *M* = value of bits Target SNR margin = *M*/4 dB	R/W
1.61:15:9	Reserved	Value always 0	RO
1.61.8:0	Min SNR margin	Assigns the minimum SNR margin for the selected tones *M* = value of bits Min SNR margin = *M*/4 dB	R/W
1.62.15:9	Reserved	Value always 0	RO
1.62.8:0	PSD level	Assigns a TX PSD level for the selected tones in dBm/Hz *P* = value of bits (2's complement) PSD level = *P*/4 – 100 dBm/Hz	R/W
1.63.15:9	Reserved	Value always 0	RO
1.63.8:0	USPBO reference	Assigns the level of the USPBO reference at the points represented by the selected tones *P* = value of bits (2's complement) PSD level = *P*/4 – 100 dBm/Hz	R/W

[a]R/W = Read/Write, RO = Read only

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45.2.1.39.1 Tone active (1.59.15)

These bits are used to control the activity of the selected tones. When the "Change tone activity" command is issued (1.64.4), the selected tones will be either activated or deactivated based on the value set in these bits.

45.2.1.39.2 Tone direction (1.59.14)

These bits are used to control the direction of the selected tones. When the "Change tone direction" command is issued (1.64.3), the selected tones will adopt the direction set in these bits.

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45.2.1.39.3 Max SNR margin (1.59.13:5)

These bits control the maximum SNR margin for the selected tones. When the "Change SNR margin" command is issued (1.64.2), the PMA/PMD will use the value set in these bits in calculations related to maximum SNR margin. The SNR margin is in units of dB, derived by dividing the value of bits 13:5 by 4.

45.2.1.39.4 Target SNR margin (1.60.8:0)

These bits control the target SNR margin for the selected tones. When the "Change SNR margin" command is issued (1.64.2), the PMA/PMD will use the value set in these bits in calculations related to target SNR margin. The target SNR margin is in units of dB, derived by dividing the value of bits 8:0 by 4.

45.2.1.39.5 Minimum SNR margin (1.61.8:0)

These bits control the minimum SNR margin for the selected tones. When the "Change SNR margin" command is issued (1.64.2), the PMA/PMD will use the value set in these bits in calculations related to minimum SNR margin. The minimum SNR margin is in units of dB, derived by dividing the value of bits 8:0 by 4.

45.2.1.39.6 PSD level (1.62.8:0)

These bits control the transmit PSD level of the selected tones. When the "Change PSD level" command is issued (1.64.1), the PMA/PMD will set the PSD level of the selected tones to according to Equation (45–2), where *x* is the value of bits 8:0:

$$power = \frac{x}{4} - 100\frac{\text{dBm}}{\text{Hz}} \tag{45–2}$$

45.2.1.39.7 USPBO reference (1.63.8:0)

These bits control the reference level for the upstream power back-off function of the PMA/PMD. When the "Change USPBO reference PSD" command (1.64.0) is issued, the portion of the USPBO reference curve that corresponds to the selected tones is changed to the value specified by these bits. The USPBO reference level is specified according to Equation (45–3), where *x* is the value of bits 8:0:

$$power = \frac{x}{4} - 100\frac{\text{dBm}}{\text{Hz}} \tag{45–3}$$

45.2.1.40 10P tone control action register (Register 1.64)

The operations in this register apply to the tones selected in the 10P tone group registers (1.57, 1.58).

This register is defined for -O port subtypes only.

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The bit definitions for the 10P tone control action register are shown in Table 45–38.

Table 45–38—10P tone control action register bit definitions

Bit(s)	Name	Description	R/W[a]
1.64.15:6	Reserved	Value always 0	RO
1.64.5	Refresh tone status	1 = refresh selected tones for the 10P tone status registers 0 = ready, operation complete	R/W, SC
1.64.4	Change tone activity	1 = activate tone active setting as in tone control parameter register 0 = ready, operation complete	R/W, SC
1.64.3	Change tone direction	1 = activate tone direction setting as in tone control parameter register 0 = ready, operation complete	R/W, SC
1.64.2	Change SNR margin	1 = activate min, max and target SNR margin settings as in tone control parameter register 0 = ready, operation complete	R/W, SC
1.64.1	Change PSD level	1 = activate PSD level setting as in tone control parameter register 0 = ready, operation complete	R/W, SC
1.64.0	Change UPBO reference PSD	1 = activate UPBO reference PSD settings as in tone control parameter register 0 = ready, operation complete	R/W, SC

[a]RO = Read only, R/W = Read/Write, SC = Self-clearing

45.2.1.40.1 Refresh tone status (1.64.5)

When this bit is set to a one, the tone status information from the local and link partner is gathered so that it may be read using the 10P tone status registers (1.65, 1.66, and 1.67). While the tones are being refreshed, this bit shall remain set as one. This bit shall be reset to zero when the refresh operation is over or upon reset.

NOTE—Refreshing a large number of tones may take a long time to complete.

45.2.1.40.2 Change tone activity (1.64.4)

When this bit is set to a one, the selected tones are enabled or disabled according to the assignment in the tone active bit of the 10P tone control parameters register (1.59.15). While the tones are being activated/deactivated, this bit shall remain set as one. This bit shall be reset to zero when the operation is over or upon reset.

45.2.1.40.3 Change tone direction (1.64.3)

When this bit is set to a one, the transmission direction of selected tones is changed according to the assignment in the tone direction bit of the 10P tone control parameters register (1.59.14). While the tones are being assigned, this bit shall remain set as one. This bit shall be reset to zero when the operation is over or upon reset.

45.2.1.40.4 Change SNR margin (1.64.2)

When this bit is set to a one, the SNR margin parameters for the selected tones are loaded according the assignment in the Minimum, Target and Maximum SNR margin bits of the 10P tone control parameters

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register (1.59.13:5, 1.60.8:0, 1.61.8:0). While the parameters are being loaded, this bit shall remain set as one. This bit shall be reset to zero when the operation is over or upon reset.

45.2.1.40.5 Change PSD level (1.64.1)

When this bit is set to a one, the PSD level for the selected tones is set according to the value in the PSD level bits of the 10P tone control parameters register (1.62.8:0). While the PSD is being set, this bit shall remain set as one. This bit shall be reset to zero when the operation is over or upon reset.

45.2.1.40.6 Change USPBO reference PSD (1.64.0)

When this bit is set to a one, the upstream power back-off reference PSD level for the selected tones is set according to the value in the USPBO PSD reference bits of the 10P tone control parameters register (1.63.8:0). While the reference PSD is being set, this bit shall remain set as one. This bit shall be reset to zero when the operation is over or upon reset.

45.2.1.41 10P tone status registers (Registers 1.65, 1.66, 1.67)

The 10P tone status registers allow the STA to query the status of any individual tone in the link. The values read in the 10P tone status register correspond to the tone whose number is set in the "Lower tone" of the 10P tone group registers (see 45.2.1.38).

The status of some tones is read from the link partner. Because the constant update of these values would be a strain on channel resources, these values are only updated for selected tones when the "Refresh tone table" command is issued in the 10P tone control action register (1.64).

The 10P tone status registers bit definitions are given in Table 45–39.

Table 45–39—10P tone status registers bit definitions

Bit(s)	Name	Description	R/W[a]
1.65.15	Refresh status	1 = tone entry has been refreshed 0 = tone entry has not been refreshed since last read	RO
1.65.14	Active	1 = tone is disabled 0 = tone is active	RO
1.65.13	Direction	1 = tone is assigned to upstream communication 0 = tone is assigned to downstream communication	RO
1.65.12:8	Reserved	Value always 0	RO
1.65.7:0	RX PSD	PSD of the tone at the receiver in dBm/Hz	RO
1.66.15:8	TX PSD	PSD of the tone at the transmitter in dBm/Hz	RO
1.66.7:3	Bit load	The number of bits currently loaded on the tone	RO
1.66.2:0	Reserved	Value always 0	RO
1.67.15:10	Reserved	Value always 0	RO
1.67.9:0	SNR margin	Current SNR margin for the tone *R* = value of bits SNR Margin = *R*/4 dB	RO

[a]RO = Read only

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45.2.1.41.1 Refresh status (1.65.15)

When read as a one, bit 1.65.15 indicates that the values for this tone table have not been read since the last "Refresh tone status" command was issued by the 10P tone control action register (1.64). Upon reading this bit or upon reset, the bit shall be reset to zero.

45.2.1.41.2 Active (1.65.14)

When read as a one, this bit indicates that the selected tone is disabled (i.e., powered off and not carrying data).

45.2.1.41.3 Direction (1.65.13)

When read as a one, this bit indicates that the selected tone is assigned to upstream communication. When read as a zero, the tone is assigned to downstream communication.

45.2.1.41.4 RX PSD (1.65.7:0)

These bits report the PSD of the selected tone as perceived at the receiver in units of dBm/Hz.

45.2.1.41.5 TX PSD (1.66.15:8)

These bits report the PSD of the selected tone as output by the transmitter in units of dBm/Hz.

45.2.1.41.6 Bit load (1.66.7:3)

These bits report the number of bits encoded on the selected tone.

45.2.1.41.7 SNR margin (1.67.9:0)

These bits report the current SNR margin for the selected tone, as perceived by the receiver, in units of dB. The value of the SNR margin is obtained by dividing the decimal value of bits 9:0 by 4.

45.2.1.42 10P outgoing indicator bits status register (Register 1.68)

The 10P outgoing indicator bits status register conveys the current state of the indicator bits being sent to the link partner (See 62.3.4.7). The bit definitions for the 10P indicator bits status register are shown in Table 45–40.

Table 45–40—10P outgoing indicator bits status register bit definition

Bit(s)	Name	Description	R/W[a]
1.68.15:9	Reserved	Value always 0	RO
1.68.8	LoM	1 = received signal below SNR margin threshold 0 = normal state	RO
1.68.7	lpr	1 = power supply voltage invalid 0 = normal state	RO
1.68.6	po	1 = PMA/PMD is being powered off 0 = normal state	RO
1.68.5	Rdi	1 = severely errored frames have been received 0 = normal state	RO
1.68.4	los	1 = signal power is lower than the threshold 0 = normal state	RO

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Table 45–40—10P outgoing indicator bits status register bit definition *(continued)*

Bit(s)	Name	Description	R/W[a]
1.68.3:2	Reserved	Value always 0	RO
1.68.1	fec-s	1 = corrected errors have been detected in the received FEC block of slow data 0 = normal state	RO
1.68.0	be-s	1 = non-corrected errors have been detected in the received block of slow data 0 = normal state	RO

[a]RO = Read only

NOTE—These bit refer to "slow" data. 10PASS-TS uses the slow data channel as referenced in T1.424. The name is kept here to simplify a comparison between the two documents.

45.2.1.42.1 LoM (1.68.8)

When read as a one, this bit indicates that the PMA/PMD is receiving a signal whose SNR margin is below the set threshold (see 45.2.1.24). The status of this condition is reported to the link partner PMA/PMD via the 10PASS-TS indicator bits.

45.2.1.42.2 lpr (1.68.7)

When read as a one, this bit indicates that the PMA/PMD is not receiving sufficient power supply input for proper operation. The specific conditions that cause this bit to be set are implementation specific. The status of this condition is reported to the link partner PMA/PMD via the 10PASS-TS indicator bits.

45.2.1.42.3 po (1.68.6)

When read as a one, this bit indicates that the PMA/PMD has been instructed to power off. The specific conditions that cause this bit to be set are implementation specific. The status of this condition is reported to the link partner PMA/PMD via the 10PASS-TS indicator bits.

45.2.1.42.4 Rdi (1.68.5)

When read as a one, this bit indicates that the PMA/PMD has received PMA/PMD frames containing severe errors. The status of this condition is reported to the link partner PMA/PMD via the 10PASS-TS indicator bits.

45.2.1.42.5 los (1.68.4)

When read as a one, this bit indicates that the PMA/PMD is not receiving a valid signal. The status of this condition is reported to the link partner PMA/PMD via the 10PASS-TS indicator bits.

45.2.1.42.6 fec-s (1.68.1)

When read as a one, this bit indicates that the PMA/PMD is receiving FEC blocks with one or more correctable errors. The status of this condition is reported to the link partner PMA/PMD via the 10PASS-TS indicator bits.

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45.2.1.42.7 be-s (1.68.0)

When read as a one, this bit indicates that the PMA/PMD is receiving FEC blocks with one or more uncorrectable errors. The status of this condition is reported to the link partner PMA/PMD via the 10PASS-TS indicator bits.

45.2.1.43 10P incoming indicator bits status register (Register 1.69)

The 10P indicator bits status register conveys the current state of the indicator bits being received from the link partner's PMA (see 62.3.4.7). The bit definitions for the 10P incoming indicator bits status register are shown in Table 45–41.

Table 45–41—10P incoming indicator bits status register bit definition

Bit(s)	Name	Description	R/W[a]
1.69.15:9	Reserved	Value always 0	RO
1.69.8	LoM	1 = received signal below SNR margin threshold 0 = normal state	RO
1.69.7	Flpr	1 = power supply voltage invalid 0 = normal state	RO
1.69.6	Fpo	1 = PMA/PMD is being powered off 0 = normal state	RO
1.69.5	Rdi	1 = severely errored frames have been received 0 = normal state	RO
1.69.4	Flos	1 = signal power is lower than the threshold 0 = normal state	RO
1.69.3:2	Reserved	Value always 0	RO
1.69.1	Ffec-s	1 = corrected errors have been detected in the received FEC block of slow data 0 = normal state	RO
1.69.0	Febe-s	1 = non-corrected errors have been detected in the received block of slow data 0 = normal state	RO

[a]RO = Read only

NOTE—These bit refer to "slow" data. 10PASS-TS uses the slow data channel as referenced in T1.424. The name is kept here to simplify a comparison between the two documents.

45.2.1.43.1 LoM (1.69.8)

When read as a one, this bit indicates that the link partner PMA/PMD is receiving a signal whose SNR margin is below the set threshold (see 45.2.1.24). The status of this condition is reported to the local PMA/PMD via the 10PASS-TS indicator bits.

45.2.1.43.2 Flpr (1.69.7)

When read as a one, this bit indicates that the link partner PMA/PMD is not receiving sufficient power supply input for proper operation. The specific conditions that cause this bit to be set are implementation specific. The status of this condition is reported to the local PMA/PMD via the 10PASS-TS indicator bits.

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45.2.1.43.3 Fpo (1.69.6)

When read as a one, this bit indicates that the link partner PMA/PMD has been instructed to power off. The specific conditions that cause this bit to be set are implementation specific. The status of this condition is reported to the local PMA/PMD via the 10PASS-TS indicator bits.

45.2.1.43.4 Rdi (1.69.5)

When read as a one, this bit indicates that the link partner PMA/PMD has received PMA/PMD frames containing severe errors. The status of this condition is reported to the local PMA/PMD via the 10PASS-TS indicator bits.

45.2.1.43.5 Flos (1.69.4)

When read as a one, this bit indicates that the link partner PMA/PMD has is not receiving a valid signal. The status of this condition is reported to the local PMA/PMD via the 10PASS-TS indicator bits.

45.2.1.43.6 Ffec-s (1.69.1)

When read as a one, this bit indicates that the link partner PMA/PMD is receiving FEC blocks with one or more correctable errors. The status of this condition is reported to the local PMA/PMD via the 10PASS-TS indicator bits.

45.2.1.43.7 Febe-s (1.69.0)

When read as a one, this bit indicates that the link partner PMA/PMD is receiving FEC blocks with one or more uncorrectable errors. The status of this condition is reported to the local PMA/PMD via the 10PASS-TS indicator bits.

45.2.1.44 10P cyclic extension configuration register (Register 1.70)

The 10P cyclic extension configuration register controls the length of the cyclic extension for the 10P PMD. For more information, see 62.3.4.2. The value of the cyclic extension is equal to the decimal value set in bits 15:0. Values of decimal 10, 20 and 40 are valid. Writes to set any other values shall be ignored. Upon reset, the PMD shall set these bits to a decimal value of 20.

The bit definitions for this register are shown in Table 45–42.

Table 45–42—10P cyclic extension configuration register bit definitions

Bit(s)	Name	Description	R/W[a]
1.70.15:0	Cyclic extension	The value of the cyclic extension	O: R/W R: RO

[a]R/W = Read/Write, RO = Read only

45.2.1.45 10P attainable downstream data rate register (Register 1.71)

The 10P attainable downstream data rate register reports the data rate that the -R link partner measures to be the highest data rate for downstream transmission. The data rate is encoded as 1 kb/s times the decimal value of the register bits 15:0. The value of the register bits are not valid until after link is “up” (see 45.2.1.16.4).

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The bit definitions for this register are found in Table 45–43.

Table 45–43—10P attainable downstream data rate register bit definitions

Bit(s)	Name	Description	R/W[a]
1.71.15:0	Attainable downstream data rate	Data rate in 1 kb/s increments	RO

[a]RO = Read only

45.2.1.46 2B general parameter register (Register 1.80)

The 2B general parameter register controls various parameters for the operation of the 2BASE-TL PMA/PMD.

This register is read only for -R ports which may be read so the STA may know the mode selected by the -O port. The selected parameters on the -O are sent to the -R link partner on link initialization. For more information on how these parameters are passed across the physical link using G.994.1 signaling, see 61B.3.2.

The bit definitions for the 2B general parameter register are found in Table 45–44.

Table 45–44— 2B general parameter register bit definition

Bit(s)	Name	Description	R/W[a]
1.80.15	Reserved	Value always 0	RO
1.80.14:10	PMMS target margin	margin = 14:10 - 10dB	R/W
1.80.9	Line probing control	1 = use line probing 0 = do not use line probing (default)	R/W
1.80.8	Noise environment	1 = current condition 0 = worst case (default)	R/W
1.80.7:2	Reserved	Value always 0	RO
1.80.1:0	Region	Selects the regional annex to operate under 00 = Annex A 01 = Annex B 10 = Annex C 11 = reserved, writes ignored	O: R/W R: RO

[a]R/W = Read/Write, RO = Read only

45.2.1.46.1 PMMS target margin (1.80.14:10)

The PMMS target margin specified in bits 14:10 specifies the noise margin that the PMMS procedure tries to attain. The margin is expressed in dB as the decimal value of bits 14:10 minus 10 dB. The margin specified is measured either against either worst case or current line conditions, based on the value set in bit 1.80.8.

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The PMMS margin value is transferred during 2BASE-TL initialization via the worst case PMMS margin bits in Table 61B–57 and Table 61B–43, or the current condition PMMS margin bits in Table 61B–48 and Table 61B–44.

45.2.1.46.2 Line probing control (1.80.9)

When set to a one, this bit tells the PMA/PMD to perform line probing the next time link is initialized. When set to a zero, the PMA/PMD does not use line probing. Line probing causes the PMA/PMD to select probe duration and the link data rate. For more information, see the documents referenced in 63.3.

45.2.1.46.3 Noise environment (1.80.8)

This bit controls the reference noise used during line probing. When set to a one, the noise environment is based on the current line conditions. When set to a zero, the noise environment is based on worst case models. For more information, see the documents referenced in 63.3.

45.2.1.46.4 Region (1.80.1:0)

These bits select the regional annex that is used for the operation of the 2BASE-TL PMA/PMD. These annexes refer to clauses in documents referenced by the 2BASE-TL PMA/PMD specification. These are not annexes in IEEE Std 802.3. For details on each annex, see the document referenced in 63.1.3.

45.2.1.47 2B PMD parameters registers (Registers 1.81 through 1.88)

The 2B PMD parameters registers set the transmission parameters for an individual 2BASE-TL PMA/PMD link. When the link is initialized, these parameters are used by the link partner PMA/PMDs in an attempt to achieve specified settings.

These registers allow one to specify a single fixed data rate or up to four data rate ranges at the -O PMA/PMD. An additional set of four data ranges are found in the 2B extended PMD parameters registers (1.102 through 1.109). Bit descriptions for the 2B extended PMD parameters registers are found in 45.2.1.61. Together these sets allow up to eight data rate ranges to be specified.

If at least one data rate range is specified with different Minimum and Maximum data rates, the link is trained with the highest attainable rate. If line probing is enabled, the highest rate is determined by the result of line probing and the “Data rate step” value is ignored. If line probing is disabled, the minimum and maximum rate, “Data rate step” and “Power” values are used to determine the highest attainable rate.

In the case of a single fixed rate specified (Minimum data rate1 equals Maximum data rate1, Data rate step[1:8] set to zero, Minimum/Maximum data rate[2:8] set to zero), the link is trained at the specified rate.

When multiple ranges are specified, the PMD selects the first attainable range, starting sequentially from the first range.

Since writing to this register does not have an immediate effect, reading this register returns the desired parameters, which are not necessarily the current operating parameters.

For more information on how these parameters are passed across the physical link using G.994.1 signaling (see 61B.3.2).

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The bit definitions for the 2B PMD parameters register are found in Table 45–45.

Table 45–45— 2B PMD parameters registers bit definition

Bit(s)	Name	Description	R/W[a]
1.81.15	Reserved	Value always 0	RO
1.81.14:8	Min data rate1	Min data rate of the first range *n* = value of the bits, *n* valid 3 to 89 Data Rate = 64*n* kb/s	O: R/W R: RO
1.81.7	Reserved	Value always 0	RO
1.81.6:0	Max data rate1	Max data rate of the first range *n* = value of the bits, *n* valid 3 to 89 Data Rate = 64*n* kb/s	O: R/W R: RO
1.82.15:14	Reserved	Value always 0	RO
1.82.13:7	Data rate step1	Data rate step of the first range *n* = value of the bits, *n* valid 1 to 86 Data Rate = 64*n* kb/s	O: R/W R: RO
1.82.6:2	Power1	*x* = multiple of 0.5 dBm to add to 5 dBm offset Power = (5 + 0.5*x*) dBm	O: R/W R: RO
1.82.1:0	Constellation1	11 = reserved 10 = 16-TCPAM 01 = 32-TCPAM 00 = automatically set by the PHY	O: R/W R: RO
1.83.15	Reserved	Value always 0	RO
1.83.14:8	Min data rate2	Min data rate of the second range *n* = value of the bits, *n* valid 3 to 89 Data Rate =64*n* kb/s	O: R/W R: RO
1.83.7	Reserved	Value always 0	RO
1.83.6:0	Max data rate2	Max data rate of the second range *n* = value of the bits, *n* valid 3 to 89 Data Rate = 64*n* kb/s	O: R/W R: RO
1.84.15:14	Reserved	Value always 0	RO
1.84.13:7	Data rate step2	Data rate step of the second range *n* = value of the bits, *n* valid 1 to 86 Data Rate = 64*n* kb/s	O: R/W R: RO
1.84.6:2	Power2	*x* = multiple of 0.5 dBm to add to 5 dBm offset Power = (5 + 0.5*x*) dBm	O: R/W R: RO
1.84.1:0	Constellation2	11 = reserved 10 = 16-TCPAM 01 = 32-TCPAM 00 = automatically set by the PHY	O: R/W R: RO
1.85.15	Reserved	Value always 0	RO
1.85.14:8	Min data rate3	Min data rate of the third range *n* = value of the bits, *n* valid 3 to 89 Data Rate = 64*n* kb/s	O: R/W R: RO
1.85.7	Reserved	Value always 0	RO

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Table 45–45— 2B PMD parameters registers bit definition *(continued)*

Bit(s)	Name	Description	R/W[a]
1.85.6:0	Max data rate3	Max data rate of the third range *n* = value of the bits, *n* valid 3 to 89 Data Rate = 64*n* kb/s	O: R/W R: RO
1.86.15:14	Reserved	Value always 0	RO
1.86.13:7	Data rate step3	Data rate step of the third range *n* = value of the bits, *n* valid 1 to 86 Data Rate = 64*n* kb/s	O: R/W R: RO
1.86.6:2	Power3	*x* = multiple of 0.5 dBm to add to 5 dBm offset Power = (5 + 0.5*x*) dBm	O: R/W R: RO
1.86.1:0	Constellation3	11 = reserved 10 = 16-TCPAM 01 = 32-TCPAM 00 = automatically set by the PHY	O: R/W R: RO
1.87.15	Reserved	Value always 0	RO
1.87.14:8	Min data rate4	Min data rate of the fourth range *n* = value of the bits, *n* valid 3 to 89 Data Rate = 64*n* kb/s	O: R/W R: RO
1.87.7	Reserved	Value always 0	RO
1.87.6:0	Max data rate4	Max data rate of the fourth range *n* = value of the bits, *n* valid 3 to 89 Data Rate = 64*n* kb/s	O: R/W R: RO
1.88.15:14	Reserved	Value always 0	RO
1.88.13:7	Data rate step4	Data rate step of the fourth range *n* = value of the bits, *n* valid 1 to 86 Data Rate = 64*n* kb/s	O: R/W R: RO
1.88.6:2	Power4	*x* = multiple of 0.5 dBm to add to 5 dBm offset Power = (5 + 0.5*x*) dBm	O: R/W R: RO
1.88.1:0	Constellation4	11 = reserved 10 = 16-TCPAM 01 = 32-TCPAM 00 = automatically set by the PHY	O: R/W R: RO

[a]R/W = Read/Write, RO = Read only

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45.2.1.47.1 Minimum data rate (1.81, 1.83, 1.85, 1.87. Bits 14:8)

Bits 14:8 in registers 1.81 through 1.87 set the minimum data rate for each of the four ranges. Valid values for these bits are decimal 3 through 89, writes to set an invalid value shall be ignored. The rate is expressed in units of kb/s and is derived by multiplying the decimal value of bits 14:8 by 64.

45.2.1.47.2 Max data rate (1.81, 1.83, 1.85, 1.87. Bits 6:0)

Bits 6:0 in registers 1.81 through 1.87 set the maximum data rate for each of the four ranges. Valid values for these bits are decimal 3 through 89, writes to set an invalid value shall be ignored. The rate is expressed in units of kb/s and is derived by multiplying the decimal value of bits 6:0 by 64.

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45.2.1.47.3 Data rate step (1.82, 1.84, 1.86, 1.88. Bits 13:7)

Bits 13:7 in registers 1.82 through 1.88 set the granularity used by the PMA/PMD when determining the line rate. Valid values for these bits are decimal 1 through 86, writes to set an invalid value shall be ignored. The data rate step is expressed in units of kb/s and is derived by multiplying the decimal value of bits 13:7 by 64.

45.2.1.47.4 Power (1.82, 1.84, 1.86, 1.88. Bits 6:2)

Bits 6:2 in registers 1.82 through 1.88 set the allowed power level for each data rate range. The power levels set in these bits override those of the annex selected in the 2B general parameter register (1.80). The power level is expressed in units of dBm and is derived by Equation (45–4), where *x* equals the value of bits 6:2.

$$power = \left(5 + \frac{x}{2}\right) \text{ dBm} \quad (45–4)$$

45.2.1.47.5 Constellation (1.82, 1.84, 1.86, 1.88. Bits 1:0)

Bits 1:0 in registers 1.82 through 1.88 set the allowed constellation for each data rate range. Setting a value of 10 or 01 restricts the constellation to 16- or 32-TCPAM respectively. When set to a value of 00, the PMD automatically determines the constellation during initialization. Attempts to set a value of 11 shall be ignored.

45.2.1.48 2B code violation errors counter (Register 1.89)

The 2B code violation errors counter is a 16-bit counter that contains the number of the 2BASE-TL CRC anomalies. See 63.2.2.3 for more information. These bits shall be set to all zeros upon an MMD reset and upon being read.

Bit definitions for the 2B code violation errors counter are found in Table 45–46.

Table 45–46—2B code violation errors counter bit definitions

Bit(s)	Name	Description	R/W[a]
1.89.15:0	Code violations [15:0]	The bytes of the counter	RO

[a]RO = Read only

45.2.1.49 2B link partner code violations register (Register 1.90)

The 2B link partner code violations register provides the -O STA with a snapshot of the -R link partner's 2B code violations counter. Because this register is not a counter, its value will be updated only when refreshed. The contents of this register are refreshed when the STA activates the "Get link partner parameter" command in the Link Partner PMA/PMD control register (see 45.2.1.17) and the command completes successfully (see 45.2.1.18.1).

This register is defined for -O port subtypes only.

The bit definitions for this register are found in Table 45–46.

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45.2.1.50 2B errored seconds counter (Register 1.91)

This 8-bit counter contains the number of errored seconds (see 63.2.2.3) These bits shall be set to all zeros when the register is read by management or upon an MMD reset.

Bit definitions for the 2B errored seconds counter are found in Table 45–47.

Table 45–47—2B errored seconds counter bit definitions

Bit(s)	Name	Description	R/W[a]
1.91.15:8	Reserved	Value always 0	RO
1.91.7:0	Errored seconds [7:0]	The byte of the counter	RO

[a]RO = Read only

45.2.1.51 2B link partner errored seconds register (Register 1.92)

The 2B link partner errored seconds register provides the -O STA with a snapshot of the -R link partner's 2B errored seconds counter. Because this register is not a counter, its value will be updated only when refreshed. The contents of this register are refreshed when the STA activates the "Get link partner parameter" command in the Link Partner PMA/PMD control register (see 45.2.1.17) and the command completes successfully (see 45.2.1.18.1).

This register is defined for -O port subtypes only.

The bit definitions for this register are found in Table 45–47.

45.2.1.52 2B severely errored seconds counter (Register 1.93)

This 8-bit counter contains the number severely errored seconds (see 63.2.2.3). These bits shall be set to all zeros when the register is read by management or upon an MMD reset.

Bit definitions for the 2B severely errored seconds register are found in Table 45–48.

Table 45–48—2B severely errored counter register bit definitions

Bit(s)	Name	Description	R/W[a]
1.93.15:8	Reserved	Value always 0	RO
1.93.7:0	Severely errored seconds [7:0]	The byte of the counter	RO

[a]RO = Read only

45.2.1.53 2B link partner severely errored seconds register (Register 1.94)

The 2B link partner severely errored seconds register provides the -O STA with a snapshot of the -R link partner's 2B severely errored seconds counter. Because this register is not a counter, its value will be updated only when refreshed. The contents of this register are refreshed when the STA activates the "Get link partner parameter" command in the Link Partner PMA/PMD control register (see 45.2.1.17) and the command completes successfully (see 45.2.1.18.1).

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This register is defined for -O port subtypes only.

The bit definitions for this register are found in Table 45–48.

45.2.1.54 2B LOSW counter (Register 1.95)

This 8-bit counter contains the number of loss of sync seconds (see 63.2.2.3). These bits shall be set to all zeros when the register is read by management or upon an MMD reset.

Bit definitions for the 2B LOSW counter are found in Table 45–49.

Table 45–49—2B LOSW counter bit definitions

Bit(s)	Name	Description	R/W[a]
1.95.15:8	Reserved	Value always 0	RO
1.95.7:0	Loss of sync seconds [7:0]	The byte of the counter	RO

[a]RO = Read only

45.2.1.55 2B link partner LOSW register (Register 1.96)

The 2B link partner LOSW register provides the -O STA with a snapshot of the -R link partner's 2B LOSW counter. Because this register is not a counter, its value will be updated only when refreshed. The contents of this register are refreshed when the STA activates the "Get link partner parameter" command in the Link partner PMA/PMD control register (see 45.2.1.17) and the command completes successfully (see 45.2.1.18.1).

This register is defined for -O port subtypes only.

The bit definitions for this register are found in Table 45–49.

45.2.1.56 2B unavailable seconds counter (Register 1.97)

This 8-bit counter contains the number of unavailable seconds (see 63.2.2.3). These bits shall be set to all zeros when the register is read by management or upon an MMD reset.

Bit definitions for the 2B unavailable seconds counter are found in Table 45–50.

Table 45–50—2B unavailable seconds counter bit definitions

Bit(s)	Name	Description	R/W[a]
1.97.15:8	Reserved	Value always 0	RO
1.97.7:0	unavailable seconds [7:0]	The byte of the counter	RO

[a]RO = Read only

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45.2.1.57 2B link partner unavailable seconds register (Register 1.98)

The 2B link partner unavailable seconds register provides the -O STA with a snapshot of the -R link partner's 2B unavailable seconds counter. Because this register is not a counter, its value will be updated only when refreshed. The contents of this register are refreshed when the STA activates the "Get link partner parameter" command in the Link Partner PMA/PMD control register (see 45.2.1.17) and the command completes successfully (see 45.2.1.18.1).

This register is defined for -O port subtypes only.

The bit definitions for this register are found in Table 45–50.

45.2.1.58 2B state defects register (Register 1.99)

The 2B state defects register is used to communicate defect states from the 2BASE-TL PMD (see 63.2.2.3). The thresholds for these defects are set using the 2B line quality threshold register (see 45.2.1.24). The register bits are cleared to zero when read by the STA or upon MMD reset. On a -R PMA/PMD, these bits are also cleared to zero upon the successful reception of a "Get link partner parameters" command (see 45.2.1.16.1).

Bit definitions for the 2B state defects register are found in Table 45–51.

Table 45–51—2B state defects register bit definitions

Bit(s)	Name	Description	R/W[a]
1.99.15	Segment defect	1 = segment defect detected 0 = normal condition	RO, LH
1.99.14	SNR margin defect	1 = SNR margin defect detected 0 = normal condition	RO, LH
1.99.13	Loop attenuation defect	1 = loop attenuation defect detected 0 = normal condition	RO, LH
1.99.12	Loss of sync word	1 = loss of sync word detected 0 = normal condition	RO, LH
1.99.11:0	Reserved	Value always 0	RO

[a]RO = Read only, LH = Latching high

45.2.1.58.1 Segment defect (1.99.15)

When read as a one, this bit indicates that the local PMA/PMD has detected a segment defect.

45.2.1.58.2 SNR margin defect (1.99.14)

When read as a one, this bit indicates that the local PMA/PMD has received a signal whose SNR is below the set threshold (see 45.2.1.24).

45.2.1.58.3 Loop attenuation defect (1.99.13)

When read as a one, this bit indicates that the PMA/PMD has detected that the loop attenuation is below the set threshold (see 45.2.1.24).

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45.2.1.58.4 Loss of sync word (1.99.12)

When read as a one, this bit indicates that the PMA/PMD has lost PMA/PMD frame sync.

45.2.1.59 2B link partner state defects register (Register 1.100)

The 2B link partner state defects register provides the -O STA with a snapshot of the -R link partner's 2B state defects register. The contents of this register are refreshed when the STA activates the "Get link partner parameter" command in the Link Partner PMA/PMD control register (see 45.2.1.17) and the command completes successfully (see 45.2.1.18.1).

This register is defined for -O port subtypes only.

The bit definitions for this register are found in Table 45–51.

45.2.1.60 2B negotiated constellation register (Register 1.101)

The bit definitions for this register are shown in Table 45–52.

Table 45–52—2B register bit definition

Bit(s)	Name	Description	R/W[a]
1.101.15:2	Reserved	Value always 0	RO
1.101.1:0	Negotiated constellation	11 = reserved 10 = 16-TCPAM 01 = 32-TCPAM 00 = undetermined	RO

[a]RO = Read only

45.2.1.60.1 Negotiated constellation (1.101.1:0)

These bits report the resulting constellation that was obtained after initialization. For more information on configuring 2BASE-TL PMA/PMD link initialization, see the 2B PMD parameter registers (see 45.2.1.47). When read as 10 or 01, the constellation has been set as either 16- or 32-TCPAM respectively. When read as 00, the local PMD has not arrived at a constellation with its link partner (as may be the case while link is down or initializing, after reset or upon a failed initialization).

45.2.1.61 2B extended PMD parameters registers (Registers 1.102 through 1.109)

The 2B extended PMD parameters registers define four additional data range sets to be used in conjunction with the 2B PMD parameters registers when additional PMD configuration detail is desired. For a complete description of the use of these registers, see 45.2.1.47.

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Bit definitions for these registers can be found in Table 45–53.

Table 45–53— 2B extended PMD parameters registers bit definition

Bit(s)	Name	Description	R/W[a]
1.102.15	Reserved	Value always 0	RO
1.102.14:8	Min data rate5	Min data rate of the fifth range *n* = value of the bits, *n* valid 3 to 89 Data Rate = 64*n* kb/s	O: R/W R: RO
1.102.7	Reserved	Value always 0	RO
1.102.6:0	Max data rate5	Max data rate of the fifth range *n* = value of the bits, *n* valid 3 to 89 Data Rate = 64*n* kb/s	O: R/W R: RO
1.103.15:14	Reserved	Value always 0	RO
1.103.13:7	Data rate step5	Data rate step of the fifth range *n* = value of the bits, *n* valid 1 to 86 Data Rate = 64*n* kb/s	O: R/W R: RO
1.103.6:2	Power5	*x* = multiple of 0.5 dBm to add to 5 dBm offset Power = (5 + 0.5*x*) dBm	O: R/W R: RO
1.103.1:0	Constellation5	11 = reserved 10 = 16-TCPAM 01 = 32-TCPAM 00 = automatically set by the PHY	O: R/W R: RO
1.104.15	Reserved	Value always 0	RO
1.104.14:8	Min data rate6	Min data rate of the sixth range *n* = value of the bits, *n* valid 3 to 89 Data Rate =64*n* kb/s	O: R/W R: RO
1.104.7	Reserved	Value always 0	RO
1.104.6:0	Max data rate6	Max data rate of the sixth range *n* = value of the bits, *n* valid 3 to 89 Data Rate = 64*n* kb/s	O: R/W R: RO
1.105.15:14	Reserved	Value always 0	RO
1.105.13:7	Data rate step6	Data rate step of the sixth range *n* = value of the bits, *n* valid 1 to 86 Data Rate = 64*n* kb/s	O: R/W R: RO
1.105.6:2	Power6	*x* = multiple of 0.5 dBm to add to 5 dBm offset Power = (5 + 0.5*x*) dBm	O: R/W R: RO
1.105.1:0	Constellation6	11 = reserved 10 = 16-TCPAM 01 = 32-TCPAM 00 = automatically set by the PHY	O: R/W R: RO
1.106.15	Reserved	Value always 0	RO
1.106.14:8	Min data rate7	Min data rate of the seventh range *n* = value of the bits, *n* valid 3 to 89 Data Rate = 64*n* kb/s	O: R/W R: RO
1.106.7	Reserved	Value always 0	RO

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Table 45–53— 2B extended PMD parameters registers bit definition *(continued)*

Bit(s)	Name	Description	R/W[a]
1.106.6:0	Max data rate7	Max data rate of the seventh range *n* = value of the bits, *n* valid 3 to 89 Data Rate = 64*n* kb/s	O: R/W R: RO
1.107.15:14	Reserved	Value always 0	RO
1.107.13:7	Data rate step7	Data rate step of the seventh range *n* = value of the bits, *n* valid 1 to 86 Data Rate = 64*n* kb/s	O: R/W R: RO
1.107.6:2	Power7	*x* = multiple of 0.5 dBm to add to 5 dBm offset Power = (5 + 0.5*x*) dBm	O: R/W R: RO
1.107.1:0	Constellation7	11 = reserved 10 = 16-TCPAM 01 = 32-TCPAM 00 = automatically set by the PHY	O: R/W R: RO
1.108.15	Reserved	Value always 0	RO
1.108.14:8	Min data rate8	Min data rate of the eighth range *n* = value of the bits, *n* valid 3 to 89 Data Rate = 64*n* kb/s	O: R/W R: RO
1.108.7	Reserved	Value always 0	RO
1.108.6:0	Max data rate8	Max data rate of the eighth range *n* = value of the bits, *n* valid 3 to 89 Data Rate = 64*n* kb/s	O: R/W R: RO
1.109.15:14	Reserved	Value always 0	RO
1.109.13:7	Data rate step8	Data rate step of the eighth range *n* = value of the bits, *n* valid 1 to 86 Data Rate = 64*n* kb/s	O: R/W R: RO
1.109.6:2	Power8	*x* = multiple of 0.5 dBm to add to 5 dBm offset Power = (5 + 0.5*x*) dBm	O: R/W R: RO
1.109.1:0	Constellation8	11 = reserved 10 = 16-TCPAM 01 = 32-TCPAM 00 = automatically set by the PHY	O: R/W R: RO

[a]R/W = Read/Write, RO = Read only

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45.2.1.61.1 Minimum data rate (1.102, 1.104, 1.106, 1.108. Bits 14:8)

Bits 14:8 in registers 1.102, 1.104, 1.106, and 1.108 set the minimum data rate for each of the four extended ranges. Valid values for these bits are decimal 3 through 89. writes to set an invalid value shall be ignored. The rate is expressed in units of kb/s and is derived by multiplying the decimal value of bits 14:8 by 64.

45.2.1.61.2 Max data rate (1.102, 1.104, 1.106, 1.108. Bits 6:0)

Bits 6:0 in registers 1.102, 1.104, 1.106, and 1.108 set the maximum data rate for each of the four extended ranges. Valid values for these bits are decimal 3 through 89, writes to set an invalid value shall be ignored. The rate is expressed in units of kb/s and is derived by multiplying the decimal value of bits 6:0 by 64.

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45.2.1.61.3 Data rate step (1.103, 1.105, 1.107, 1.109. Bits 13:7)

Bits 13:7 in registers 1.103, 1.105, 1.107 and 1.109 set the granularity used by the PMA/PMD when determining the line rate. Valid values for these bits are decimal 1 through 86, writes to set an invalid value shall be ignored. The data rate step is expressed in units of kb/s and is derived by multiplying the decimal value of bits 13:7 by 64.

45.2.1.61.4 Power (1.103, 1.105, 1.107, 1.109. Bits 6:2)

Bits 6:2 in registers 1.103, 1.105, 1.107 and 1.109 set the allowed power level for each extended data rate range. The power levels set in these bits override those of the annex selected in the 2B general parameter register (1.80). The power level is expressed in units of dBm and is derived by Equation (45–5), where *x* equals the value of bits 6:2.

$$\text{power} = \left(5 + \frac{x}{2}\right) \text{dBm} \tag{45–5}$$

45.2.1.61.5 Constellation (1.103, 1.105, 1.107, 1.109. Bits 1:0)

Bits 1:0 in registers 1.103, 1.105, 1.107 and 1.109 set the allowed constellation for each extended data rate range. Setting a value of 10 or 01 restricts the constellation to 16- or 32-TCPAM respectively. When set to a value of 00, the PMD automatically determines the constellation during initialization. Attempts to set a value of 11 shall be ignored.

45.2.1.62 10GBASE-T status (Register 1.129)

The assignments of in the 10GBASE-T status register is shown in Table 45–54.

Table 45–54—10GBASE-T status register bit definitions

Bit(s)	Name	Description	R/W[a]
1.129.15:1	Reserved	Value always 0	RO
1.129.0	LP information valid	1 = Link partner information is valid 0 = Link partner information is invalid	RO

[a]RO = Read only

45.2.1.62.1 LP information valid (1.129.0)

When read as a one, bit 1.129.0 indicates that the startup protocol defined in 55.4.2.5 has been completed, and that the contents of bits 1.130.11:0, 1.131.15:10, 1.145.14:8, 1.146.14:8, and 1.146.6:0, which are established during the startup protocol, are valid. When read as a zero, bit 1.129.0 indicates that the startup process has not been completed, and that the contents of these bits that are established during the startup protocol are invalid. A 10GBASE-T PMA shall return a value of zero in bit 1.129.0 if PMA link_status=FAIL.

45.2.1.63 10GBASE-T pair swap and polarity register (Register 1.130)

Register 1.130 reflects the status of the pair-to-pair connectivity between the local device and the link partner (see Table 45–55). The polarity of each individual pair is also indicated.

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Table 45–55—10GBASE-T pair swap and polarity register bit definitions

Bit(s)	Name	Description	R/W[a]
1.130.15:12	Reserved	Value always 0	RO
1.130.11	Pair D polarity	1 = Polarity of pair D is reversed 0 = Polarity of pair D is not reversed	RO
1.130.10	Pair C polarity	1 = Polarity of pair C is reversed 0 = Polarity of pair C is not reversed	RO
1.130.9	Pair B polarity	1 = Polarity of pair B is reversed 0 = Polarity of pair B is not reversed	RO
1.130.8	Pair A polarity	1 = Polarity of pair A is reversed 0 = Polarity of pair A is not reversed	RO
1.130.7:2	Reserved	Value always 0	RO
1.130.1:0	MDI/MDI-X connection	1 0 1 1 = No crossover 1 0 = Reserved 0 1 = Reserved 0 0 = Pair A/B and pair C/D crossover	RO

[a]RO = Read only

45.2.1.63.1 Pair D polarity (1.130.11)

When read as zero, bit 1.130.11 indicates that the polarity within pair D is not reversed. When read as one, bit 1.130.11 indicates that the polarity of pair D is reversed.

45.2.1.63.2 Pair C polarity (1.130.10)

When read as zero, bit 1.130.10 indicates that the polarity within pair C is not reversed. When read as one, bit 1.130.10 indicates that the polarity of pair C is reversed.

45.2.1.63.3 Pair B polarity (1.130.9)

When read as zero, bit 1.130.9 indicates that the polarity within pair B is not reversed. When read as one, bit 1.130.9 indicates that the polarity of pair B is reversed.

45.2.1.63.4 Pair A polarity (1.130.8)

When read as zero, bit 1.130.8 indicates that the polarity within pair A is not reversed. When read as one, bit 1.130.8 indicates that the polarity of pair A is reversed.

45.2.1.63.5 MDI/MDI-X connection (1.130.1:0)

Bits 1.130.1:0 indicate the resolution of the automatic MDI/MDI-X configuration defined in 55.4.4. This function is intended to eliminate the need for crossover cables between similar devices. The automatic configuration method used shall comply with 40.4.4.1 and 40.4.4.2.

45.2.1.64 10GBASE-T TX power backoff and PHY short reach setting (Register 1.131)

The complete assignment of bits in the 10GBASE-T TX power backoff and short reach mode settings register is shown in Table 45–56.

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Table 45–56—10GBASE-T TX power backoff and PHY short reach setting register bit definitions

Bit(s)	Name	Description	R/W[a]
1.131.15:13	Link partner TX power backoff setting	15 14 13 1 1 1 = 14 dB 1 1 0 = 12 dB 1 0 1 = 10 dB 1 0 0 = 8 dB 0 1 1 = 6 dB 0 1 0 = 4 dB 0 0 1 = 2 dB 0 0 0 = 0 dB	RO
1.131.12:10	TX power backoff setting	12 11 10 1 1 1 = 14 dB 1 1 0 = 12 dB 1 0 1 = 10 dB 1 0 0 = 8 dB 0 1 1 = 6 dB 0 1 0 = 4 dB 0 0 1 = 2 dB 0 0 0 = 0 dB	RO
1.131.9:1	Reserved	Value always 0	RO
1.131.0	Short reach mode	1 = PHY is operating in short reach mode 0 = PHY is not operating in short reach mode	R/W

[a]RO = Read only, R/W = Read/Write

45.2.1.64.1 10GBASE-T TX power backoff settings (1.131.15:10)

The 10GBASE-T TX power backoff settings reflects the TX power backoff selected during the startup negotiation process.The startup negotiation process and all TX power backoff settings are defined in 55.4.2.5 and 55.4.5.1. If LP information valid bit, 1.129.0, is set to one then bits 1.131.15:13 indicates the TX power backoff setting of the link partner and bits 1.131.12:10 indicates the TX power backoff setting of the local device.

45.2.1.64.2 PHY short reach mode (1.131.0)

The short reach mode of the 10GBASE-T PHY provides a means for operation on a cable plant that has parametric performance equivalent to 30 m of Class F and Class E_A cabling as defined in 55.5.4.5. If bit 1.131.0 is a one, the PHY is in short reach mode. If bit 1.131.0 is a zero the PHY is operating in normal mode. The default value for this bit is zero.

45.2.1.65 10GBASE-T test mode register (Register 1.132)

The assignment of bits in the 10GBASE-T test mode register is shown in Table 45–57. The default values for each bit should be chosen so that the initial state of the device upon power up or reset is a normal operational state without management intervention.

45.2.1.65.1 Test mode control (1.132.15:13)

Transmitter test mode operations defined by bits 1.132.15:13, are described in 55.5.2 and Table 55–12. The default value for bits 1.132.15:13 is zero.

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Table 45–57—10GBASE-T test mode register bit definitions

Bit(s)	Name	Description	R/W[a]
1.132.15:13	Test mode control	15 14 13 1 1 1 = Test mode 7 1 1 0 = Test mode 6 1 0 1 = Test mode 5 1 0 0 = Test mode 4 0 1 1 = Test mode 3 0 1 0 = Test mode 2 0 0 1 = Test mode 1 0 0 0 = Normal operation	R/W
1.132.12:10	Transmitter test frequencies	12 11 10 1 1 1 = Reserved 1 1 0 = Dual tone 5 1 0 1 = Dual tone 4 1 0 0 = Dual tone 3 0 1 1 = Reserved 0 1 0 = Dual tone 2 0 0 1 = Dual tone 1 0 0 0 = Reserved	R/W
1.132.9:0	Reserved	Value always 0	RO

[a]R/W = Read/Write, RO = Read only

45.2.1.65.2 Transmitter test frequencies (1.132.12:10)

When test mode 4 is selected by setting bits 1.132.15:13 to one, zero, zero respectively, bits 1.132.12:10 select the transmit test frequency as shown in Table 45–57. Detailed use and operation of these transmitter test frequencies is described in 55.5.2.

45.2.1.66 SNR operating margin channel A register (Register 1.133)

Register 1.133 contains the current SNR operating margin measured at the slicer input for channel A for the 10GBASE-T PMA. It is reported with 0.1 dB of resolution to an accuracy of 0.5 dB within the range of –12.7 dB to 12.7 dB. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

45.2.1.67 SNR operating margin channel B register (Register 1.134)

Register 1.134 contains the current SNR operating margin measured at the slicer input for channel B for the 10GBASE-T PMA. It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –12.7 dB to 12.7 dB. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

45.2.1.68 SNR operating margin channel C register (Register 1.135)

Register 1.135 contains the current SNR operating margin measured at the slicer input for channel C for the 10GBASE-T PMA. It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –12.7 dB to 12.7 dB. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

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45.2.1.69 SNR operating margin channel D register (Register 1.136)

Register 1.136 contains the current SNR operating margin measured at the slicer input for channel D for the 10GBASE-T PMA. It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –12.7 dB to 12.7 dB. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

45.2.1.70 Minimum margin channel A register (Register 1.137)

The Minimum margin channel A register contains a latched copy of the lowest value observed in the SNR operating margin channel A register (1.133) since the last read. It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –12.7 dB to 12.7 dB. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

45.2.1.71 Minimum margin channel B register (Register 1.138)

The Minimum margin channel B register contains a latched copy of the lowest value observed in the SNR operating margin channel B register (1.134) since the last read. It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –12.7 dB to 12.7 dB. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

45.2.1.72 Minimum margin channel C register (Register 1.139)

The Minimum margin channel C register contains a latched copy of the lowest value observed in the SNR operating margin channel C register (1.135) since the last read. It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –12.7 dB to 12.7 dB. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

45.2.1.73 Minimum margin channel D register (Register 1.140)

The Minimum margin channel D register contains a latched copy of the lowest value observed in the SNR operating margin channel D register (1.136) since the last read. It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –12.7 dB to 12.7 dB. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

45.2.1.74 RX signal power channel A register (Register 1.141)

The RX signal power channel A register is read only and contains the receive signal power measured at the MDI during training as described in 55.4.3.1. The RX signal power should reflect the power measured when the device transitions out of the state PMA_Training_Init_M or PMA_Training_Init_S (as appropriate, see 55.4.6.1), when the link partner is transmitting with PBO_tx = 4 (8 dB power backoff). It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –20 dBm to 5.5 dBm. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

45.2.1.75 RX signal power channel B register (Register 1.142)

The RX signal power channel B register is read only and contains the receive signal power measured at the MDI during training as described in 55.4.3.1. The RX signal power should reflect the power measured when the device transitions out of the state PMA_Training_Init_M or PMA_Training_Init_S (as appropriate, see 55.4.6.1), when the link partner is transmitting with PBO_tx = 4 (8 dB power backoff). It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –20 dBm to 5.5 dBm. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

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45.2.1.76 RX signal power channel C register (Register 1.143)

The RX signal power channel C register is read only and contains the receive signal power measured at the MDI during training as described in 55.4.3.1. The RX signal power should reflect the power measured when the device transitions out of the state PMA_Training_Init_M or PMA_Training_Init_S (as appropriate, see 55.4.6.1), when the link partner is transmitting with PBO_tx = 4 (8 dB power backoff). It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –20 dBm to 5.5 dBm. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

45.2.1.77 RX signal power channel D register (Register 1.144)

The RX signal power channel D register is read only and contains the receive signal power measured at the MDI during training as described in 55.4.3.1. The RX signal power should reflect the power measured when the device transitions out of the state PMA_Training_Init_M or PMA_Training_Init_S (as appropriate, see 55.4.6.1), when the link partner is transmitting with PBO_tx = 4 (8 dB power backoff). It is reported in units of 0.1 dB to an accuracy of 0.5 dB within the range of –20 dBm to 5.5 dBm. The number is in offset two's complement notation, with 0.0 dB represented by 0x8000. Implementation of this register is optional.

45.2.1.78 10GBASE-T skew delay register (Registers 1.145 and 1.146)

The skew delay register reports the current skew delay on each of the pair with respect to physical pair A (see Table 45–58). It is reported with 1.25 ns resolution to an accuracy of 2.5 ns. The number reported is in two's complement notation with positive values representing delay and negative values representing advance with respect to physical pair A. If the delay exceed the maximum amount that can be represented by the range (–80 ns to +78.75 ns), the field displays the maximum respective value. The value shall be updated at least once per second.

Table 45–58—10GBASE-T skew delay register bit definitions

Bit(s)	Name	Description	R/W[a]
1.145.15	Reserved	Value always 0	RO
1.145.14:8	Skew delay B	Skew delay for pair B	RO
1.145.7:0	Reserved	Value always 0	RO
1.146.15	Reserved	Value always 0	RO
1.146.14:8	Skew delay D	Skew delay for pair D	RO
1.146.7	Reserved	Value always 0	RO
1.146.6:0	Skew delay C	Skew delay for pair C	RO

[a]RO = Read only

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45.2.1.79 10GBASE-T fast retrain status and control register (Register 1.147)

Table 45–59—10GBASE-T fast retrain status and control register bit definitions

Bit(s)	Name	Description	R/W[a]
1.147.15:11	LP fast retrain count	Counts the number of fast retrains requested by the link partner	RO/NR
1.147.10:6	LD fast retrain count	Counts the number of fast retrains requested by the local device	RO/NR
1.147.5	Reserved	Value always 0	RO
1.147.4	Fast retrain ability	1 = Fast retrain capability is supported 0 = Fast retrain capability is not supported	RO
1.147.3	Fast retrain negotiated	1 = Fast retrain capability was negotiated 0 = Fast retrain capability was not negotiated	RO
1.147.2:1	Fast retrain signal type	11 = Reserved 10 = PHY signals Link Interruption during fast retrain 01 = PHY signals Local Fault during fast retrain 00 = PHY signals IDLE during fast retrain	R/W
1.147.0	Fast retrain enable	1 = Fast retrain capability is enabled 0 = Fast retrain capability is disabled	R/W

[a] RO = Read only, R/W = Read/Write, NR = Non Roll-over

45.2.1.79.1 LP fast retrain count (1.147.15:11)

These bits map to fr_rx_counter as defined in 55.4.5.1. The counter is a 5-bit count of the number of 10GBASE-T fast retrains requested by the link partner. These bits shall be reset to all zeros when read or upon execution of the PMA reset. These bits shall be held at all ones in the case of overflow.

45.2.1.79.2 LD fast retrain count (1.147.10:6)

These bits map to fr_tx_counter as defined in 55.4.5.1. The counter is a 5-bit count of the number of 10GBASE-T fast retrains requested by the local device. These bits shall be reset to all zeros when read or upon execution of the PMA reset. These bits shall be held at all ones in the case of overflow.

45.2.1.79.3 Fast retrain ability (1.147.4)

When read as a one, bit 1.147.4 indicates that the PHY supports fast retrain, as defined in 55.4.2.5.15. When read as a zero, bit 1.147.4 indicates that the PHY does not support fast retrain.

45.2.1.79.4 Fast retrain negotiated (1.147.3)

When read as a one, bit 1.147.3 indicates that the PHY negotiated fast retrain, as defined in 55.4.2.5.15 during the most recent auto-negotiation. This is the condition where both the local device indicated fast retrain ability (bit 7.32.1 is one) and the link partner indicated fast retrain ability (bit 7.33.1 is one). When read as a zero, bit 1.147.3 indicates that the PHY did not negotiate fast retrain. See 45.2.7.10.6.

45.2.1.79.5 Fast retrain signal type (1.147.2:1)

For PHYs that support fast retrain, these bits map to fr_sigtype as defined in 55.3.6.2.2. When Fast retrain signal type is set to 00, the PMA sends IDLE characters on the receive path during fast retrain. When Fast

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retrain signal type is set to 01, the PMA sends Local Fault on the receive path during fast retrain. When Fast retrain signal type is set to 10, the PMA sends Link Interruption on the receive path during fast retrain.

45.2.1.79.6 Fast retrain enable (1.147.0)

For PHYs that support fast retrain, this bit controls fr_enable as defined in 55.4.5.1. When PMA reset is executed, this bit is set to one.

NOTE—Setting this bit to zero while a link is up will cause the PHY to stop supporting fast retrain, and the link will drop if the link partner initiates a fast retrain.

45.2.1.80 BASE-R PMD control register (Register 1.150)

The BASE-R PMD control register is used for 10GBASE-KR and other PHY types using the PMDs described in Clause 72, Clause 84, Clause 85, Clause 92, Clause 93, or Clause 94. The assignment of bits in the BASE-R PMD control register is shown in Table 45–60.

Table 45–60—BASE-R PMD control register

Bit(s)	Name	Description	R/W[a]
1.150.15:2	Reserved	Value always 0	RO
1.150.1	Training enable	1 = Enable the BASE-R start-up protocol 0 = Disable the BASE-R start-up protocol	R/W
1.150.0	Restart training	1 = Restart BASE-R start-up protocol 0 = Normal operation	R/W SC

[a]R/W = Read/Write, SC = Self-clearing, RO = Read only

45.2.1.80.1 Restart training (1.150.0)

This bit maps to the state variable mr_restart_training as defined in 72.6.10.3.1.

45.2.1.80.2 Training enable (1.150.1)

This bit maps to the state variable mr_training_enable as defined in 72.6.10.3.1.

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45.2.1.81 BASE-R PMD status register (Register 1.151)

The BASE-R PMD status register is used for 10GBASE-KR and other PHY types using the PMDs described in Clause 72, Clause 84, Clause 85, Clause 92, Clause 93, or Clause 94. The assignment of bits in the BASE-R PMD status register is shown in Table 45–61.

Table 45–61—BASE-R PMD status register

Bit(s)	Name	Description	R/W[a]
1.151.15	Training failure 3	1 = Training failure has been detected for lane 3 0 = Training failure has not been detected for lane 3	RO
1.151.14	Start-up protocol status 3	1 = Start-up protocol in progress for lane 3 0 = Start-up protocol complete for lane 3	RO
1.151.13	Frame lock 3	1 = Training frame delineation detected for lane 3 0 = Training frame delineation not detected for lane 3	RO
1.151.12	Receiver status 3	1 = Receiver trained and ready to receive data for lane 3 0 = Receiver training for lane 3	RO
1.151.11	Training failure 2	1 = Training failure has been detected for lane 2 0 = Training failure has not been detected for lane 2	RO
1.151.10	Start-up protocol status 2	1 = Start-up protocol in progress for lane 2 0 = Start-up protocol complete for lane 2	RO
1.151.9	Frame lock 2	1 = Training frame delineation detected for lane 2 0 = Training frame delineation not detected for lane 2	RO
1.151.8	Receiver status 2	1 = Receiver trained and ready to receive data for lane 2 0 = Receiver training for lane 2	RO
1.151.7	Training failure 1	1 = Training failure has been detected for lane 1 0 = Training failure has not been detected for lane 1	RO
1.151.6	Start-up protocol status 1	1 = Start-up protocol in progress for lane 1 0 = Start-up protocol complete for lane 1	RO
1.151.5	Frame lock 1	1 = Training frame delineation detected for lane 1 0 = Training frame delineation not detected for lane 1	RO
1.151.4	Receiver status 1	1 = Receiver trained and ready to receive data for lane 1 0 = Receiver training for lane 1	RO
1.151.3	Training failure 0	1 = Training failure has been detected for lane 0 0 = Training failure has not been detected for lane 0	RO
1.151.2	Start-up protocol status 0	1 = Start-up protocol in progress for lane 0 0 = Start-up protocol complete for lane 0	RO
1.151.1	Frame lock 0	1 = Training frame delineation detected for lane 0 0 = Training frame delineation not detected for lane 0	RO
1.151.0	Receiver status 0	1 = Receiver trained and ready to receive data for lane 0 0 = Receiver training for lane 0	RO

[a]RO = Read only

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45.2.1.81.1 Receiver status 0 (1.151.0)

This bit maps to the state variable rx_trained as defined in 72.6.10.3.1.

45.2.1.81.2 Frame lock 0 (1.151.1)

This bit maps to the state variable frame_lock as defined in 72.6.10.3.1.

45.2.1.81.3 Start-up protocol status 0 (1.151.2)

This bit maps to the state variable training as defined in 72.6.10.3.1.

45.2.1.81.4 Training failure 0 (1.151.3)

This bit maps to the state variable training_failure as defined in 72.6.10.3.1.

45.2.1.81.5 Receiver status 1, 2, 3 (1.151.4, 1.151.8, 1.151.12)

These bits are defined identically to 1.151.0 for lanes 1, 2, and 3 respectively.

45.2.1.81.6 Frame lock 1, 2, 3 (1.151.5, 1.151.9, 1.151.13)

These bits are defined identically to 1.151.1 for lanes 1, 2, and 3 respectively.

45.2.1.81.7 Start-up protocol status 1, 2, 3 (1.151.6, 1.151.10, 1.151.14)

These bits are defined identically to 1.151.2 for lanes 1, 2, and 3 respectively.

45.2.1.81.8 Training failure 1, 2, 3 (1.151.7, 1.151.11, 1.151.15)

These bits are defined identically to 1.151.3 for lanes 1, 2, and 3 respectively.

45.2.1.82 BASE-R LP coefficient update, lane 0 register (Register 1.152)

The BASE-R LP coefficient update, lane 0 register is used for 10GBASE-KR and other PHY types using the PMDs described in Clause 72, Clause 84, Clause 85, Clause 92, Clause 93, or Clause 94. The BASE-R LP coefficient update, lane 0 register reflects the contents of the first 16-bit word of the training frame most recently received from the control channel for lane 0 or for a single-lane PHY.

The assignment of bits in the BASE-R LP coefficient update, lane 0 register is shown in Table 45–62. Normally the bits in this register are read only; however, when training is disabled by setting low bit 1 in the BASE-R PMD control register, the BASE-R LP coefficient update, lane 0 register becomes writeable.

A copy of this register may be implemented at address 1.1100 to assist PHY access for devices using post-read-increment-address access for a multi-lane PCS. If implemented, all accesses to the copy have identical behavior as accesses to the original register.

45.2.1.82.1 Preset (1.152.13)

The preset control bit requests that the coefficients be set to a state where equalization is turned off. The function and values of the preset bit is defined in 72.6.10.2.3.1.

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45.2.1.82.2 Initialize (1.152.12)

The initialize control is sent to request that the coefficients be set to configure the transmit equalizer to its INITIALIZE state. The function and values of the initialize bit is defined in 72.6.10.2.3.2.

45.2.1.82.3 Coefficient (k) update (1.152.5:0)

Each coefficient, k, is assigned a 2-bit field describing a requested update. Three request encodings are defined: increment, decrement, and hold. The valid range for k is –1 to +1 where k = 0 denotes the main, or gain, tap. The function and values of the coefficient (k) update bits are defined in 72.6.10.2.3.3.

Table 45–62—BASE-R LP coefficient update, lane 0 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.152.15:14	Reserved	Value always 0	RO
1.152.13	Preset	1 = Preset coefficients 0 = Normal operation	R/W
1.152.12	Initialize	1 = Initialize coefficients 0 = Normal operation	R/W
1.152.11:6	Reserved	Value always 0	RO
1.152.5:4	Coefficient (+1) update	5 4 1 1 = reserved 0 1 = increment 1 0 = decrement 0 0 = hold	R/W
1.152.3:2	Coefficient (0) update	3 2 1 1 = reserved 0 1 = increment 1 0 = decrement 0 0 = hold	R/W
1.152.1:0	Coefficient (–1) update	1 0 1 1 = reserved 0 1 = increment 1 0 = decrement 0 0 = hold	R/W

[a]R/W = Read/Write, RO = Read only

45.2.1.83 BASE-R LP status report, lane 0 register (Register 1.153)

The BASE-R LP status report, lane 0 register is used for 10GBASE-KR and other PHY types using the PMDs described in Clause 72, Clause 84, Clause 85, Clause 92, Clause 93, or Clause 94. The BASE-R LP status report, lane 0 register reflects the contents of the second 16-bit word of the training frame most recently received from the control channel for lane 0 or for a single-lane PHY

The assignment of bits in the BASE-R LP status report, lane 0 register is shown in Table 45–63.

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A copy of this register may be implemented at address 1.1200 to assist PHY access for devices using post-read-increment-address access for a multi-lane PCS. If implemented, all accesses to the copy have identical behavior as the original register.

Table 45–63—BASE-R LP status report, lane 0 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.153.15	Receiver ready	1 = The LP receiver has determined that training is complete and is prepared to receive data 0 = The LP receiver is requesting that training continue	RO
1.153.14:6	Reserved	Value always 0	RO
1.153.5:4	Coefficient (+1) status	5 4 1 1 = maximum 1 0 = minimum 0 1 = updated 0 0 = not_updated	RO
1.153.3:2	Coefficient (0) status	3 2 1 1 = maximum 1 0 = minimum 0 1 = updated 0 0 = not_updated	RO
1.153.1:0	Coefficient (–1) status	1 0 1 1 = maximum 1 0 = minimum 0 1 = updated 0 0 = not_updated	RO

[a]RO = Read only

45.2.1.83.1 Receiver ready (1.153.15)

The function and values for the receiver ready bit are defined in 72.6.10.2.4.4.

45.2.1.83.2 Coefficient (k) status (1.153.5:0)

The function and values for the coefficient status bits are defined in 72.6.10.2.4.5.

45.2.1.84 BASE-R LD coefficient update, lane 0 register (Register 1.154)

The BASE-R LD coefficient update, lane 0 register is used for 10GBASE-KR and other PHY types using the PMDs described in Clause 72, Clause 84, Clause 85, Clause 92, Clause 93, or Clause 94. The BASE-R LD coefficient update, lane 0 register reflects the contents of the first 16-bit word of the outgoing training frame as defined by the LD receiver adaptation process in 72.6.10.2.5 for lane 0 or for a single-lane PHY.

The assignment of bits in the BASE-R LD coefficient update, lane 0 register is shown in Table 45–64.

A copy of this register may be implemented at address 1.1300 to assist PHY access for devices using post-read-increment-address access for a multi-lane PCS. If implemented, all accesses to the copy have identical behavior as the original register.

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45.2.1.84.1 Preset (1.154.13)

The function and values of the preset bit is defined in 72.6.10.2.3.1.

45.2.1.84.2 Initialize (1.154.12)

The function and values of the initialize bit is defined in 72.6.10.2.3.2.

45.2.1.84.3 Coefficient (k) update(1.154.5:0)

The function and values of the coefficient (k) update bits are defined in 72.6.10.2.3.3.

Table 45–64—BASE-R LD coefficient update, lane 0 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.154.15:14	Reserved	Value always 0	RO
1.154.13	Preset	1 = Preset coefficients 0 = Normal operation	RO
1.154.12	Initialize	1 = Initialize coefficients 0 = Normal operation	RO
1.154.11:6	Reserved	Value always 0	RO
1.154.5:4	Coefficient (+1) update	5 4 1 1 = reserved 0 1 = increment 1 0 = decrement 0 0 = hold	RO
1.154.3:2	Coefficient (0) update	3 2 1 1 = reserved 0 1 = increment 1 0 = decrement 0 0 = hold	RO
1.154.1:0	Coefficient (–1) update	1 0 1 1 = reserved 0 1 = increment 1 0 = decrement 0 0 = hold	RO

[a]RO = Read only

45.2.1.85 BASE-R LD status report, lane 0 register (Register 1.155)

The BASE-R LD status report, lane 0 register is used for 10GBASE-KR and other PHY types using the PMDs described in Clause 72, Clause 84, Clause 85, Clause 92, Clause 93, or Clause 94. The BASE-R LD status report, lane 0 register reflects the contents of the second 16-bit word of the current outgoing training frame, as defined in the training state diagram in Figure 72–5 for lane 0 or for a single-lane PHY.

The assignment of bits in the BASE-R LD status report, lane 0 register is shown in Table 45–65.

A copy of this register may be implemented at address 1.1400 to assist PHY access for devices using post-read-increment-address access for a multi-lane PCS. If implemented, all accesses to the copy have identical behavior as the original register.

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Table 45–65—BASE-R LD status report, lane 0 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.155.15	Receiver ready	1 = The LD receiver has determined that training is complete and is prepared to receive data 0 = The LD receiver is requesting that training continue	RO
1.155.14:6	Reserved	Value always 0	RO
1.155.5:4	Coefficient (+1) status	5 4 1 1 = maximum 1 0 = minimum 0 1 = updated 0 0 = not_updated	RO
1.155.3:2	Coefficient (0) status	3 2 1 1 = maximum 1 0 = minimum 0 1 = updated 0 0 = not_updated	RO
1.155.1:0	Coefficient (–1) status	1 0 1 1 = maximum 1 0 = minimum 0 1 = updated 0 0 = not_updated	RO

[a]RO = Read only

45.2.1.85.1 Receiver ready (1.155.15)

The function and values for the receiver ready bit are defined in 72.6.10.2.4.4.

45.2.1.85.2 Coefficient (k) status (1.155.5:0)

The function and values for the coefficient status bits are defined in 72.6.10.2.4.5.

45.2.1.86 BASE-R PMD status 2 register (Register 1.156)

The BASE-R PMD status 2 register is used for 100GBASE-CR10 and other PHY types using the PMDs described in Clause 72, Clause 84, or Clause 85 over more than 4 lanes. The assignment of bits in the BASE-R PMD status 2 register is shown in Table 45–66.

Table 45–66—BASE-R PMD status 2 register

Bit(s)	Name	Description	R/W[a]
1.156.15	Training failure 7	1 = Training failure has been detected for lane 7 0 = Training failure has not been detected for lane 7	RO
1.156.14	Start-up protocol status 7	1 = Start-up protocol in progress for lane 7 0 = Start-up protocol complete for lane 7	RO
1.156.13	Frame lock 7	1 = Training frame delineation detected for lane 7 0 = Training frame delineation not detected for lane 7	RO

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Table 45–66—BASE-R PMD status 2 register *(continued)*

1.156.12	Receiver status 7	1 = Receiver trained and ready to receive data for lane 7 0 = Receiver training for lane 7	RO
1.156.11	Training failure 6	1 = Training failure has been detected for lane 6 0 = Training failure has not been detected for lane 6	RO
1.156.10	Start-up protocol status 6	1 = Start-up protocol in progress for lane 6 0 = Start-up protocol complete for lane 6	RO
1.156.9	Frame lock 6	1 = Training frame delineation detected for lane 6 0 = Training frame delineation not detected for lane 6	RO
1.156.8	Receiver status 6	1 = Receiver trained and ready to receive data for lane 6 0 = Receiver training for lane 6	RO
1.156.7	Training failure 5	1 = Training failure has been detected for lane 5 0 = Training failure has not been detected for lane 5	RO
1.156.6	Start-up protocol status 5	1 = Start-up protocol in progress for lane 5 0 = Start-up protocol complete for lane 5	RO
1.156.5	Frame lock 5	1 = Training frame delineation detected for lane 5 0 = Training frame delineation not detected for lane 5	RO
1.156.4	Receiver status 5	1 = Receiver trained and ready to receive data for lane 5 0 = Receiver training for lane 5	RO
1.156.3	Training failure 4	1 = Training failure has been detected for lane 4 0 = Training failure has not been detected for lane 4	RO
1.156.2	Start-up protocol status 4	1 = Start-up protocol in progress for lane 4 0 = Start-up protocol complete for lane 4	RO
1.156.1	Frame lock 4	1 = Training frame delineation detected for lane 4 0 = Training frame delineation not detected for lane 4	RO
1.156.0	Receiver status 4	1 = Receiver trained and ready to receive data for lane 4 0 = Receiver training for lane 4	RO

[a]RO = Read only

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45.2.1.86.1 Receiver status 4, 5, 6, 7 (1.156.0, 1.156.4, 1.156.8, 1.156.12)

These bits are defined identically to 1.151.0 for lanes 4, 5, 6, and 7 respectively.

45.2.1.86.2 Frame lock 4, 5, 6, 7 (1.156.1, 1.156.5, 1.156.9, 1.156.13)

These bits are defined identically to 1.151.1 for lanes 4, 5, 6, and 7 respectively.

45.2.1.86.3 Start-up protocol status 4, 5, 6, 7 (1.156.2, 1.156.6, 1.156.10, 1.156.14)

These bits are defined identically to 1.151.2 for lanes 4, 5, 6, and 7 respectively.

45.2.1.86.4 Training failure 4, 5, 6, 7 (1.156.3, 1.156.7, 1.156.11, 1.156.15)

These bits are defined identically to 1.151.3 for lanes 4, 5, 6, and 7 respectively.

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45.2.1.87 BASE-R PMD status 3 register (Register 1.157)

The BASE-R PMD status 3 register is used for 100GBASE-CR10 and other PHY types using the PMDs described in Clause 72, Clause 84, or Clause 85 over more than 8 lanes. The assignment of bits in the BASE-R PMD status 3 register is shown in Table 45–67.

Table 45–67—BASE-R PMD status 3 register

Bit(s)	Name	Description	R/W[a]
1.157.15:8	Reserved	Value always 0	RO
1.157.7	Training failure 9	1 = Training failure has been detected for lane 9 0 = Training failure has not been detected for lane 9	RO
1.157.6	Start-up protocol status 9	1 = Start-up protocol in progress for lane 9 0 = Start-up protocol complete for lane 9	RO
1.157.5	Frame lock 9	1 = Training frame delineation detected for lane 9 0 = Training frame delineation not detected for lane 9	RO
1.157.4	Receiver status 9	1 = Receiver trained and ready to receive data for lane 9 0 = Receiver training for lane 9	RO
1.157.3	Training failure 8	1 = Training failure has been detected for lane 8 0 = Training failure has not been detected for lane 8	RO
1.157.2	Start-up protocol status 8	1 = Start-up protocol in progress for lane 8 0 = Start-up protocol complete for lane 8	RO
1.157.1	Frame lock 8	1 = Training frame delineation detected for lane 8 0 = Training frame delineation not detected for lane 8	RO
1.157.0	Receiver status 8	1 = Receiver trained and ready to receive data for lane 8 0 = Receiver training for lane 8	RO

[a]RO = Read only

45.2.1.87.1 Receiver status 8, 9 (1.157.0, 1.157.4)

These bits are defined identically to 1.151.0 for lanes 8 and 9 respectively.

45.2.1.87.2 Frame lock 8, 9 (1.157.1, 1.157.5)

These bits are defined identically to 1.151.1 for lanes 8 and 9 respectively.

45.2.1.87.3 Start-up protocol status 8, 9 (1.157.2, 1.157.6)

These bits are defined identically to 1.151.2 for lanes 8 and 9 respectively.

45.2.1.87.4 Training failure 8, 9 (1.157.3, 1.157.7)

These bits are defined identically to 1.151.3 for lanes 8 and 9 respectively.

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45.2.1.88 1000BASE-KX control register (Register 1.160)

The assignment of bits in the 1000BASE-KX control register is shown in Table 45–68.

Table 45–68—1000BASE-KX control register

Bit(s)	Name	Description	R/W[a]
1.160.15:1	Reserved	Value always 0	RO
1.160.0	PMD transmit disable	1 = Disable transmitter output 0 = Enable transmitter output	R/W

[a]RO = Read only, R/W = Read/Write

45.2.1.88.1 PMD transmit disable (1.160.0)

This bit disables the 1000BASE-KX transmitter as defined in 70.6.5.

45.2.1.89 1000BASE-KX status register (Register 1.161)

The assignment of bits in the 1000BASE-KX status register is shown in Table 45–69.

Table 45–69—1000BASE-KX status register

Bit(s)	Name	Description	R/W[a]
1.161.15:14	Reserved	Value always 0	RO
1.161.13	Transmit fault ability	1 = PMA/PMD has the ability to detect a fault condition on the transmit path 0 = PMA/ PMD does not have the ability to detect a fault condition on the transmit path	RO
1.161.12	Receive fault ability	1 = PMA/PMD has the ability to detect a fault condition on the receive path 0 = PMA/ PMD does not have the ability to detect a fault condition on the receive path	RO
1.161.11	Transmit fault	1 = Fault condition on transmit path 0 = No fault condition on transmit path	LH
1.161.10	Receive fault	1 = Fault condition on receive path 0 = No fault condition on receive path	LH
1.161.9	Reserved	Value always 0	RO
1.161.8	PMD transmit disable ability	1 = PMD has the ability to disable the transmit path 0 = PMD does not have the ability to disable the transmit path	RO
1.161.7:1	Reserved	Value always 0	RO
1.161.0	Signal detect signal from PMD	1 = PMD has asserted signal detect 0 = PMD has not asserted signal detect	RO

[a]RO = Read only, LH = Latching high

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45.2.1.89.1 PMD transmit fault ability (1.161.13)

When read as a one, bit 1.161.13 indicates that the PMA/PMD has the ability to detect a fault condition on the transmit path. When read as a zero, bit 1.161.13 indicates that the PMA/PMD does not have the ability to detect a fault condition on the transmit path.

45.2.1.89.2 PMD receive fault ability (1.161.12)

When read as a one, bit 1.161.12 indicates that the PMA/PMD has the ability to detect a fault condition on the receive path. When read as a zero, bit 1.161.12 indicates that the PMA/PMD does not have the ability to detect a fault condition on the receive path.

45.2.1.89.3 PMD transmit fault (1.161.11)

When read as a one, bit 1.161.11 indicates that the PMA/PMD has detected a fault condition on the transmit path. When read as a zero, bit 1.161.11 indicates that the PMA/PMD has not detected a fault condition on the transmit path. Detection of a fault condition on the transmit path is optional and the ability to detect such a condition is advertised by bit 1.161.13. A PMA/PMD that is unable to detect a fault condition on the transmit path shall return a value of zero for this bit. The transmit fault bit shall be implemented with latching high behavior.

The default value of bit 1.161.11 is zero.

45.2.1.89.4 PMD receive fault (1.161.10)

When read as a one, bit 1.161.10 indicates that the PMA/PMD has detected a fault condition on the receive path. When read as a zero, bit 1.161.10 indicates that the PMA/PMD has not detected a fault condition on the receive path. Detection of a fault condition on the receive path is optional and the ability to detect such a condition is advertised by bit 1.161.12. A PMA/PMD that is unable to detect a fault condition on the receive path shall return a value of zero for this bit. The receive fault bit shall be implemented with latching high behavior.

The default value of bit 1.161.10 is zero.

45.2.1.89.5 PMD transmit disable ability (1.161.8)

When read as a one, bit 1.161.8 indicates that the PMD is able to perform the transmit disable function. When read as a zero, bit 1.161.8 indicates that the PMD is not able to perform the transmit disable function.

45.2.1.89.6 1000BASE-KX signal detect (1.161.0)

The PMD signal detect function is optional see 70.6.4. The 1000BASE-X PCS requires signal detect to be one before synchronization can occur. If the signal detect function is not implemented this bit is set to one.

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45.2.1.90 PMA overhead control 1, 2, and 3 registers (Register 1.162 through 1.164)

Assignment of bits in the PMA overhead control 1, 2, and 3 registers is shown in Table 45–70. These bits shall be reset to the default values indicated in Table 45–70 upon PHY reset. For the 100GBASE-KP4 PHY the use of these registers is specified in 94.2.2.3 and 94.2.3.1.

Table 45–70—PMA overhead control 1, 2, and 3 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.162.15:13	Reserved	Value always 0	RO
1.162.12:8	PMA transmit overhead sequence 0	Sequence of overhead groups for lane 0 Default = 00110	R/W
1.162.7:0	PMA transmit overhead pattern	Bit pattern for 8-bit transmit overhead group Default = 01100110	R/W
1.163.15	Reserved	Value always 0	RO
1.163.14:10	PMA transmit overhead sequence 3	Sequence of overhead groups for lane 3 Default = 11001	R/W
1.163.9:5	PMA transmit overhead sequence 2	Sequence of overhead groups for lane 2 Default = 10101	R/W
1.163.4:0	PMA transmit overhead sequence 1	Sequence of overhead groups for lane 1 Default = 01010	R/W
1.164.15:8	Reserved	Value always 0	RO
1.164.7:0	PMA receive overhead pattern	Bit pattern for 8-bit receive overhead group Default = 01100110	R/W

[a]R/W = Read/Write, RO = Read only

45.2.1.91 PMA overhead status 1 and 2 registers (Register 1.165, 1.166)

Assignment of bits in the PMA overhead status 1 and 2 registers is shown in Table 45–71. These bits shall be reset to all zeros upon PHY reset. For the 100GBASE-KP4 PHY the use of these registers is specified in 94.2.3.1.

Table 45–71—PMA overhead status 1 and 2 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.165.15:12	Reserved	Value always 0	RO
1.165.11:6	PMA receive overhead sequence 1	Sequence of overhead groups for lane 1	RO
1.165.5:0	PMA receive overhead sequence 0	Sequence of overhead groups for lane 0	RO
1.166.15:12	Reserved	Value always 0	RO
1.166.11:6	PMA receive overhead sequence 3	Sequence of overhead groups for lane 3	RO
1.166.5:0	PMA receive overhead sequence 2	Sequence of overhead groups for lane 2	RO

[a]RO = Read only

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45.2.1.92 BASE-R FEC ability register (Register 1.170)

The assignment of bits in the BASE-R FEC ability register is shown in Table 45–72.

Table 45–72—BASE-R FEC ability register bit definitions

Bit(s)	Name	Description	R/W[a]
1.170.15:2	Reserved	Value always 0	RO
1.170.1	BASE-R FEC error indication ability	A read of 1 in this bit indicates that the sublayer is able to report FEC decoding errors to the PCS layer	RO
1.170.0	BASE-R FEC ability	A read of 1 in this bit indicates that the sublayer supports FEC	RO

[a]RO Read only

45.2.1.92.1 BASE-R FEC ability (1.170.0)

When read as a one, this bit indicates that the sublayer supports forward error correction (FEC). When read as a zero, the sublayer does not support forward error correction.

45.2.1.92.2 BASE-R FEC error indication ability (1.170.1)

When read as a one, this bit indicates that the BASE-R FEC sublayer is able to indicate decoding errors to the PCS layer (see 74.8.3). When read as a zero, the BASE-R FEC sublayer is not able to indicate decoding errors to the PCS layer. BASE-R FEC error indication is controlled by the FEC enable error indication bit in the BASE-R FEC control register (see 45.2.1.93.2).

45.2.1.93 BASE-R FEC control register (Register 1.171)

The assignment of bits in the BASE-R FEC control register is shown in Table 45–73.

Table 45–73—BASE-R FEC control register bit definitions

Bit(s)	Name	Description	R/W[a]
1.171.15:2	Reserved	Value always 0	RO
1.171.1	FEC enable error indication	A write of 1 to this bit configures the FEC decoder to indicate errors to the PCS layer	R/W
1.171.0	FEC enable	A write of 1 to this bit enables FEC A write of 0 to this bit disables FEC	R/W

[a]R/W = Read/Write, RO Read only

45.2.1.93.1 FEC enable (1.171.0)

When written as a one, this bit enables FEC for the BASE-R PHY. When written as a zero, FEC is disabled in the BASE-R PHY. This bit shall be set to zero upon execution of PHY reset.

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45.2.1.93.2 FEC enable error indication (1.171.1)

This bit enables the BASE-R FEC decoder to indicate decoding errors to the upper layers (PCS) through the sync bits for the BASE-R PHY in the Local Device. When written as a one, this bit enables indication of decoding errors through the sync bits to the PCS layer. When written as zero the error indication function is disabled. Writes to this bit are ignored and reads return a zero if the BASE-R FEC does not have the ability to indicate decoding errors to the PCS layer (see 45.2.1.92.2 and 74.8.3).

45.2.1.94 10GBASE-R FEC corrected blocks counter (Register 1.172, 1.173)

The assignment of bits in the 10GBASE-R FEC corrected blocks counter register is shown in Table 45–74. See 74.8.4.1 for a definition of this register. These bits shall be reset to all zeros when the register is read by the management function or upon PHY reset. These bits shall be held at all ones in the case of overflow. Registers 1.172, 1.173 are used to read the value of a 32-bit counter. When registers 1.172 and 1.173 are used to read the 32-bit counter value, the register 1.172 is read first, the value of the register 1.173 is latched when (and only when) register 1.172 is read and reads of register 1.173 returns the latched value rather than the current value of the counter.

Table 45–74—10GBASE-R FEC corrected blocks counter register bit definitions

Bit(s)	Name	Description	R/W[a]
1.172.15:0	FEC corrected blocks lower	FEC_corrected_blocks_counter[15:0]	RO, NR
1.173.15:0	FEC corrected blocks upper	FEC_corrected_blocks_counter[31:16]	RO, NR

[a]RO = Read only, NR = Non Roll-over

For a multi-PCS lane PHY, this register may be a copy of register 1.300 BASE-R FEC corrected blocks counter, lane 0. If implemented, all accesses to the copy shall have identical behavior as the original register.

45.2.1.95 10GBASE-R FEC uncorrected blocks counter (Register 1.174, 1.175)

The assignment of bits in the 10GBASE-R FEC uncorrected blocks counter register is shown in Table 45–75. See 74.8.4.2 for a definition of this register. These bits shall be reset to all zeros when the register is read by the management function or upon PHY reset. These bits shall be held at all ones in the case of overflow. Registers 1.174, 1.175 are used to read the value of a 32-bit counter. When registers 1.174 and 1.175 are used to read the 32-bit counter value, the register 1.174 is read first, the value of the register 1.175 is latched when (and only when) register 1.174 is read and reads of register 1.175 returns the latched value rather than the current value of the counter.

Table 45–75—10GBASE-R FEC uncorrected blocks counter register bit definitions

Bit(s)	Name	Description	R/W[a]
1.174.15:0	FEC uncorrected blocks lower	FEC_uncorrected_blocks_counter[15:0]	RO, NR
1.175.15:0	FEC uncorrected blocks upper	FEC_uncorrected_blocks_counter[31:16]	RO, NR

[a]RO = Read only, NR = Non Roll-over

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For a multi-PCS lane PHY, this register may be a copy of register 1.700 BASE-R FEC uncorrected blocks counter, lane 0. If implemented, all accesses to the copy shall have identical behavior as the original register.

45.2.1.96 CAUI-4 chip-to-module recommended CTLE register (Register 1.179)

The assignment of bits in the CAUI-4 chip-to-module recommended CTLE register is shown in Table 45–76.

Table 45–76—CAUI-4 chip-to-module recommended CTLE register bit definitions

Bit(s)	Name	Description	R/W[a]
1.179.15:5	Reserved	Value always 0	RO
1.179.4:1	Recommended CTLE peaking	4 3 2 1 1 1 x x = Reserved 1 0 1 x = Reserved 1 0 0 1 = 9 dB 1 0 0 0 = 8 dB 0 1 1 1 = 7 dB 0 1 1 0 = 6 dB 0 1 0 1 = 5 dB 0 1 0 0 = 4 dB 0 0 1 1 = 3 dB 0 0 1 0 = 2 dB 0 0 0 1 = 1 dB 0 0 0 0 = Reserved	R/W
1.179.0	Reserved	Value always 0	RO

[a]R/W = Read/Write, RO = Read only

45.2.1.96.1 Recommended CTLE peaking (1.179.4:1)

The value of these bits sets the CTLE peaking value recommended by a host that implements the optional CAUI-4 chip-to-module interface defined in Annex 83E (see 83E.3.1.6). The module may optionally use this information to adjust its CTLE setting.

45.2.1.97 CAUI-4 chip-to-chip transmitter equalization, receive direction, lane 0 register (Register 1.180)

The assignment of bits in the CAUI-4 chip-to-chip transmitter equalization, receive direction, lane 0 register is shown in Table 45–77. The transmitter, receive direction, is the transmitter that sends data towards the PCS.

45.2.1.97.1 Request flag (1.180.15)

The value of this bit indicates the value of the variable *Request_flag* in the lane 0 CAUI-4 receiver in the receive direction (see 83D.3.3.2). This indicates whether the CAUI-4 chip-to-chip device is issuing a request to change the remote transmitter equalization in the CAUI-4 chip-to-chip lane 0 transmitter in the receive direction. If a lane 0 CAUI-4 receiver in the receive direction is not present in the package, then the value returned for this bit should be zero.

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Table 45–77—CAUI-4 chip-to-chip transmitter equalization, receive direction, lane 0 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.180.15	Request flag	1 = Change in equalization is requested 0 = No change in equalization is requested	RO
1.180.14:12	Post-cursor request	14 13 12 1 1 1 Reserved 1 1 0 Reserved 1 0 1 *Requested_eq_c1* = 5 (c(1) ratio –0.25) 1 0 0 *Requested_eq_c1* = 4 (c(1) ratio –0.2) 0 1 1 *Requested_eq_c1* = 3 (c(1) ratio –0.15) 0 1 0 *Requested_eq_c1* = 2 (c(1) ratio –0.1) 0 0 1 *Requested_eq_c1* = 1 (c(1) ratio –0.05) 0 0 0 *Requested_eq_c1* = 0 (c(1) ratio 0)	RO
1.180.11:10	Pre-cursor request	11 10 1 1 *Requested_eq_cm1* = 3 (c(–1) ratio –0.15) 1 0 *Requested_eq_cm1* = 2 (c(–1) ratio –0.1) 0 1 *Requested_eq_cm1* = 1 (c(–1) ratio –0.05) 0 0 *Requested_eq_cm1* = 0 (c(–1) ratio 0)	RO
1.180.9:7	Post-cursor remote setting	9 8 7 1 1 1 Reserved 1 1 0 Reserved 1 0 1 *Remote_eq_c1* = 5 (c(1) ratio –0.25) 1 0 0 *Remote_eq_c1* = 4 (c(1) ratio –0.2) 0 1 1 *Remote_eq_c1* = 3 (c(1) ratio –0.15) 0 1 0 *Remote_eq_c1* = 2 (c(1) ratio –0.1) 0 0 1 *Remote_eq_c1* = 1 (c(1) ratio –0.05) 0 0 0 *Remote_eq_c1* = 0 (c(1) ratio 0)	R/W
1.180.6:5	Pre-cursor remote setting	6 5 1 1 *Remote_eq_cm1* = 3 (c(–1) ratio –0.15) 1 0 *Remote_eq_cm1* = 2 (c(–1) ratio –0.1) 0 1 *Remote_eq_cm1* = 1 (c(–1) ratio –0.05) 0 0 *Remote_eq_cm1* = 0 (c(–1) ratio 0)	R/W
1.180.4:2	Post-cursor local setting	4 3 2 1 1 1 Reserved 1 1 0 Reserved 1 0 1 *Local_eq_c1* = 5 (c(1) ratio –0.25) 1 0 0 *Local_eq_c1* = 4 (c(1) ratio –0.2) 0 1 1 *Local_eq_c1* = 3 (c(1) ratio –0.15) 0 1 0 *Local_eq_c1* = 2 (c(1) ratio –0.1) 0 0 1 *Local_eq_c1* = 1 (c(1) ratio –0.05) 0 0 0 *Local_eq_c1* = 0 (c(1) ratio 0)	R/W
1.180.1:0	Pre-cursor local setting	1 0 1 1 *Local_eq_cm1* = 3 (c(–1) ratio –0.15) 1 0 *Local_eq_cm1* = 2 (c(–1) ratio –0.1) 0 1 *Local_eq_cm1* = 1 (c(–1) ratio –0.05) 0 0 *Local_eq_cm1* = 0 (c(–1) ratio 0)	R/W

[a]R/W = Read/Write, RO = Read only

45.2.1.97.2 Post-cursor request (1.180.14:12)

The value of these bits indicates the value of the variable *Requested_eq_c1* in the lane 0 CAUI-4 receiver in the receive direction (see 83D.3.3.2). When *Request_flag* is equal to 1, this value indicates the ratio of the

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post-cursor coefficient c(1), which is requested for the transmitter equalization in the CAUI-4 chip-to-chip lane 0 transmitter in the receive direction.

45.2.1.97.3 Pre-cursor request (1.180.11:10)

The value of these bits indicates the value of the variable *Requested_eq_cm1* in the lane 0 CAUI-4 receiver in the receive direction (see 83D.3.3.2). When *Request_flag* is equal to 1, this value indicates the ratio of the pre-cursor coefficient c(–1), which is requested for the transmitter equalization in the CAUI-4 chip-to-chip lane 0 transmitter in the receive direction.

45.2.1.97.4 Post-cursor remote setting (1.180.9:7)

The value of these bits sets the variable *Remote_eq_c1* for the lane 0 CAUI-4 receiver in the receive direction (see 83D.3.3.2). This is used by a CAUI-4 receiver that implements the optional transmitter equalization feedback as an indication of the ratio of the post-cursor coefficient c(1) being used in lane 0 of the CAUI-4 transmitter in the receive direction (see 83D.3.1.1). It may be used to generate values for the request flag and the request bits. If a lane 0 CAUI-4 receiver in the receive direction is not present in the package, then these bits have no effect.

45.2.1.97.5 Pre-cursor remote setting (1.180.6:5)

The value of these bits sets the variable *Remote_eq_cm1* for the lane 0 CAUI-4 receiver in the receive direction (see 83D.3.3.2). This is used by a CAUI-4 receiver that implements the optional transmitter equalization feedback as an indication of the ratio of the pre-cursor coefficient c(–1) being used in lane 0 of the CAUI-4 transmitter in the receive direction (see 83D.3.1.1). It may be used to generate values for the request flag and the request bits. If a lane 0 CAUI-4 receiver in the receive direction is not present in the package, then these bits have no effect.

45.2.1.97.6 Post-cursor local setting (1.180.4:2)

The value of these bits sets the variable *Local_eq_c1* for the lane 0 CAUI-4 transmitter in the receive direction (see 83D.3.1.1 and Table 83D–3), which controls the weight of the transmitter equalization post-cursor coefficient c(1). If a lane 0 CAUI-4 transmitter in the receive direction is not present in the package, then these bits have no effect.

45.2.1.97.7 Pre-cursor local setting (1.180.1:0)

The value of these bits sets the variable *Local_eq_cm1* for the lane 0 CAUI-4 transmitter in the receive direction (see 83D.3.1.1 and Table 83D–2), which controls the weight of the transmitter equalization pre-cursor coefficient c(–1). If a lane 0 CAUI-4 transmitter in the receive direction is not present in the package, then these bits have no effect.

45.2.1.98 CAUI-4 chip-to-chip transmitter equalization, receive direction, lane 1 through lane 3 registers (Registers 1.181, 1.182, 1.183)

The CAUI-4 chip-to-chip transmitter equalization, receive direction, lane 1 through lane 3 registers are defined similarly to register 1.180 (which is used for lane 0, see 45.2.1.97) but for lanes 1 through 3, respectively. The transmitter, receive direction, is the transmitter that sends data towards the PCS.

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45.2.1.99 CAUI-4 chip-to-chip transmitter equalization, transmit direction, lane 0 register (Register 1.184)

The assignment of bits in the CAUI-4 chip-to-chip transmitter equalization, transmit direction, lane 0 register is shown in Table 45–78. The transmitter, transmit direction, is the transmitter that sends data towards the PMD.

Table 45–78—CAUI-4 chip-to-chip transmitter equalization, transmit direction, lane 0 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.184.15	Request flag	1 = Change in equalization is requested 0 = No change in equalization is requested	RO
1.184.14:12	Post-cursor request	14 13 12 1 1 1 Reserved 1 1 0 Reserved 1 0 1 *Requested_eq_c1* = 5 (c(1) ratio –0.25) 1 0 0 *Requested_eq_c1* = 4 (c(1) ratio –0.2) 0 1 1 *Requested_eq_c1* = 3 (c(1) ratio –0.15) 0 1 0 *Requested_eq_c1* = 2 (c(1) ratio –0.1) 0 0 1 *Requested_eq_c1* = 1 (c(1) ratio –0.05) 0 0 0 *Requested_eq_c1* = 0 (c(1) ratio 0)	RO
1.184.11:10	Pre-cursor request	11 10 1 1 *Requested_eq_cm1* = 3 (c(–1) ratio –0.15) 1 0 *Requested_eq_cm1* = 2 (c(–1) ratio –0.1) 0 1 *Requested_eq_cm1* = 1 (c(–1) ratio –0.05) 0 0 *Requested_eq_cm1* = 0 (c(–1) ratio 0)	RO
1.184.9:7	Post-cursor remote setting	9 8 7 1 1 1 Reserved 1 1 0 Reserved 1 0 1 *Remote_eq_c1* = 5 (c(1) ratio –0.25) 1 0 0 *Remote_eq_c1* = 4 (c(1) ratio –0.2) 0 1 1 *Remote_eq_c1* = 3 (c(1) ratio –0.15) 0 1 0 *Remote_eq_c1* = 2 (c(1) ratio –0.1) 0 0 1 *Remote_eq_c1* = 1 (c(1) ratio –0.05) 0 0 0 *Remote_eq_c1* = 0 (c(1) ratio 0)	R/W
1.184.6:5	Pre-cursor remote setting	6 5 1 1 *Remote_eq_cm1* = 3 (c(–1) ratio –0.15) 1 0 *Remote_eq_cm1* = 2 (c(–1) ratio –0.1) 0 1 *Remote_eq_cm1* = 1 (c(–1) ratio –0.05) 0 0 *Remote_eq_cm1* = 0 (c(–1) ratio 0)	R/W
1.184.4:2	Post-cursor local setting	4 3 2 1 1 1 Reserved 1 1 0 Reserved 1 0 1 *Local_eq_c1* = 5 (c(1) ratio –0.25) 1 0 0 *Local_eq_c1* = 4 (c(1) ratio –0.2) 0 1 1 *Local_eq_c1* = 3 (c(1) ratio –0.15) 0 1 0 *Local_eq_c1* = 2 (c(1) ratio –0.1) 0 0 1 *Local_eq_c1* = 1 (c(1) ratio–0.05) 0 0 0 *Local_eq_c1* = 0 (c(1) ratio 0)	R/W
1.184.1:0	Pre-cursor local setting	1 0 1 1 *Local_eq_cm1* = 3 (c(–1) ratio –0.15) 1 0 *Local_eq_cm1* = 2 (c(–1) ratio –0.1) 0 1 *Local_eq_cm1* = 1 (c(–1) ratio –0.05) 0 0 *Local_eq_cm1* = 0 (c(–1) ratio 0)	R/W

[a]R/W = Read/Write, RO = Read only

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45.2.1.99.1 Request flag (1.184.15)

The value of this bit indicates the value of the variable *Request_flag* in the lane 0 CAUI-4 receiver in the transmit direction (see 83D.3.3.2). This indicates whether the CAUI-4 chip-to-chip device is issuing a request to change the remote transmitter equalization in the CAUI-4 chip-to-chip lane 0 transmitter in the transmit direction. If a lane 0 CAUI-4 receiver in the transmit direction is not present in the package, then the value returned for this bit should be zero.

45.2.1.99.2 Post-cursor request (1.184.14:12)

The value of these bits indicates the value of the variable *Requested_eq_c1* in the lane 0 CAUI-4 receiver in the transmit direction (see 83D.3.3.2). When *Request_flag* is equal to 1, this value indicates the ratio of the post-cursor coefficient c(1), which is requested for the transmitter equalization in the CAUI-4 chip-to-chip lane 0 transmitter in the transmit direction.

45.2.1.99.3 Pre-cursor request (1.184.11:10)

The value of these bits indicates the value of the variable *Requested_eq_cm1* in the lane 0 CAUI-4 receiver in the transmit direction (see 83D.3.3.2). When *Request_flag* is equal to 1, this value indicates the ratio of the pre-cursor coefficient c(–1), which is requested for the transmitter equalization in the CAUI-4 chip-to-chip lane 0 transmitter in the transmit direction.

45.2.1.99.4 Post-cursor remote setting (1.184.9:7)

The value of these bits sets the variable *Remote_eq_c1* for the lane 0 CAUI-4 receiver in the transmit direction (see 83D.3.3.2). This is used by a CAUI-4 receiver that implements the optional transmitter equalization feedback as an indication of the ratio of the post-cursor coefficient c(1) being used in lane 0 of the CAUI-4 transmitter in the transmit direction (see 83D.3.1.1). It may be used to generate values for the request flag and the request bits. If a lane 0 CAUI-4 receiver in the transmit direction is not present in the package, then these bits have no effect.

45.2.1.99.5 Pre-cursor remote setting (1.184.6:5)

The value of these bits sets the variable *Remote_eq_cm1* for the lane 0 CAUI-4 receiver in the transmit direction (see 83D.3.3.2). This is used by a CAUI-4 receiver that implements the optional transmitter equalization feedback as an indication of the ratio of the pre-cursor coefficient c(–1) being used in lane 0 of the CAUI-4 transmitter in the transmit direction (see 83D.3.1.1). It may be used to generate values for the request flag and the request bits. If a lane 0 CAUI-4 receiver in the transmit direction is not present in the package, then these bits have no effect.

45.2.1.99.6 Post-cursor local setting (1.184.4:2)

The value of these bits sets the variable *Local_eq_c1* for the lane 0 CAUI-4 transmitter in the transmit direction (see 83D.3.1.1 and Table 83D–3), which controls the weight of the transmitter equalization post-cursor coefficient c(1). If a lane 0 CAUI-4 transmitter in the transmit direction is not present in the package, then these bits have no effect.

45.2.1.99.7 Pre-cursor local setting (1.184.1:0)

The value of these bits sets the variable *Local_eq_cm1* for the lane 0 CAUI-4 transmitter in the transmit direction (see 83D.3.1.1 and Table 83D–2), which controls the weight of the transmitter equalization pre-cursor coefficient c(–1). If a lane 0 CAUI-4 transmitter in the transmit direction is not present in the package, then these bits have no effect.

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45.2.1.100 CAUI-4 chip-to-chip transmitter equalization, transmit direction, lane 1 through lane 3 registers (Registers 1.185, 1.186, 1.187)

The CAUI-4 chip-to-chip transmitter equalization, transmit direction, lane 1 through lane 3 registers are defined similarly to register 1.184 (which is used for lane 0, see 45.2.1.99) but for lanes 1 through 3, respectively. The transmitter, transmit direction, is the transmitter that sends data towards the PMD.

45.2.1.101 RS-FEC control register (Register 1.200)

The assignment of bits in the RS-FEC control register is shown in Table 45–79.

Table 45–79—RS-FEC control register bit definitions

Bit(s)	Name	Description	R/W[a]
1.200.15:2	Reserved	Value always 0	RO
1.200.1	FEC bypass indication enable	1 = FEC decoder does not indicate errors to the PCS 0 = FEC decoder indicates errors to the PCS layer	R/W
1.200.0	FEC bypass correction enable	1 = FEC decoder performs error detection without error correction 0 = FEC decoder performs error detection and error correction	R/W

[a]R/W = Read/Write, RO = Read only

45.2.1.101.1 FEC bypass indication enable (1.200.1)

This bit enables the RS-FEC decoder to bypass error indication to the upper layers (PCS) through the sync bits for the BASE-R PHY in the Local Device. When set to a one, this bit enables bypass of the error indication. When set to a zero, errors are indicated to the PCS through the sync bits. Writes to this bit are ignored and reads return a zero if the RS-FEC does not have the ability to bypass indicating decoding errors to the PCS layer (see 91.5.3.3).

45.2.1.101.2 FEC bypass correction enable (1.200.0)

When this bit is set to one the Reed-Solomon decoder performs error detection without error correction (see 91.5.3.3). When this bit is set to zero, the decoder also performs error correction. Writes to this bit are ignored and reads return a zero if the RS-FEC does not have the ability to bypass correction.

45.2.1.102 RS-FEC status register (Register 1.201)

The assignment of bits in the RS-FEC status register is shown in Table 45–80.

45.2.1.102.1 PCS align status (1.201.15)

When read as a one, bit 1.201.15 indicates that the RS-FEC described in Clause 91 has locked and aligned all transmit PCS lanes. When read as a zero, bit 1.201.15 indicates that the RS-FEC has not locked and aligned all transmit PCS lanes. A device that implements the RS-FEC status register but does not implement a separated RS-FEC shall return a one for bit 1.201.15.

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Table 45–80—RS-FEC status register bit definitions

Bit(s)	Name	Description	R/W[a]
1.201.15	PCS align status	1 = FEC encoder has locked and aligned all PCS lanes 0 = FEC encoder has not locked and aligned all PCS lanes	RO
1.201.14	RS-FEC align status	1 = RS-FEC receive lanes locked and aligned 0 = RS-FEC receive lanes not locked and aligned	RO
1.201.13:12	Reserved	Value always 0	RO
1.201.11	FEC AM lock 3	1 = RS-FEC receive lane 3 locked and aligned 0 = RS-FEC receive lane 3 not locked and aligned	RO
1.201.10	FEC AM lock 2	1 = RS-FEC receive lane 2 locked and aligned 0 = RS-FEC receive lane 2 not locked and aligned	RO
1.201.9	FEC AM lock 1	1 = RS-FEC receive lane 1 locked and aligned 0 = RS-FEC receive lane 1 not locked and aligned	RO
1.201.8	FEC AM lock 0	1 = RS-FEC receive lane 0 locked and aligned 0 = RS-FEC receive lane 0 not locked and aligned	RO
1.201.7:3	Reserved	Value always 0	RO
1.201.2	RS-FEC high SER	1 = FEC errors have exceeded threshold 0 = FEC errors have not exceeded threshold	RO/LH
1.201.1	FEC bypass indication ability	1 = FEC decoder has the ability to bypass error indication 0 = FEC decoder does not have the ability to bypass error indication	RO
1.201.0	FEC bypass correction ability	1 = FEC decoder has the ability to bypass error correction 0 = FEC decoder does not have the ability to bypass error correction	RO

[a]RO = Read only, LH = Latching high

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45.2.1.102.2 RS-FEC align status (1.201.14)

When read as a one, bit 1.201.14 indicates that the RS-FEC described in Clause 91 has locked and aligned all receive RS-FEC lanes. When read as a zero, bit 1.201.14 indicates that the RS-FEC has not locked and aligned all receive RS-FEC lanes.

45.2.1.102.3 FEC AM lock 3 (1.201.11)

When read as a one, bit 1.201.11 indicates that the RS-FEC described in Clause 91 has locked and aligned lane 3 of the PMA service interface. When read as a zero, bit 1.201.11 indicates that the RS-FEC has not locked and aligned lane 3 of the PMA service interface. This bit reflects the state of amps_lock[3] (see 91.5.3.1).

45.2.1.102.4 FEC AM lock 2 (1.201.10)

When read as a one, bit 1.201.10 indicates that the RS-FEC described in Clause 91 has locked and aligned lane 2 of the PMA service interface. When read as a zero, bit 1.201.10 indicates that the RS-FEC has not locked and aligned lane 2 of the PMA service interface. This bit reflects the state of amps_lock[2] (see 91.5.3.1).

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45.2.1.102.5 FEC AM lock 1 (1.201.9)

When read as a one, bit 1.201.9 indicates that the RS-FEC described in Clause 91 has locked and aligned lane 1 of the PMA service interface. When read as a zero, bit 1.201.9 indicates that the RS-FEC has not locked and aligned lane 1 of the PMA service interface. This bit reflects the state of amps_lock[1] (see 91.5.3.1).

45.2.1.102.6 FEC AM lock 0 (1.201.8)

When read as a one, bit 1.201.8 indicates that the RS-FEC described in Clause 91 has locked and aligned lane 0 of the PMA service interface. When read as a zero, bit 1.201.8 indicates that the RS-FEC has not locked and aligned lane 0 of the PMA service interface. This bit reflects the state of amps_lock[0] (see 91.5.3.1).

45.2.1.102.7 RS-FEC high SER (1.201.2)

When FEC_bypass_indication_enable is set to one, this bit is set to one if the number of RS-FEC symbol errors in a window of 8192 codewords exceeds the threshold (see 91.5.3.3) and is set to zero otherwise. The bit is set to zero if FEC_bypass_indication_enable is set to zero. This bit shall be implemented with latching high behavior.

45.2.1.102.8 FEC bypass indication ability (1.201.1)

The Reed-Solomon decoder may have the option to perform error detection without error indication (see 91.5.3.3) to reduce the delay contributed by the RS-FEC sublayer. This bit is set to one to indicate that the decoder has this ability to bypass error indication. The bit is set to zero if this ability is not supported.

45.2.1.102.9 FEC bypass correction ability (1.201.0)

The Reed-Solomon decoder may have the option to perform error detection without error correction (see 91.5.3.3) to reduce the delay contributed by the RS-FEC sublayer. This bit is set to one to indicate that the decoder has this ability to bypass error correction. The bit is set to zero if this ability is not supported.

45.2.1.103 RS-FEC corrected codewords counter (Register 1.202, 1.203)

The assignment of bits in the RS-FEC corrected codewords counter register is shown in Table 45–81. See 91.6.8 for a definition of this register. These bits shall be reset to all zeros when the register is read by the management function or upon PHY reset. These bits shall be held at all ones in the case of overflow. Registers 1.202, 1.203 are used to read the value of a 32-bit counter. When registers 1.202 and 1.203 are used to read the 32-bit counter value, the register 1.202 is read first, the value of the register 1.203 is latched when (and only when) register 1.202 is read, and reads of register 1.203 return the latched value rather than the current value of the counter.

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Table 45–81—RS-FEC corrected codewords counter register bit definitions

Bit(s)	Name	Description	R/W[a]
1.202.15:0	FEC corrected codewords lower	FEC_corrected_cw_counter[15:0]	RO, NR
1.203.15:0	FEC corrected codewords upper	FEC_corrected_cw_counter[31:16]	RO, NR

[a]RO = Read only, NR = Non Roll-over

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45.2.1.104 RS-FEC uncorrected codewords counter (Register 1.204, 1.205)

The assignment of bits in the RS-FEC uncorrected codewords counter register is shown in Table 45–82. See 91.6.9 for a definition of this register. These bits shall be reset to all zeros when the register is read by the management function or upon PHY reset. These bits shall be held at all ones in the case of overflow. Registers 1.204, 1.205 are used to read the value of a 32-bit counter. When registers 1.204 and 1.205 are used to read the 32-bit counter value, the register 1.204 is read first, the value of the register 1.205 is latched when (and only when) register 1.204 is read, and reads of register 1.205 return the latched value rather than the current value of the counter.

Table 45–82—RS-FEC uncorrected codewords counter register bit definitions

Bit(s)	Name	Description	R/W[a]
1.204.15:0	FEC uncorrected codewords lower	FEC_uncorrected_cw_counter[15:0]	RO, NR
1.205.15:0	FEC uncorrected codewords upper	FEC_uncorrected_cw_counter[31:16]	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.1.105 RS-FEC lane mapping register (Register 1.206)

The assignment of bits in the RS-FEC lane mapping register is shown in Table 45–83. When the RS-FEC detects and locks the RS-FEC for PMA service interface lane 0, the detected RS-FEC lane number is recorded bits 1:0 in this register. Similarly, the detected RS-FEC lane numbers for PMA service lanes 1, 2, and 3 are recorded in register bits 3:2, 5:4, and 7:6, respectively. The contents of the RS-FEC lane mapping register bits 7:0 are valid when RS-FEC align status (1.201.14) is set to one and are invalid otherwise.

Table 45–83—RS-FEC lane mapping register

Bit(s)	Name	Description	R/W[a]
1.206.15:8	Reserved	Value always 0	RO
1.206.7:6	RS-FEC lane 3 mapping	RS-FEC lane mapped to PMA lane 3	RO
1.206.5:4	RS-FEC lane 2 mapping	RS-FEC lane mapped to PMA lane 2	RO
1.206.3:2	RS-FEC lane 1 mapping	RS-FEC lane mapped to PMA lane 1	RO
1.206.1:0	RS-FEC lane 0 mapping	RS-FEC lane mapped to PMA lane 0	RO

[a]RO = Read only

45.2.1.106 RS-FEC symbol error counter lane 0 (Register 1.210, 1.211)

The assignment of bits in the RS-FEC symbol error counter lane 0 register is shown in Table 45–84. Symbol errors detected in FEC lane 0 are counted and shown in register 1.210.15:0 and 1.211.15:0. See 91.6.11 for a definition of this register. These bits shall be reset to all zeros when the register is read by the management function or upon PHY reset. These bits shall be held at all ones in the case of overflow. Registers 1.210, 1.211 are used to read the value of a 32-bit counter. When registers 1.210 and 1.211 are used to read the 32-bit counter value, the register 1.210 is read first, the value of the register 1.211 is latched when (and only

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when) register 1.210 is read, and reads of register 1.211 return the latched value rather than the current value of the counter.

Table 45–84—RS-FEC symbol error counter register bit definitions

Bit(s)	Name	Description	R/W[a]
1.210.15:0	FEC symbol errors, lane 0 lower	FEC_symbol_error_counter_0[15:0]	RO, NR
1.211.15:0	FEC symbol errors, lane 0 upper	FEC_symbol_error_counter_0[31:16]	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.1.107 RS-FEC symbol error counter lane 1 through 3 (Register 1.212, 1.213, 1.214, 1.215, 1.216, 1.217)

The behavior of the RS-FEC symbol error counters, lane 1 through 3 is identical to that described for FEC lane 0 in 45.2.1.106. Errors detected in each FEC lane are counted and shown in the corresponding register. FEC lane 1, lower 16 bits are shown in register 1.212; FEC lane 1, upper 16 bits are shown in register 1.213; FEC lane 2, lower 16 bits are shown in register 1.214; through register 1.217 for FEC lane 3, upper 16 bits.

45.2.1.108 RS-FEC BIP error counter lane 0 (Register 1.230)

The assignment of bits in the RS-FEC BIP error counter lane 0 is shown in Table 45–159. The RS-FEC described in Clause 91 calculates a BIP value for each PCS lane (see 91.5.2.4, 91.6.3). Errors detected in PCS lane 0 are counted and shown in register 1.230.15:0. The 16-bit counter shall be reset to all zeros when register 1.230 is read or upon PMA/PMD reset. The 16-bit counter shall be held at all ones in the case of overflow. A device that does not implement a separated RS-FEC shall return a zero for all bits in the RS-FEC BIP error counter, lane 0 register.

Table 45–85—RS-FEC BIP error counter lane 0 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.230.15:0	BIP error counter, lane 0	Errors detected by BIP in PCS lane 0	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.1.109 RS-FEC BIP error counter, lane 1 through 19 (Registers 1.231 through 1.249)

The behavior of the RS-FEC BIP error counters, lane 1 through 19 is identical to that described for lane 0 in 45.2.1.108. Errors detected in each PCS lane are counted and shown in register bits 15:0 in the corresponding register. PCS lane 1 is shown in register 1.231; PCS lane 2 is shown in register 1.232; through register 1.249 for PCS lane 19.

45.2.1.110 RS-FEC PCS lane 0 mapping register (Register 1.250)

The assignment of bits in the RS-FEC PCS lane 0 mapping register is shown in Table 45–86. When the RS-FEC instance of the multi-lane PCS described in Clause 82 detects and locks the alignment marker for service interface lane 0, the detected PCS lane number is recorded in this register. The contents of the Lane 0 mapping register is valid when the transmit PCS align status bit (register 1.201.15) is set to one and is

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invalid otherwise (see 45.2.1.102). A device that does not implement a separated RS-FEC shall return a zero for all bits in the RS-FEC PCS lane 0 mapping register.

Table 45–86—RS-FEC PCS lane 0 mapping register bit definitions

Bit(s)	Name	Description	R/W[a]
1.250.15:5	Reserved	Value always 0	RO
1.250.4:0	Lane 0 mapping	PCS lane received in service interface lane 0	RO

[a]RO = Read only

45.2.1.111 RS-FEC PCS lanes 1 through 19 mapping registers (Registers 1.251 through 1.269)

The definition of Lanes 1 through 19 mapping registers is identical to that described for lane 0 in 45.2.1.110. The lane mapping for lane 1 is in register 1.251; lane 2 is in register 1.252; etc.

45.2.1.112 RS-FEC PCS alignment status 1 register (Register 1.280)

The assignment of bits in the RS-FEC PCS alignment status 1 register is shown in Table 45–136. All the bits in the RS-FEC PCS alignment status 1 register are read only; a write to the RS-FEC PCS alignment status 1 register shall have no effect. A device that does not implement a separated RS-FEC shall return a zero for all bits in the RS-FEC PCS alignment status 1 register. It is the responsibility of the STA management entity to ensure that a port type is supported by all MMDs before interrogating any of its status bits.

Table 45–87—RS-FEC PCS alignment status 1 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.280.15:8	Reserved	Value always 0	RO
1.280.7	Block 7 lock	1 = Lane 7 is locked 0 = Lane 7 is not locked	RO
1.280.6	Block 6 lock	1 = Lane 6 is locked 0 = Lane 6 is not locked	RO
1.280.5	Block 5 lock	1 = Lane 5 is locked 0 = Lane 5 is not locked	RO
1.280.4	Block 4 lock	1 = Lane 4 is locked 0 = Lane 4 is not locked	RO
1.280.3	Block 3 lock	1 = Lane 3 is locked 0 = Lane 3 is not locked	RO

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Table 45–87—RS-FEC PCS alignment status 1 register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
1.280.2	Block 2 lock	1 = Lane 2 is locked 0 = Lane 2 is not locked	RO
1.280.1	Block 1 lock	1 = Lane 1 is locked 0 = Lane 1 is not locked	RO
1.280.0	Block 0 lock	1 = Lane 0 is locked 0 = Lane 0 is not locked	RO

[a]RO = Read only

45.2.1.112.1 Block 7 lock (1.280.7)

When read as a one, bit 1.280.7 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 7. When read as a zero, bit 1.280.7 indicates that the RS-FEC transmit function lane 7 has not achieved block lock. This bit reflects the state of block_lock[7] (see 91.5.2.1).

45.2.1.112.2 Block 6 lock (1.280.6)

When read as a one, bit 1.280.6 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 6. When read as a zero, bit 1.280.6 indicates that the RS-FEC transmit function lane 6 has not achieved block lock. This bit reflects the state of block_lock[6] (see 91.5.2.1).

45.2.1.112.3 Block 5 lock (1.280.5)

When read as a one, bit 1.280.5 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 5. When read as a zero, bit 1.280.5 indicates that the RS-FEC transmit function lane 5 has not achieved block lock. This bit reflects the state of block_lock[5] (see 91.5.2.1).

45.2.1.112.4 Block 4 lock (1.280.4)

When read as a one, bit 1.280.4 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 4. When read as a zero, bit 1.280.4 indicates that the RS-FEC transmit function lane 4 has not achieved block lock. This bit reflects the state of block_lock[4] (see 91.5.2.1).

45.2.1.112.5 Block 3 lock (1.280.3)

When read as a one, bit 1.280.3 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 3. When read as a zero, bit 1.280.3 indicates that the RS-FEC transmit function lane 3 has not achieved block lock. This bit reflects the state of block_lock[3] (see 91.5.2.1).

45.2.1.112.6 Block 2 lock (1.280.2)

When read as a one, bit 1.280.2 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 2. When read as a zero, bit 1.280.2 indicates that the RS-FEC transmit function lane 2 has not achieved block lock. This bit reflects the state of block_lock[2] (see 91.5.2.1).

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45.2.1.112.7 Block 1 lock (1.280.1)

When read as a one, bit 1.280.1 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 1. When read as a zero, bit 1.280.1 indicates that the RS-FEC transmit function lane 1 has not achieved block lock. This bit reflects the state of block_lock[1] (see 91.5.2.1).

45.2.1.112.8 Block 0 lock (1.280.0)

When read as a one, bit 1.280.0 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 0. When read as a zero, bit 1.280.0 indicates that the RS-FEC transmit function lane 0 has not achieved block lock. This bit reflects the state of block_lock[0] (see 91.5.2.1).

45.2.1.113 RS-FEC PCS alignment status 2 register (Register 1.281)

The assignment of bits in the RS-FEC PCS alignment status 2 register is shown in Table 45–137. All the bits in the RS-FEC PCS alignment status 2 register are read only; a write to the RS-FEC PCS alignment status 2 register shall have no effect. A device that does not implement a separated RS-FEC shall return a zero for all bits in the RS-FEC PCS alignment status 2 register. It is the responsibility of the STA management entity to ensure that a port type is supported by all MMDs before interrogating any of its status bits.

Table 45–88—RS-FEC PCS alignment status 2 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.281.15:12	Reserved	Value always 0	RO
1.281.11	Block 19 lock	1 = Lane 19 is locked 0 = Lane 19 is not locked	RO
1.281.10	Block 18 lock	1 = Lane 18 is locked 0 = Lane 18 is not locked	RO
1.281.9	Block 17 lock	1 = Lane 17 is locked 0 = Lane 17 is not locked	RO
1.281.8	Block 16 lock	1 = Lane 16 is locked 0 = Lane 16 is not locked	RO
1.281.7	Block 15 lock	1 = Lane 15 is locked 0 = Lane 15 is not locked	RO
1.281.6	Block 14 lock	1 = Lane 14 is locked 0 = Lane 14 is not locked	RO
1.281.5	Block 13 lock	1 = Lane 13 is locked 0 = Lane 13 is not locked	RO
1.281.4	Block 12 lock	1 = Lane 12 is locked 0 = Lane 12 is not locked	RO
1.281.3	Block 11 lock	1 = Lane 11 is locked 0 = Lane 11 is not locked	RO

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Table 45–88—RS-FEC PCS alignment status 2 register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
1.281.2	Block 10 lock	1 = Lane 10 is locked 0 = Lane 10 is not locked	RO
1.281.1	Block 9 lock	1 = Lane 9 is locked 0 = Lane 9 is not locked	RO
1.281.0	Block 8 lock	1 = Lane 8 is locked 0 = Lane 8 is not locked	RO

[a]RO = Read only

45.2.1.113.1 Block 19 lock (1.281.11)

When read as a one, bit 1.281.11 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 19. When read as a zero, bit 1.281.11 indicates that the RS-FEC transmit function lane 19 has not achieved block lock. This bit reflects the state of block_lock[19] (see 91.5.2.1).

45.2.1.113.2 Block 18 lock (1.281.10)

When read as a one, bit 1.281.10 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 18. When read as a zero, bit 1.281.10 indicates that the RS-FEC transmit function lane 18 has not achieved block lock. This bit reflects the state of block_lock[18] (see 91.5.2.1).

45.2.1.113.3 Block 17 lock (1.281.9)

When read as a one, bit 1.281.9 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 17. When read as a zero, bit 1.281.9 indicates that the RS-FEC transmit function lane 17 has not achieved block lock. This bit reflects the state of block_lock[17] (see 91.5.2.1).

45.2.1.113.4 Block 16 lock (1.281.8)

When read as a one, bit 1.281.8 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 16. When read as a zero, bit 1.281.8 indicates that the RS-FEC transmit function lane 16 has not achieved block lock. This bit reflects the state of block_lock[16] (see 91.5.2.1).

45.2.1.113.5 Block 15 lock (1.281.7)

When read as a one, bit 1.281.7 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 15. When read as a zero, bit 1.281.7 indicates that the RS-FEC transmit function lane 15 has not achieved block lock. This bit reflects the state of block_lock[15] (see 91.5.2.1).

45.2.1.113.6 Block 14 lock (1.281.6)

When read as a one, bit 1.281.6 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 14. When read as a zero, bit 1.281.6 indicates that the RS-FEC transmit function lane 14 has not achieved block lock. This bit reflects the state of block_lock[14] (see 91.5.2.1).

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45.2.1.113.7 Block 13 lock (1.281.5)

When read as a one, bit 1.281.5 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 13. When read as a zero, bit 1.281.5 indicates that the RS-FEC transmit function lane 13 has not achieved block lock. This bit reflects the state of block_lock[13] (see 91.5.2.1).

45.2.1.113.8 Block 12 lock (1.281.4)

When read as a one, bit 1.281.4 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 12. When read as a zero, bit 1.281.4 indicates that the RS-FEC transmit function lane 12 has not achieved block lock. This bit reflects the state of block_lock[12] (see 91.5.2.1).

45.2.1.113.9 Block 11 lock (1.281.3)

When read as a one, bit 1.281.3 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 11. When read as a zero, bit 1.281.3 indicates that the RS-FEC transmit function lane 11 has not achieved block lock. This bit reflects the state of block_lock[11] (see 91.5.2.1).

45.2.1.113.10 Block 10 lock (1.281.2)

When read as a one, bit 1.281.2 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 10. When read as a zero, bit 1.281.2 indicates that the RS-FEC transmit function lane 10 has not achieved block lock. This bit reflects the state of block_lock[10] (see 91.5.2.1).

45.2.1.113.11 Block 9 lock (1.281.1)

When read as a one, bit 1.281.1 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 9. When read as a zero, bit 1.281.1 indicates that the RS-FEC transmit function lane 9 has not achieved block lock. This bit reflects the state of block_lock[9] (see 91.5.2.1).

45.2.1.113.12 Block 8 lock (1.281.0)

When read as a one, bit 1.281.0 indicates that the RS-FEC transmit function has achieved block lock for service interface lane 8. When read as a zero, bit 1.281.0 indicates that the RS-FEC transmit function lane 8 has not achieved block lock. This bit reflects the state of block_lock[8] (see 91.5.2.1).

45.2.1.114 RS-FEC PCS alignment status 3 register (Register 1.282)

The assignment of bits in the RS-FEC PCS alignment status 3 register is shown in Table 45–89. All the bits in the RS-FEC PCS alignment status 3 register are read only; a write to the RS-FEC PCS alignment status 3 register shall have no effect. A device that does not implement a separated RS-FEC shall return a zero for all bits in the RS-FEC PCS alignment status 3 register. It is the responsibility of the STA management entity to ensure that a port type is supported by all MMDs before interrogating any of its status bits.

45.2.1.114.1 Lane 7 aligned (1.282.7)

When read as a one, bit 1.282.7 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 7. When read as a zero, bit 1.282.7 indicates that the RS-FEC transmit function lane 7 has not achieved alignment marker lock. This bit reflects the state of am_lock[7] (see 91.5.2.2).

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Table 45–89—RS-FEC PCS alignment status 3 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.282.15:8	Reserved	Value always 0	RO
1.282.7	Lane 7 aligned	1 = Lane 7 alignment marker is locked 0 = Lane 7 alignment marker is not locked	RO
1.282.6	Lane 6 aligned	1 = Lane 6 alignment marker is locked 0 = Lane 6 alignment marker is not locked	RO
1.282.5	Lane 5 aligned	1 = Lane 5 alignment marker is locked 0 = Lane 5 alignment marker is not locked	RO
1.282.4	Lane 4 aligned	1 = Lane 4 alignment marker is locked 0 = Lane 4 alignment marker is not locked	RO
1.282.3	Lane 3 aligned	1 = Lane 3 alignment marker is locked 0 = Lane 3 alignment marker is not locked	RO
1.282.2	Lane 2 aligned	1 = Lane 2 alignment marker is locked 0 = Lane 2 alignment marker is not locked	RO
1.282.1	Lane 1 aligned	1 = Lane 1 alignment marker is locked 0 = Lane 1 alignment marker is not locked	RO
1.282.0	Lane 0 aligned	1 = Lane 0 alignment marker is locked 0 = Lane 0 alignment marker is not locked	RO

[a]RO = Read only

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45.2.1.114.2 Lane 6 aligned (1.282.6)

When read as a one, bit 1.282.6 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 6. When read as a zero, bit 1.282.6 indicates that the RS-FEC transmit function lane 6 has not achieved alignment marker lock. This bit reflects the state of am_lock[6] (see 91.5.2.2).

45.2.1.114.3 Lane 5 aligned (1.282.5)

When read as a one, bit 1.282.5 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 5. When read as a zero, bit 1.282.5 indicates that the RS-FEC transmit function lane 5 has not achieved alignment marker lock. This bit reflects the state of am_lock[5] (see 91.5.2.2).

45.2.1.114.4 Lane 4 aligned (1.282.4)

When read as a one, bit 1.282.4 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 4. When read as a zero, bit 1.282.4 indicates that the RS-FEC transmit function lane 4 has not achieved alignment marker lock. This bit reflects the state of am_lock[4] (see 91.5.2.2).

45.2.1.114.5 Lane 3 aligned (1.282.3)

When read as a one, bit 1.282.3 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 3. When read as a zero, bit 1.282.3 indicates that the RS-FEC transmit function lane 3 has not achieved alignment marker lock. This bit reflects the state of am_lock[3] (see 91.5.2.2).

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45.2.1.114.6 Lane 2 aligned (1.282.2)

When read as a one, bit 1.282.2 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 2. When read as a zero, bit 1.282.2 indicates that the RS-FEC transmit function lane 2 has not achieved alignment marker lock. This bit reflects the state of am_lock[2] (see 91.5.2.2).

45.2.1.114.7 Lane 1 aligned (1.282.1)

When read as a one, bit 1.282.1 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 1. When read as a zero, bit 1.282.1 indicates that the RS-FEC transmit function lane 1 has not achieved alignment marker lock. This bit reflects the state of am_lock[1] (see 91.5.2.2).

45.2.1.114.8 Lane 0 aligned (1.282.0)

When read as a one, bit 1.282.0 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 0. When read as a zero, bit 1.282.0 indicates that the RS-FEC transmit function lane 0 has not achieved alignment marker lock. This bit reflects the state of am_lock[0] (see 91.5.2.2).

45.2.1.115 RS-FEC PCS alignment status 4 register (Register 1.283)

The assignment of bits in the RS-FEC PCS alignment status 4 register is shown in Table 45–90. All the bits in the RS-FEC PCS alignment status 4 register are read only; a write to the RS-FEC PCS alignment status 4 register shall have no effect. A device that does not implement a separated RS-FEC shall return a zero for all bits in the RS-FEC PCS alignment status 4 register. It is the responsibility of the STA management entity to ensure that a port type is supported by all MMDs before interrogating any of its status bits.

Table 45–90—RS-FEC PCS alignment status 4 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.283.15:12	Reserved	Value always 0	RO
1.283.11	Lane 19 aligned	1 = Lane 19 alignment marker is locked 0 = Lane 19 alignment marker is not locked	RO
1.283.10	Lane 18 aligned	1 = Lane 18 alignment marker is locked 0 = Lane 18 alignment marker is not locked	RO
1.283.9	Lane 17 aligned	1 = Lane 17 alignment marker is locked 0 = Lane 17 alignment marker is not locked	RO
1.283.8	Lane 16 aligned	1 = Lane 16 alignment marker is locked 0 = Lane 16 alignment marker is not locked	RO
1.283.7	Lane 15 aligned	1 = Lane 15 alignment marker is locked 0 = Lane 15 alignment marker is not locked	RO
1.283.6	Lane 14 aligned	1 = Lane 14 alignment marker is locked 0 = Lane 14 alignment marker is not locked	RO
1.283.5	Lane 13 aligned	1 = Lane 13 alignment marker is locked 0 = Lane 13 alignment marker is not locked	RO
1.283.4	Lane 12 aligned	1 = Lane 12 alignment marker is locked 0 = Lane 12 alignment marker is not locked	RO

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Table 45–90—RS-FEC PCS alignment status 4 register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
1.283.3	Lane 11 aligned	1 = Lane 11 alignment marker is locked 0 = Lane 11 alignment marker is not locked	RO
1.283.2	Lane 10 aligned	1 = Lane 10 alignment marker is locked 0 = Lane 10 alignment marker is not locked	RO
1.283.1	Lane 9 aligned	1 = Lane 9 alignment marker is locked 0 = Lane 9 alignment marker is not locked	RO
1.283.0	Lane 8 aligned	1 = Lane 8 alignment marker is locked 0 = Lane 8 alignment marker is not locked	RO

[a]RO = Read only

45.2.1.115.1 Lane 19 aligned (1.283.11)

When read as a one, bit 1.283.11 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 19. When read as a zero, bit 1.283.11 indicates that the RS-FEC transmit function lane 19 has not achieved alignment marker lock. This bit reflects the state of am_lock[19] (see 91.5.2.2).

45.2.1.115.2 Lane 18 aligned (1.283.10)

When read as a one, bit 1.283.10 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 18. When read as a zero, bit 1.283.10 indicates that the RS-FEC transmit function lane 18 has not achieved alignment marker lock. This bit reflects the state of am_lock[18] (see 91.5.2.2).

45.2.1.115.3 Lane 17 aligned (1.283.9)

When read as a one, bit 1.283.9 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 17. When read as a zero, bit 1.283.9 indicates that the RS-FEC transmit function lane 17 has not achieved alignment marker lock. This bit reflects the state of am_lock[17] (see 91.5.2.2).

45.2.1.115.4 Lane 16 aligned (1.283.8)

When read as a one, bit 1.283.8 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 16. When read as a zero, bit 1.283.8 indicates that the RS-FEC transmit function lane 16 has not achieved alignment marker lock. This bit reflects the state of am_lock[16] (see 91.5.2.2).

45.2.1.115.5 Lane 15 aligned (1.283.7)

When read as a one, bit 1.283.7 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 15. When read as a zero, bit 1.283.7 indicates that the RS-FEC transmit function lane 15 has not achieved alignment marker lock. This bit reflects the state of am_lock[15] (see 91.5.2.2).

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45.2.1.115.6 Lane 14 aligned (1.283.6)

When read as a one, bit 1.283.6 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 14. When read as a zero, bit 1.283.6 indicates that the RS-FEC transmit function lane 14 has not achieved alignment marker lock. This bit reflects the state of am_lock[14] (see 91.5.2.2).

45.2.1.115.7 Lane 13 aligned (1.283.5)

When read as a one, bit 1.283.5 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 13. When read as a zero, bit 1.283.5 indicates that the RS-FEC transmit function lane 13 has not achieved alignment marker lock. This bit reflects the state of am_lock[13] (see 91.5.2.2).

45.2.1.115.8 Lane 12 aligned (1.283.4)

When read as a one, bit 1.283.4 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 12. When read as a zero, bit 1.283.4 indicates that the RS-FEC transmit function lane 12 has not achieved alignment marker lock. This bit reflects the state of am_lock[12] (see 91.5.2.2).

45.2.1.115.9 Lane 11 aligned (1.283.3)

When read as a one, bit 1.283.3 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 11. When read as a zero, bit 1.283.3 indicates that the RS-FEC transmit function lane 11 has not achieved alignment marker lock. This bit reflects the state of am_lock[11] (see 91.5.2.2).

45.2.1.115.10 Lane 10 aligned (1.283.2)

When read as a one, bit 1.283.2 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 10. When read as a zero, bit 1.283.2 indicates that the RS-FEC transmit function lane 10 has not achieved alignment marker lock. This bit reflects the state of am_lock[10] (see 91.5.2.2).

45.2.1.115.11 Lane 9 aligned (1.283.1)

When read as a one, bit 1.283.1 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 9. When read as a zero, bit 1.283.1 indicates that the RS-FEC transmit function lane 9 has not achieved alignment marker lock. This bit reflects the state of am_lock[9] (see 91.5.2.2).

45.2.1.115.12 Lane 8 aligned (1.283.0)

When read as a one, bit 1.283.0 indicates that the RS-FEC transmit function has achieved alignment marker lock for service interface lane 8. When read as a zero, bit 1.283.0 indicates that the RS-FEC transmit function lane 8 has not achieved alignment marker lock. This bit reflects the state of am_lock[8] (see 91.5.2.2).

45.2.1.116 BASE-R FEC corrected blocks counter, lanes 0 through 19

(Register 1.300, 1.301, 1.302, 1.303, 1.304, 1.305, 1.306, 1.307, 1.308, 1.309, 1.310, 1.311, 1.312, 1.313, 1.314, 1.315, 1.316, 1.317, 1.318, 1.319, 1.320, 1.321, 1.322, 1.323, 1.324, 1.325, 1.326, 1.327, 1.328, 1.329, 1.330, 1.331, 1.332, 1.333, 1.334, 1.335, 1.336, 1.337, 1.338, 1.339)

For multi-PCS lane BASE-R PHYs, the even-numbered registers in this set are defined similarly to register 1.172 (see 45.2.1.94) but for lanes 0 through 19 respectively of multi-PCS lane PHYs. The odd-numbered

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registers in this set are defined similarly to register 1.173 (see 45.2.1.94) but for lanes 0 through 19 respectively of multilane PHYs. Note that the lane numbers refer to the service interface lanes and do not necessarily correspond to the PCS lane numbers.

Registers corresponding to lanes that are not used for the selected PHY shall return all zeros.

45.2.1.117 BASE-R FEC uncorrected blocks counter, lanes 0 through 19

(Register 1.700, 1.701, 1.702, 1.703, 1.704, 1.705, 1.706, 1.707, 1.708, 1.709, 1.710, 1.711, 1.712, 1.713, 1.714, 1.715, 1.716, 1.717, 1.718, 1.719, 1.720, 1.721, 1.722, 1.723, 1.724, 1.725, 1.726, 1.727, 1.728, 1.729, 1.730, 1.731, 1.732, 1.733, 1.734, 1.735, 1.736, 1.737, 1.738, 1.739)

For multi-PCS lane BASE-R PHYs, the even-numbered registers in this set are defined similarly to register 1.174 (see 45.2.1.95) but for lanes 0 through 19 respectively of multi-PCS lane PHYs. The odd-numbered registers in this set are defined similarly to register 1.175 (see 45.2.1.95) but for lanes 0 through 19 respectively of multilane PHYs. Note that the lane numbers refer to the service interface lanes and do not necessarily correspond to the PCS lane numbers.

Registers corresponding to lanes that are not used for the selected PHY shall return all zeros.

45.2.1.118 BASE-R LP coefficient update register, lanes 1 through 9

(Register 1.1101, 1.1102, 1.1103, 1.1104, 1.1105, 1.1106, 1.1107, 1.1108, 1.1109)

For multi-PCS lane BASE-R PHYs, these registers are defined similarly to register 1.152 (which is used for lane 0, see 45.2.1.82) but for lanes 1 through 9 respectively of multi-PCS lane PHYs.

Registers corresponding to lanes that are not used for the selected PHY shall return all zeros.

45.2.1.119 BASE-R LP status report register, lanes 1 through 9

(Register 1.1201, 1.1202, 1.1203, 1.1204, 1.1205, 1.1206, 1.1207, 1.1208, 1.1209)

For multi-PCS lane BASE-R PHYs, these registers are defined similarly to register 1.153 (which is used for lane 0, see 45.2.1.83) but for lanes 1 through 9 respectively of multi-PCS lane PHYs.

Registers corresponding to lanes that are not used for the selected PHY shall return all zeros.

45.2.1.120 BASE-R LD coefficient update register, lanes 1 through 9

(Register 1.1301, 1.1302, 1.1303, 1.1304, 1.1305, 1.1306, 1.1307, 1.1308, 1.1309)

For multi-PCS lane BASE-R PHYs, these registers are defined similarly to register 1.154 (which is used for lane 0, see 45.2.1.84) but for lanes 1 through 9 respectively of multi-PCS lane PHYs.

Registers corresponding to lanes that are not used for the selected PHY shall return all zeros.

45.2.1.121 BASE-R LD status report register, lanes 1 through 9

(Register 1.1401, 1.1402, 1.1403, 1.1404, 1.1405, 1.1406, 1.1407, 1.1408, 1.1409)

For multi-PCS lane BASE-R PHYs, these registers are defined similarly to register 1.155 (which is used for lane 0, see 45.2.1.85) but for lanes 1 through 9 respectively of multi-PCS lane PHYs.

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Registers corresponding to lanes that are not used for the selected PHY shall return all zeros.

45.2.1.122 PMD training pattern lanes 0 through 3 (Register 1.1450 through 1.1453)

The assignment of bits in the PMD training pattern lane 0 register is shown in Table 45–91. The assignment of bits in the PMD training pattern lanes 1 through 3 registers are defined similarly to lane 0. Register 1.1450 controls the PMD training pattern for PMD lane 0; register 1.1451 controls the PMD training pattern for PMD lane 1; etc.

Table 45–91—PMD training pattern lane 0 bit definitions

Bit(s)	Name	Description	R/W[a]
1.1450.15:13	Reserved	Value always 0	RO
1.1450.12:11	Polynomial identifier	Identifier (0, 1, 2, or 3) selecting polynomial for PRBS	R/W
1.1450.10:0	Seed	11 bit, binary seed for sequence	R/W

[a]R/W = Read/Write, RO = Read only

Register bits 12:11 contain a 2-bit identifier that selects the polynomial used for training in the particular PMD lane according to the definition in 92.7.12. The polynomial identifier for each lane should be unique; two lanes having the same identifier could impair operation of the PMD control function. The default identifiers are (binary): for lane 0, 00; for lane 1, 01; for lane 2, 10; for lane 3, 11. Register bits 10:0 contain the 11-bit seed for the sequence, where register bit 0 gives seed bit S0; register bit 1 gives seed bit S1; etc., through register bit 10 gives seed bit S10. The default seeds are (binary, S0 is left-most bit): for lane 0, 10101111110; for lane 1, 11001000101; for lane 2, 11100101101; for lane 3, 11110110110. This produces the following initial output (hexadecimal representation where the hex symbols are transmitted from left to right and the most significant bit of each hex symbol is transmitted first): for lane 0, fbf1cb3e; for lane 1, fbb1e665; for lane 2, f3fdae46; for lane 3, f2ffa46b.

45.2.1.123 Test-pattern ability (Register 1.1500)

The test-pattern ability register is used for PHY types that implement square wave testing and PRBS testing in the PMA. These functions are described in 83.5.10. The assignment of bits in the test-pattern ability register is shown in Table 45–92.

Table 45–92—Test-pattern ability register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1500.15:13	Reserved	Value always 0	RO
1.1500.12	Square wave test ability	1 = Square wave testing supported 0 = Square wave testing not supported	RO
1.1500.11:6	Reserved	Value always 0	RO
1.1500.5	PRBS9 Tx generator ability	1 = PRBS9 transmit direction pattern generator supported 0 = PRBS9 transmit direction pattern generator not supported	RO
1.1500.4	PRBS9 Rx generator ability	1 = PRBS9 receive direction pattern generator supported 0 = PRBS9 receive direction pattern generator not supported	RO

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Table 45–92—Test-pattern ability register bit definitions *(continued)*

1.1500.3	PRBS31 Tx generator ability	1 = PRBS31 Transmit direction pattern generator supported 0 = PRBS31 Tx direction pattern generator not supported	RO
1.1500.2	PRBS31 Tx checker ability	1 = PRBS31 Transmit direction pattern checker supported 0 = PRBS31 Tx direction pattern checker not supported	RO
1.1500.1	PRBS31 Rx generator ability	1 = PRBS31 Receive direction pattern generator supported 0 = PRBS31 Rx direction pattern generator not supported	RO
1.1500.0	PRBS31 Rx checker ability	1 = PRBS31 Receive direction pattern checker supported 0 = PRBS31 Rx direction pattern checker not supported	RO

[a]RO = Read only

If square wave testing is supported and this register is implemented then bit 1.1500.12 shall be set to 1. The square wave test is controlled by register 1.1510 (see 45.2.1.125).

If PRBS9 pattern testing is supported and this register is implemented then bit 1.1500.5 shall indicate the generation ability in the transmit direction and bit 1.1500.4 shall indicate the generation ability in the receive direction. The PRBS pattern test is controlled by register 1.1501 (see 45.2.1.124).

If PRBS31 pattern testing is supported and this register is implemented then bit 1.1500.3 shall indicate the generation ability in the transmit direction and bit 1.1500.1 shall indicate the generation ability in the receive direction. Bit 1.1500.2 shall indicate the checker ability in the transmit direction and bit 1.1500.0 shall indicate the checker ability in the receive direction. The PRBS pattern test is controlled by register 1.1501 (see 45.2.1.124).

45.2.1.124 PRBS pattern testing control (Register 1.1501)

The PRBS pattern testing control register is used for PHY types that implement PRBS pattern testing in the PMA. This function is described in 83.5.10. The assignment of bits in the PRBS pattern testing control register is shown in Table 45–93.

Table 45–93—PRBS pattern testing control register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1501.15:12	Reserved	Value always 0	RO
1.1501.11	Transmitter linearity test pattern enable	1 = Enable transmitter linearity test-pattern 0 = Disable transmitter linearity test-pattern	R/W
1.1501.10	QPRBS13 pattern enable	1 = Enable QPRBS13 test-pattern 0 = Disable QPRBS13 test-pattern	R/W
1.1501.9	JP03B pattern enable	1 = Enable JP03B test-pattern 0 = Disable JP03B test-pattern	R/W
1.1501.8	JP03A pattern enable	1 = Enable JP03A test-pattern 0 = Disable JP03A test-pattern	R/W
1.1501.7	PRBS31 pattern enable	1 = Enable PRBS31 test-pattern 0 = Disable PRBS31 test-pattern	R/W

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Table 45–93—PRBS pattern testing control register bit definitions *(continued)*

1.1501.6	PRBS9 pattern enable	1 = Enable PRBS9 test-pattern 0 = Disable PRBS9 test-pattern	R/W
1.1501.5:4	Reserved	Value always 0	RO
1.1501.3	Tx generator enable	1 = Enable transmit direction test-pattern generator 0 = Disable transmit direction test-pattern generator	R/W
1.1501.2	Tx checker enable	1 = Enable transmit direction test-pattern checker 0 = Disable transmit direction test-pattern checker	R/W
1.1501.1	Rx generator enable	1 = Enable receive direction test-pattern generator 0 = Disable receive direction test-pattern generator	R/W
1.1501.0	Rx checker enable	1 = Enable receive direction test-pattern checker 0 = Disable receive direction test-pattern checker	R/W

[a]R/W = Read/Write, RO = Read only

Register 1.1501, bit 7 enables testing with the PRBS31 pattern defined in 83.5.10. Register 1.1501, bit 6 enables testing with the PRBS9 pattern defined in 83.5.10. The assertion of register 1.1501 bits 7 and 6 is mutually exclusive. If both bits are asserted the behavior is undefined. The assertion of register 1.1501, bits 7 and 6 works in conjunction with register 1.1501, bits 3:0. If none of the bits 3:0 are asserted then bits 7 and 6 have no effect.

Register 1.1501, bit 3 enables PRBS generation in the transmit direction. Register 1.1501, bit 2 enables PRBS checking in the transmit direction. Register 1.1501, bit 1 enables PRBS generation in the receive direction. Register 1.1501, bit 0 enables PRBS checking in the receive direction. If neither of the bits 7 and 6 are asserted then bits 3:0 have no effect.

Register 1.1501 bit 8 enables testing with the JP03A pattern defined in 94.2.9.1 for 100GBASE-KP4 PMA/PMD. Register 1.1501 bit 9 enables testing with the JP03B pattern defined in 94.2.9.2 for 100GBASE-KP4 PMA/PMD. Register field 1.1501 bit 10 enables testing with the QPRBS13 pattern defined in 94.2.9.3 for 100GBASE-KP4 PMA/PMD. Register field 1.1501 bit 11 enables the transmitter linearity test pattern defined in 94.2.9.4 for 100GBASE-KP4 PMA/PMD. The assertion of bits 1.1501.8, 1.1501.9, 1.1501.10, 1.1501.11 are mutually exclusive. If more than one bit is asserted, the behavior is undefined. The assertion of 1.1501.8, 1.1501.9, 1.501.10, and 1.1501.11 operates in conjunction with register 1.1501 bit 3 for 100GBASE-KP4 PMA/PMD. For other PMA/PMD types or if bit 1.1501.3 is not asserted, then 1.1501.8, 1.1501.9, 1.501.10, and 1.1501.11 have no effect.

45.2.1.125 Square wave testing control (Register 1.1510)

The square wave testing control register is used for PHY types that implement transmit square wave testing in the PMA. This function is described in 83.5.10. The assignment of bits in the square wave testing control register is shown in Table 45–94.

Register 1.1510, bits 0 through 9 enable square wave output on PMA lanes 0 through 9 respectively. Lanes for which a square wave pattern is not enabled act as determined by other registers.

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Table 45–94—Square wave testing control register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1510.15:10	Reserved	Value always 0	RO
1.1510.9	Lane 9 SW enable	1 = Enable square wave on lane 9 0 = Disable square wave on lane 9	R/W
1.1510.8	Lane 8 SW enable	1 = Enable square wave on lane 8 0 = Disable square wave on lane 8	R/W
1.1510.7	Lane 7 SW enable	1 = Enable square wave on lane 7 0 = Disable square wave on lane 7	R/W
1.1510.6	Lane 6 SW enable	1 = Enable square wave on lane 6 0 = Disable square wave on lane 6	R/W
1.1510.5	Lane 5 SW enable	1 = Enable square wave on lane 5 0 = Disable square wave on lane 5	R/W
1.1510.4	Lane 4 SW enable	1 = Enable square wave on lane 4 0 = Disable square wave on lane 4	R/W
1.1510.3	Lane 3 SW enable	1 = Enable square wave on lane 3 0 = Disable square wave on lane 3	R/W
1.1510.2	Lane 2 SW enable	1 = Enable square wave on lane 2 0 = Disable square wave on lane 2	R/W
1.1510.1	Lane 1 SW enable	1 = Enable square wave on lane 1 0 = Disable square wave on lane 1	R/W
1.1510.0	Lane 0 SW enable	1 = Enable square wave on lane 0 0 = Disable square wave on lane 0	R/W

[a]R/W = Read/Write, RO = Read only

45.2.1.126 PRBS Tx pattern testing error counter (Register 1.1600, 1.1601, 1.1602, 1.1603, 1.1604, 1.1605, 1.1606, 1.1607, 1.1608, 1.1609)

The PRBS Tx pattern testing error counter registers are used for PHY types that implement PRBS Tx pattern testing in the PMA. This function is described in 83.5.10. The assignment of bits in the PRBS Tx pattern testing error counter registers are shown in Table 45–95. Register 1.1600 contains the PRBS Tx pattern testing error counter for lane 0, register 1.1601 contains the PRBS Tx pattern testing error counter for lane 1, and registers 1.1602 through 1.1609 contain the PRBS Tx pattern testing error counters for lanes 2 through 9 respectively. Counters corresponding to lanes that are not implemented in a PMA shall read all zeros.

Table 45–95—PRBS Tx pattern testing error counter

Bit(s)	Name	Description	R/W[a]
1.1600[b].15:0	Error counter		RO, NR

[a]RO = Read only, NR = Non Roll-over.
[b]All instances of address 1.1600 also apply to addresses 1.1601 through 1.1609.

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The PRBS Tx pattern testing error counter is a 16-bit counter as defined in 83.5.10. These bits shall be reset to all zeros when the register is read by the management function or upon execution of the PMA reset. These bits shall be held at all ones in the case of overflow.

45.2.1.127 PRBS Rx pattern testing error counter (Register 1.1700, 1.1701, 1.1702, 1.1703, 1.1704, 1.1705, 1.1706, 1.1707, 1.1708, 1.1709)

The PRBS Rx pattern testing error counter registers are used for PHY types that implement PRBS Rx pattern testing in the PMA. This function is described in 83.5.10. The assignment of bits in the PRBS Rx pattern testing error counter registers is identical to the PRBS Tx pattern testing error counter as shown in Table 45–95. Register 1.1700 contains the PRBS Rx pattern testing error counter for lane 0, register 1.1701 contains the PRBS Rx pattern testing error counter for lane 1, and registers 1.1702 through 1.1709 contain the PRBS Rx pattern testing error counters for lanes 2 through 9 respectively. Counters corresponding to lanes that are not implemented in a PMA shall read all zeros.

The PRBS Rx pattern testing error counter is a 16-bit counter as defined in 83.5.10. These bits shall be reset to all zeros when the register is read by the management function or upon execution of the PMA reset. These bits shall be held at all ones in the case of overflow.

45.2.1.128 TimeSync PMA/PMD capability (Register 1.1800)

The TimeSync PMA/PMD capability register (see Table 45–96) indicates the capability of the PMA/PMD to report the transmit and receive data delay, stored in registers 1.1801 and 1.1805 through 1.1808 respectively.

Table 45–96—TimeSync PMA/PMD capability

Bit(s)	Name	Description	R/W[a]
1.1800.15:2	Reserved	Value always 0	RO
1.1800.1	TimeSync transmit path data delay	1 = PMA/PMD provides information on transmit path data delay in registers 1.1801 through 1.1804 0 = PMA/PMD does not provide information on transmit path data delay	RO
1.1800.0	TimeSync receive path data delay	1 = PMA/PMD provides information on receive path data delay in registers 1.1805 through 1.1808 0 = PMA/PMD does not provide information on receive path data delay	RO

[a]RO = Read only.

45.2.1.129 TimeSync PMA/PMD transmit path data delay (Registers 1.1801, 1.1802, 1.1803, 1.1804)

The TimeSync PMA/PMD transmit path data delay register contains the maximum (Registers 1.1801, 1.1802, see Table 45–97) and minimum (Registers 1.1803, 1.1804, see Table 45–97) values of the transmit

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path data delay. The transmit path data delay is expressed in units of ns. The values contained in these registers are valid when the link is established, as indicated by bit 2 in Register 1.1 (see 45.2.1.2.4).

Table 45–97—TimeSync PMA/PMD transmit path data delay register

Bit(s)	Name	Description	R/W[a]
1.1801.15:0	Maximum PMA/PMD transmit path data delay, lower	PMA/PMD_delay_TX_max [15:0]	RO, MW
1.1802.15:0	Maximum PMA/PMD transmit path data delay, upper	PMA/PMD_delay_TX_max [31:16]	RO, MW
1.1803.15:0	Minimum PMA/PMD transmit path data delay, lower	PMA/PMD_delay_TX_min [15:0]	RO, MW
1.1804.15:0	Minimum PMA/PMD transmit path data delay, upper	PMA/PMD_delay_TX_min [31:16]	RO, MW

[a]RO = Read only, MW = Multi-word.

45.2.1.130 TimeSync PMA/PMD receive path data delay (Registers 1.1805, 1.1806, 1.1807, 1.1808)

The TimeSync PMA/PMD receive path data delay register contains the maximum (Registers 1.1805, 1.1806, see Table 45–98) and minimum (Registers 1.1807, 1.1808, see Table 45–98) values of the receive path data delay. The receive path data delay is expressed in units of ns. The values contained in these registers are valid when the link is established, as indicated by bit 2 in Register 1.1 (see 45.2.1.2.4).

Table 45–98—TimeSync PMA/PMD receive path data delay register

Bit(s)	Name	Description	R/W[a]
1.1805.15:0	Maximum PMA/PMD receive path data delay, lower	PMA/PMD_delay_RX_max [15:0]	RO, MW
1.1806.15:0	Maximum PMA/PMD receive path data delay, upper	PMA/PMD_delay_RX_max [31:16]	RO, MW
1.1807.15:0	Minimum PMA/PMD receive path data delay, lower	PMA/PMD_delay_RX_min [15:0]	RO, MW
1.1808.15:0	Minimum PMA/PMD receive path data delay, upper	PMA/PMD_delay_RX_min [31:16]	RO, MW

[a]RO = Read only, MW = Multi-word.

45.2.2 WIS registers

The assignment of registers in the WIS is shown in Table 45–99. For the WIS octet fields, bit 8 of the corresponding field in the WIS frame maps to the lowest numbered bit of the field in the register.

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Table 45–99—WIS registers

Register address	Register name	Subclause
2.0	WIS control 1	45.2.2.1
2.1	WIS status 1	45.2.2.2
2.2, 2.3	WIS device identifier	45.2.2.3
2.4	WIS speed ability	45.2.2.4
2.5, 2.6	WIS devices in package	45.2.2.5
2.7	10G WIS control 2	45.2.2.6
2.8	10G WIS status 2	45.2.2.7
2.9	10G WIS test-pattern error counter	45.2.2.8
2.10 through 2.13	Reserved	
2.14, 2.15	WIS package identifier	45.2.2.9
2.16 through 2.32	Reserved	
2.33	10G WIS status 3	45.2.2.10
2.34 through 2.36	Reserved	
2.37	10G WIS far end path block error count	45.2.2.11
2.38	Reserved	
2.39 through 2.46	10G WIS J1 transmit	45.2.2.12
2.47 through 2.54	10G WIS J1 receive	45.2.2.13
2.55, 2.56	10G WIS far end line BIP errors	45.2.2.14
2.57, 2.58	10G WIS line BIP errors	45.2.2.15
2.59	10G WIS path block error count	45.2.2.16
2.60	10G WIS section BIP error count	45.2.2.17
2.61 through 2.63	Reserved	
2.64 through 2.71	10G WIS J0 transmit	45.2.2.18
2.72 through 2.79	10G WIS J0 receive	45.2.2.19
2.80 through 2.1799	Reserved	
2.1800	TimeSync WIS capability	45.2.2.20
2.1801 through 2.1804	TimeSync WIS transmit path data delay	45.2.2.21

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Table 45–99—WIS registers *(continued)*

Register address	Register name	Subclause
2.1805 through 2.1808	TimeSync WIS receive path data delay	45.2.2.22
2.1809 through 2.32767	Reserved	
2.32 768 through 2.65 535	Vendor specific	

45.2.2.1 WIS control 1 register (Register 2.0)

The assignment of bits in the WIS control 1 register is shown in Table 45–100. The default value for each bit of the WIS control 1 register should be chosen so that the initial state of the device upon power up or reset is a normal operational state without management intervention.

Table 45–100—WIS control 1 register bit definitions

Bit(s)	Name	Description	R/W[a]
2.0.15	Reset	1 = WIS reset 0 = Normal operation	R/W SC
2.0.14	Loopback	1 = Enable loopback mode 0 = Disable loopback mode	R/W
2.0.13	Speed selection	1 = Operation at 10 Gb/s and above 0 = Unspecified	R/W
2.0.12	Reserved	Value always 0	RO
2.0.11	Low power	1 = Low-power mode 0 = Normal operation	R/W
2.0.10:7	Reserved	Value always 0	RO
2.0.6	Speed selection	1 = Operation at 10 Gb/s and above 0 = Unspecified	R/W
2.0.5:2	Speed selection	5 4 3 2 1 x x x = Reserved x 1 x x = Reserved x x 1 x = Reserved 0 0 0 1 = Reserved 0 0 0 0 = 10 Gb/s	R/W
2.0.1:0	Reserved	Value always 0	RO

[a]R/W = Read/Write, SC = Self-clearing, RO = Read only

45.2.2.1.1 Reset (2.0.15)

Resetting a WIS is accomplished by setting bit 2.0.15 to a one. This action shall set all to their default states. As a consequence, this action may change the internal state of the WIS and the state of the physical link.

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This action may also initiate a reset in any other MMDs that are instantiated in the same package. This bit is self-clearing, and a WIS shall return a value of one in bit 2.0.15 when a reset is in progress and a value of zero otherwise. A WIS is not required to accept a write transaction to any of its registers until the reset process is completed. The reset process shall be completed within 0.5 s from the setting of bit 2.0.15. During a reset, a WIS shall respond to reads from register bits 2.0.15 and 2.8.15:14. All other register bits should be ignored.

NOTE—This operation may interrupt data communication.

45.2.2.1.2 Loopback (2.0.14)

The WIS shall be placed in a loopback mode of operation when bit 2.0.14 is set to a one. When bit 2.0.14 is set to a one, the WIS shall ignore all data presented to it by the PMA sublayer. When bit 2.0.14 is set to a one, the WIS shall accept data on the transmit path and return it on the receive path. For 10 Gb/s operation, the detailed behavior of the WIS during loopback is specified in 50.3.9.

The default value of bit 2.0.14 is zero.

NOTE—The signal path through the WIS that is exercised in the loopback mode of operation is implementation specific, but it is recommended that the signal path encompass as much of the WIS circuitry as is practical. The intention of providing this loopback mode of operation is to permit a diagnostic or self-test function to perform the transmission and reception of a PDU, thus testing the transmit and receive data paths. Other loopback signal paths may be enabled using loopback controls within other MMDs.

45.2.2.1.3 Low power (2.0.11)

A WIS may be placed into a low-power mode by setting bit 2.0.11 to a one. This action may also initiate a low-power mode in any other MMDs that are instantiated in the same package. The low-power mode is exited by resetting the WIS. The behavior of the WIS in transition to and from the low-power mode is implementation specific and any interface signals should not be relied upon. While in the low-power mode, the device shall, as a minimum, respond to management transactions necessary to exit the low-power mode. The default value of bit 2.0.11 is zero.

45.2.2.1.4 Speed selection (2.0.13, 2.0.6, and 2.0.5:2)

Speed selection bits 2.0.13 and 2.0.6 shall both be written as a one. Any attempt to change the bits to an invalid setting shall be ignored. These two bits are set to one in order to make them compatible with Clause 22.

The speed of the WIS may be selected using bits 5 through 2. The speed abilities of the WIS are advertised in the WIS speed ability register. A WIS may ignore writes to the WIS speed selection bits that select speeds it has not advertised in the WIS speed ability register. It is the responsibility of the STA entity to ensure that mutually acceptable speeds are applied consistently across all the MMDs on a particular PHY.

The WIS speed selection defaults to a supported ability.

45.2.2.2 WIS status 1 register (Register 2.1)

The assignment of bits in the WIS status 1 register is shown in Table 45–101. All the bits in the WIS status 1 register are read only; a write to the WIS status 1 register shall have no effect.

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Table 45–101—WIS status 1 register bit definitions

Bit(s)	Name	Description	R/W[a]
2.1.15:8	Reserved	Value always 0	RO
2.1.7	Fault	1 = Fault condition 0 = No fault condition	RO/LH
2.1.6:3	Reserved	Value always 0	RO
2.1.2	Link status	1 = WIS link up 0 = WIS link down	RO/LL
2.1.1	Low-power ability	1 = WIS supports low-power mode 0 = WIS does not support low-power mode	RO
2.1.0	Reserved	Value always 0	RO

[a]RO = Read only, LH = Latching high, LL = Latching low

45.2.2.2.1 Fault (2.1.7)

When read as a one, bit 2.1.7 indicates that the WIS has detected a fault condition. When read as a zero, bit 2.1.7 indicates that the WIS has not detected a fault condition. The fault bit shall be implemented with latching high behavior.

The default value of bit 2.1.7 is zero.

45.2.2.2.2 Link status (2.1.2)

When read as a one, bit 2.1.2 indicates that the WIS receive link is up. When read as a zero, bit 2.1.2 indicates that the WIS receive link is down. The link status bit shall be implemented with latching low behavior.

45.2.2.2.3 Low-power ability (2.1.1)

When read as a one, bit 2.1.1 indicates that the WIS supports the low-power feature. When read as a zero, bit 2.1.1 indicates that the WIS does not support the low-power feature. If a WIS supports the low-power feature, then it is controlled using the low-power bit in the WIS control register.

45.2.2.3 WIS device identifier (Registers 2.2 and 2.3)

Registers 2.2 and 2.3 provide a 32-bit value, which may constitute a unique identifier for a particular type of WIS. The identifier shall be composed of the 3rd through 24th bits of the Organizationally Unique Identifier (OUI) assigned to the device manufacturer by the IEEE, plus a six-bit model number, plus a four-bit revision number. A WIS may return a value of zero in each of the 32 bits of the WIS device identifier.

The format of the WIS device identifier is specified in 22.2.4.3.1.

45.2.2.4 WIS speed ability (Register 2.4)

The assignment of bits in the WIS speed ability register is shown in Table 45–102.

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Table 45–102—WIS speed ability register bit definitions

Bit(s)	Name	Description	R/W[a]
2.4.15:1	Reserved for future speeds	Value always 0	RO
2.4.0	10G capable	1 = WIS is capable of operating at 10 Gb/s 0 = WIS is not capable of operating at 10 Gb/s	RO

[a]RO = Read only

45.2.2.4.1 10G capable (2.4.0)

When read as a one, bit 2.4.0 indicates that the WIS is able to operate at a data rate of 10 Gb/s (9.58 Gb/s payload rate). When read as a zero, bit 2.4.0 indicates that the WIS is not able to operate at a data rate of 10 Gb/s (9.58 Gb/s payload rate).

45.2.2.5 WIS devices in package (Registers 2.5 and 2.6)

The WIS devices in package registers are defined in Table 45–2.

45.2.2.6 10G WIS control 2 register (Register 2.7)

The assignment of bits in the 10G WIS control 2 register is shown in Table 45–103. The default value for each bit of the 10G WIS control 2 register should be chosen so that the initial state of the device upon power up or reset is a normal operational state without management intervention.

Table 45–103—10G WIS control 2 register bit definitions

Bit(s)	Name	Description	R/W[a]
2.7.15:6	Reserved	Value always 0	RO
2.7.5	PRBS31 receive test-pattern enable	1 = Enable PRBS31 test-pattern mode on the receive path 0 = Disable PRBS31 test-pattern mode on the receive path	R/W
2.7.4	PRBS31 transmit test-pattern enable	1 = Enable PRBS31 test-pattern mode on the transmit path 0 = Disable PRBS31 test-pattern mode on the transmit path	R/W
2.7.3	Test-pattern selection	1 = Select square wave test pattern 0 = Select mixed-frequency test pattern	R/W
2.7.2	Receive test-pattern enable	1 = Enable test-pattern mode on the receive path 0 = Disable test-pattern mode on the receive path	R/W
2.7.1	Transmit test-pattern enable	1 = Enable test-pattern mode on the transmit path 0 = Disable test-pattern mode on the transmit path	R/W
2.7.0	PCS type selection	1 = Select 10GBASE-W PCS type 0 = Select 10GBASE-R PCS type	R/W

[a]RO = Read only, R/W = Read/Write

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45.2.2.6.1 PRBS31 receive test-pattern enable (2.7.5)

If the WIS supports the optional PRBS31 (see 49.2.8) pattern testing advertised in bit 2.8.1 and the mandatory receive test-pattern enable bit (2.7.2) is not one, setting bit 2.7.5 to a one shall set the receive path of the WIS into the PRBS31 test-pattern mode. Setting bit 2.7.5 to a zero shall disable the PRBS31 test-pattern mode on the receive path of the WIS. The behavior of the WIS when in PRBS31 test-pattern mode is specified in 50.3.8.2.

45.2.2.6.2 PRBS31 transmit test-pattern enable (2.7.4)

If the WIS supports the optional PRBS31 pattern testing advertised in bit 2.8.1 and the mandatory transmit test-pattern enable bit (2.7.1) is not one, then setting bit 2.7.4 to a one shall set the transmit path of the WIS into the PRBS31 test-pattern mode. Setting bit 2.7.4 to a zero shall disable the PRBS31 test-pattern mode on the transmit path of the WIS. The behavior of the WIS when in PRBS31 test-pattern mode is specified in 50.3.8.2.

45.2.2.6.3 Test-pattern selection (2.7.3)

Bit 2.7.3 controls the type of pattern sent by the transmitter when in test-pattern mode. Setting bit 2.7.3 to a one shall select the square wave test pattern. Setting bit 2.7.3 to a zero shall select the mixed-frequency test pattern. The details of the test patterns are specified in Clause 50.

45.2.2.6.4 Receive test-pattern enable (2.7.2)

Setting bit 2.7.2 to a one shall set the receive path of the WIS into the test-pattern mode. Setting bit 2.7.2 to a zero shall disable the test-pattern mode on the receive path of the WIS. The behavior of the WIS when in test-pattern mode is specified in Clause 50.

45.2.2.6.5 Transmit test-pattern enable (2.7.1)

Setting bit 2.7.1 to a one shall set the transmit path of the WIS into the test-pattern mode. Setting bit 2.7.1 to a zero shall disable the test-pattern mode on the transmit path of the WIS. The behavior of the WIS when in test-pattern mode is specified in Clause 50.

45.2.2.6.6 PCS type selection (2.7.0)

Setting bit 2.7.0 to a one shall enable the 10GBASE-W logic and set the speed of the WIS-PMA interface to 9.95328 Gb/s. Setting bit 2.7.0 to a zero shall disable the 10GBASE-W logic, set the speed of the PCS-PMA interface to 10.3125 Gb/s and bypass the data around the 10GBASE-W logic. A WIS that is only capable of supporting 10GBASE-W operation and is unable to support 10GBASE-R operation shall ignore values written to this bit and shall return a value of one when read. It is the responsibility of the STA entity to ensure that mutually acceptable MMD types are applied consistently across all the MMDs on a particular PHY.

45.2.2.7 10G WIS status 2 register (Register 2.8)

The assignment of bits in the 10G WIS status 2 register is shown in Table 45–104. All the bits in the 10G WIS status 2 register are read only; a write to the 10G WIS status 2 register shall have no effect.

45.2.2.7.1 Device present (2.8.15:14)

When read as <10>, bits 2.8.15:14 indicate that a device is present and responding at this register address. When read as anything other than <10>, bits 2.8.15:14 indicate that no device is present at this address or that the device is not functioning properly.

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Table 45–104—10G WIS status 2 register bit definitions

Bit(s)	Name	Description	R/W[a]
2.8.15:14	Device present	15 14 1 0 = Device responding at this address 1 1 = No device responding at this address 0 1 = No device responding at this address 0 0 = No device responding at this address	RO
2.8.13:2	Reserved	Value always 0	RO
2.8.1	PRBS31 pattern testing ability	1 = WIS is able to support PRBS31 pattern testing 0 = WIS is not able to support PRBS31 pattern testing	RO
2.8.0	10GBASE-R ability	1 = WIS is able to support 10GBASE-R port types 0 = WIS is not able to support 10GBASE-R port types	RO

[a]RO = Read only

45.2.2.7.2 PRBS31 pattern testing ability (2.8.1)

When read as a one, bit 2.8.1 indicates that the WIS is able to support PRBS31 pattern testing. When read as a zero, bit 2.8.1 indicates that the WIS is not able to support PRBS31 pattern testing. If the WIS is able to support PRBS31 pattern testing, then the pattern generation and checking is controlled using bits 2.7.5:4.

45.2.2.7.3 10GBASE-R ability (2.8.0)

When read as a one, bit 2.8.0 indicates that the WIS is able to bypass the WIS logic and adjust the XSBI interface speed to support 10GBASE-R port types. When read as a zero, bit 2.8.0 indicates that the WIS is not able to bypass the WIS logic and cannot support 10GBASE-R port types.

45.2.2.8 10G WIS test-pattern error counter register (Register 2.9)

The assignment of bits in the 10G WIS test-pattern error counter register is shown in Table 45–105. This register is only required when the PRBS31 pattern generation capability is supported.

Table 45–105—10G WIS test-pattern error counter register bit definitions

Bit(s)	Name	Description	R/W[a]
2.9.15:0	Test-pattern error counter	Error counter	RO

[a]RO = Read only

The test-pattern error counter is a sixteen bit counter that contains the number of errors received during a pattern test. These bits shall be reset to all zeros when the test-pattern error counter is read by the management function or upon execution of the WIS reset. These bits shall be held at all ones in the case of overflow. The test-pattern methodology is described in 49.2.8.

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45.2.2.9 WIS package identifier (Registers 2.14 and 2.15)

Registers 2.14 and 2.15 provide a 32-bit value, which may constitute a unique identifier for a particular type of package that the WIS is instantiated within. The identifier shall be composed of the 3rd through 24th bits of the Organizationally Unique Identifier (OUI) assigned to the package manufacturer by the IEEE, plus a six-bit model number, plus a four-bit revision number. A WIS may return a value of zero in each of the 32 bits of the WIS package identifier.

A non-zero package identifier may be returned by one or more MMDs in the same package. The package identifier may be the same as the device identifier.

The format of the WIS package identifier is specified in 22.2.4.3.1.

45.2.2.10 10G WIS status 3 register (Register 2.33)

The assignment of bits in the 10G WIS status 3 register is shown in Table 45–106. All the bits in the 10G WIS status 3 register are read only; a write to the 10G WIS status 3 register shall have no effect.

Table 45–106—10G WIS status 3 register bit definitions

Bit(s)	Name	Description	R/W[a]
2.33.15:12	Reserved	Value always 0	RO
2.33.11	SEF	Severely errored frame	RO/LH
2.33.10	Far end PLM-P/LCD-P	1 = Far end path label mismatch / Loss of code-group delineation 0 = No far end path label mismatch / Loss of code-group delineation	RO/LH
2.33.9	Far end AIS-P/LOP-P	1 = Far end path alarm indication signal / Path loss of pointer 0 = No far end path alarm indication signal / Path loss of pointer	RO/LH
2.33.8	Reserved	Value always 0	RO
2.33.7	LOF	1 = Loss of frame flag raised 0 = Loss of frame flag lowered	RO/LH
2.33.6	LOS	1 = Loss of signal flag raised 0 = Loss of signal flag lowered	RO/LH
2.33.5	RDI-L	1 = Line remote defect flag raised 0 = Line remote defect flag lowered	RO/LH
2.33.4	AIS-L	1 = Line alarm indication flag raised 0 = Line alarm indication flag lowered	RO/LH
2.33.3	LCD-P	1 = Path loss of code-group delineation flag raised 0 = Path loss of code-group delineation flag lowered	RO/LH

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Table 45–106—10G WIS status 3 register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
2.33.2	PLM-P	1 = Path label mismatch flag raised 0 = Path label mismatch flag lowered	RO/LH
2.33.1	AIS-P	1 = Path alarm indication signal raised 0 = Path alarm indication signal lowered	RO/LH
2.33.0	LOP-P	1 = Loss of pointer flag raised 0 = Loss of pointer flag lowered	RO/LH

[a]RO = Read only, LH = Latching high

45.2.2.10.1 SEF (2.33.11)

When read as a one, bit 2.33.11 indicates that the SEF flag has been raised by the WIS. When read as a zero, bit 2.33.11 indicates that the SEF flag is lowered. The SEF bit shall be implemented with latching high behavior.

The SEF functionality implemented by the WIS is described in 50.3.2.5.

45.2.2.10.2 Far end PLM-P/LCD-P (2.33.10)

When read as a one, bit 2.33.10 indicates that the far end path label mismatch/loss of code-group delineation flag has been raised. When read as a zero, bit 2.33.10 indicates that the far end path label mismatch/loss of code-group delineation flag is lowered. The far end PLM-P/LCD-P bit shall be implemented with latching high behavior.

The far end path label mismatch/loss of code-group delineation functionality implemented by the WIS is described in 50.3.2.5.

45.2.2.10.3 Far end AIS-P/LOP-P (2.33.9)

When read as a one, bit 2.33.9 indicates that the far end path alarm indication signal/path loss of pointer flag has been raised by the WIS. When read as a zero, bit 2.33.9 indicates that the far end path alarm indication signal/path loss of pointer flag is lowered. The far end AIS-P/LOP-P bit shall be implemented with latching high behavior.

The far end path alarm indication signal/path loss of pointer functionality implemented by the WIS is described in 50.3.2.5.

45.2.2.10.4 LOF (2.33.7)

When read as a one, bit 2.33.7 indicates that the loss of frame flag has been raised. When read as a zero, bit 2.33.7 indicates that the loss of frame flag is lowered. The LOF bit shall be implemented with latching high behavior.

The LOF functionality implemented by the WIS is described in 50.3.2.5.

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45.2.2.10.5 LOS (2.33.6)

When read as a one, bit 2.33.6 indicates that the loss of signal flag has been raised. When read as a zero, bit 2.33.6 indicates that the loss of signal flag is lowered. The LOS bit shall be implemented with latching high behavior.

The LOS functionality implemented by the WIS is described in 50.3.2.5.

45.2.2.10.6 RDI-L (2.33.5)

When read as a one, bit 2.33.5 indicates that the line remote defect flag has been raised. When read as a zero, bit 2.33.5 indicates that the line remote defect flag is lowered. The RDI-L bit shall be implemented with latching high behavior.

The RDI-L functionality implemented by the WIS is described in 50.3.2.5.

45.2.2.10.7 AIS-L (2.33.4)

When read as a one, bit 2.33.4 indicates that the line alarm indication flag has been raised. When read as a zero, bit 2.33.4 indicates that the line alarm indication flag is lowered. The AIS-L bit shall be implemented with latching high behavior.

The AIS-L functionality implemented by the WIS is described in 50.3.2.5.

45.2.2.10.8 LCD-P (2.33.3)

When read as a one, bit 2.33.3 indicates that the loss of code-group delineation flag has been raised. When read as a zero, bit 2.33.3 indicates that the loss of code-group delineation flag is lowered. The LCD-P bit shall be implemented with latching high behavior.

The loss of code-group delineation functionality implemented by the WIS is described in 50.3.2.5.

45.2.2.10.9 PLM-P (2.33.2)

When read as a one, bit 2.33.2 indicates that the path label mismatch flag has been raised. When read as a zero, bit 2.33.2 indicates that the path label mismatch flag is lowered. The PLM-P bit shall be implemented with latching high behavior.

The PLM-P functionality implemented by the WIS is described in 50.3.2.5.

45.2.2.10.10 AIS-P (2.33.1)

When read as a one, bit 2.33.1 indicates that the path alarm indication signal has been raised. When read as a zero, bit 2.33.1 indicates that the path alarm indication signal is lowered. The AIS-P bit shall be implemented with latching high behavior.

The path alarm indication signal functionality implemented by the WIS is described in 50.3.2.5.

45.2.2.10.11 LOP-P (2.33.0)

When read as a one, bit 2.33.0 indicates that the loss of pointer flag has been raised. When read as a zero, bit 2.33.0 indicates that the loss of pointer flag is lowered. The LOP-P bit shall be implemented with latching high behavior.

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The LOP-P functionality implemented by the WIS is described in 50.3.2.5.

45.2.2.11 10G WIS far end path block error count (Register 2.37)

The assignment of bits in the 10G WIS far end path block error count register is shown in Table 45–107.

Table 45–107—10G WIS far end path block error count register bit definitions

Bit(s)	Name	Description	R/W[a]
2.37.15:0	Far end path block error count	Far end path block error count	RO

[a]RO = Read only,

The 10G WIS far end path block error count is incremented by one whenever a far end path block error, defined in Annex 50A, is detected as described in 50.3.2.5. The counter wraps around to zero when it is incremented beyond its maximum value of 65 535. It is cleared to zero when the WIS is reset.

45.2.2.12 10G WIS J1 transmit (Registers 2.39 through 2.46)

The assignment of octets in the 10G WIS J1 transmit registers is shown in Table 45–108.

Table 45–108—10G WIS J1 transmit 0–15 register bit definitions

Bit(s)	Name	Description	R/W[a]
2.46.15:8	J1 transmit 15	Transmitted path trace octet 15	R/W
2.46.7:0	J1 transmit 14	Transmitted path trace octet 14	R/W
2.45.15:8	J1 transmit 13	Transmitted path trace octet 13	R/W
2.45.7:0	J1 transmit 12	Transmitted path trace octet 12	R/W
2.44.15:8	J1 transmit 11	Transmitted path trace octet 11	R/W
2.44.7:0	J1 transmit 10	Transmitted path trace octet 10	R/W
2.43.15:8	J1 transmit 9	Transmitted path trace octet 9	R/W
2.43.7:0	J1 transmit 8	Transmitted path trace octet 8	R/W
2.42.15:8	J1 transmit 7	Transmitted path trace octet 7	R/W
2.42.7:0	J1 transmit 6	Transmitted path trace octet 6	R/W
2.41.15:8	J1 transmit 5	Transmitted path trace octet 5	R/W
2.41.7:0	J1 transmit 4	Transmitted path trace octet 4	R/W
2.40.15:8	J1 transmit 3	Transmitted path trace octet 3	R/W

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Table 45–108—10G WIS J1 transmit 0–15 register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
2.40.7:0	J1 transmit 2	Transmitted path trace octet 2	R/W
2.39.15:8	J1 transmit 1	Transmitted path trace octet 1	R/W
2.39.7:0	J1 transmit 0	Transmitted path trace octet 0	R/W

[a]R/W = Read/Write

The first transmitted path trace octet is J1 transmit 15, which contains the delineation octet. The default value for the J1 transmit 15 octet is 137 (hexadecimal 89). The last transmitted path trace octet is J1 transmit 0. The default value for the J1 transmit 0 through 14 octets is 0. The transmitted path trace is described in 50.3.2.1.

45.2.2.13 10G WIS J1 receive (Registers 2.47 through 2.54)

The assignment of octets in the 10G WIS J1 receive registers is shown in Table 45–109.

Table 45–109—10G WIS J1 receive 0–15 register bit definitions

Bit(s)	Name	Description	R/W[a]
2.54.15:8	J1 receive 15	Received path trace octet 15	RO
2.54.7:0	J1 receive 14	Received path trace octet 14	RO
2.53.15:8	J1 receive 13	Received path trace octet 13	RO
2.53.7:0	J1 receive 12	Received path trace octet 12	RO
2.52.15:8	J1 receive 11	Received path trace octet 11	RO
2.52.7:0	J1 receive 10	Received path trace octet 10	RO
2.51.15:8	J1 receive 9	Received path trace octet 9	RO
2.51.7:0	J1 receive 8	Received path trace octet 8	RO
2.50.15:8	J1 receive 7	Received path trace octet 7	RO
2.50.7:0	J1 receive 6	Received path trace octet 6	RO
2.49.15:8	J1 receive 5	Received path trace octet 5	RO
2.49.7:0	J1 receive 4	Received path trace octet 4	RO
2.48.15:8	J1 receive 3	Received path trace octet 3	RO

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Table 45–109—10G WIS J1 receive 0–15 register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
2.48.7:0	J1 receive 2	Received path trace octet 2	RO
2.47.15:8	J1 receive 1	Received path trace octet 1	RO
2.47.7:0	J1 receive 0	Received path trace octet 0	RO

[a]RO = Read only

The first received path trace octet is J1 receive 15. The last received path trace octet is J1 receive 0. The received path trace is described in 50.3.2.4.

45.2.2.14 10G WIS far end line BIP errors (Registers 2.55 and 2.56)

The assignment of octets in the 10G WIS far end line BIP errors registers is shown in Table 45–110.

Table 45–110—10G WIS far end line BIP errors 0–1 register bit definitions

Bit(s)	Name	Description	R/W[a]
2.56.15:0	WIS far end line BIP errors 0	Least significant word of the WIS far end line BIP errors counter	RO
2.55.15:0	WIS far end line BIP errors 1	Most significant word of the WIS far end line BIP errors counter	RO

[a]RO = Read only

The 10G WIS far end line BIP Errors register pair reflects the contents of the far end line BIP errors counter (as described in 50.3.11.3) that is incremented on each WIS frame by the number of far end line BIP errors reported by the far end, as described in 50.3.2.5. Whenever the most significant 16 bit register of the counter (2.55) is read, the 32 bit counter value is latched into the register pair, with the most significant bits appearing in 2.55 and the least significant 16 bits appearing in 2.56, the value being latched before the contents of 2.55 (the most significant 16 bits) are driven on the MDIO interface. A subsequent read from register 2.56 will return the least significant 16 bits of the latched value, but will not change the register contents. Writes to these registers have no effect.

NOTE—These counters do not follow the behavior described in 45.2 for 32-bit counters.

45.2.2.15 10G WIS line BIP errors (Registers 2.57 and 2.58)

The assignment of octets in the 10G WIS line BIP errors registers is shown in Table 45–111.

The 10G WIS line BIP errors register pair reflects the contents of the line BIP errors counter (as described in 50.3.11.3) that is incremented on each WIS frame by the number of line BIP errors detected on the incoming data stream, as described in 50.3.2.5. Whenever the most significant 16 bit register of the counter (2.57) is read, the 32 bit counter value is latched into the register pair, with the most significant bits appearing in 2.57 and the least significant 16 bits appearing in 2.58, the value being latched before the contents of 2.57 (the most significant 16 bits) are driven on the MDIO interface. A subsequent read from register 2.58 will return the least significant 16 bits of the latched value, but will not change the register contents. Writes to these registers have no effect.

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Table 45–111—10G WIS line BIP errors 0–1 register bit definitions

Bit(s)	Name	Description	R/W[a]
2.58.15:0	WIS line BIP errors 0	Least significant word of the WIS line BIP errors counter	RO
2.57.15:0	WIS line BIP errors 1	Most significant word of the WIS line BIP errors counter	RO

[a]RO = Read only

NOTE—These counters do not follow the behavior described in 45.2 for 32-bit counters.

45.2.2.16 10G WIS path block error count (Register 2.59)

The assignment of bits in the 10G WIS path block error count register is shown in Table 45–112.

Table 45–112—10G WIS path block error count register bit definitions

Bit(s)	Name	Description	R/W[a]
2.59.15:0	Path block error count	Path block error counter	RO

[a]RO = Read only

45.2.2.16.1 Path block error count (2.59.15:0)

The path block error count is incremented by one whenever a B3 parity error (defined in Annex 50A) is detected, as described in 50.3.2.5. The counter wraps around to zero when it is incremented beyond its maximum value of 65 535. It is cleared to zero when the WIS is reset.

45.2.2.17 10G WIS section BIP error count (Register 2.60)

The assignment of bits in the 10G WIS section BIP error count register is shown in Table 45–113.

Table 45–113—10G WIS section BIP error count register bit definitions

Bit(s)	Name	Description	R/W[a]
2.60.15:0	Section BIP error count	Section BIP error count	RO

[a]RO = Read only

45.2.2.17.1 Section BIP error count (2.60.15:0)

The section BIP error count is incremented by the number of section BIP errors detected within each WIS frame, as described in 50.3.2.5. The counter wraps around to zero when it is incremented beyond its maximum value of 65 535. It is cleared to zero when the WIS is reset.

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45.2.2.18 10G WIS J0 transmit (Registers 2.64 through 2.71)

The assignment of octets in the 10G WIS J0 transmit registers is shown in Table 45–114.

Table 45–114—10G WIS J0 transmit 0–15 register bit definitions

Bit(s)	Name	Description	R/W[a]
2.71.15:8	J0 transmit 15	Transmitted section trace octet 15	R/W
2.71.7:0	J0 transmit 14	Transmitted section trace octet 14	R/W
2.70.15:8	J0 transmit 13	Transmitted section trace octet 13	R/W
2.70.7:0	J0 transmit 12	Transmitted section trace octet 12	R/W
2.69.15:8	J0 transmit 11	Transmitted section trace octet 11	R/W
2.69.7:0	J0 transmit 10	Transmitted section trace octet 10	R/W
2.68.15:8	J0 transmit 9	Transmitted section trace octet 9	R/W
2.68.7:0	J0 transmit 8	Transmitted section trace octet 8	R/W
2.67.15:8	J0 transmit 7	Transmitted section trace octet 7	R/W
2.67.7:0	J0 transmit 6	Transmitted section trace octet 6	R/W
2.66.15:8	J0 transmit 5	Transmitted section trace octet 5	R/W
2.66.7:0	J0 transmit 4	Transmitted section trace octet 4	R/W
2.65.15:8	J0 transmit 3	Transmitted section trace octet 3	R/W
2.65.7:0	J0 transmit 2	Transmitted section trace octet 2	R/W
2.64.15:8	J0 transmit 1	Transmitted section trace octet 1	R/W
2.64.7:0	J0 transmit 0	Transmitted section trace octet 0	R/W

[a]R/W = Read/Write

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The J0 transmit octets allow a receiver to verify its continued connection to the WIS transmitter. The first transmitted section trace octet is J0 transmit 15, which contains the delineation octet. The default value for the J0 transmit 15 octet is 137 (hexadecimal 89). The last transmitted section trace octet is J0 transmit 0. The default value for the J0 transmit 0 through 14 octets is 0. The transmitted section trace is described in 50.3.2.3.

45.2.2.19 10G WIS J0 receive (Registers 2.72 through 2.79)

The assignment of octets in the 10G WIS J0 receive registers is shown in Table 45–115.

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Table 45–115— 10G WIS J0 receive 0–15 register bit definitions

Bit(s)	Name	Description	R/W[a]
2.79.15:8	J0 receive 15	Received section trace octet 15	RO
2.79.7:0	J0 receive 14	Received section trace octet 14	RO
2.78.15:8	J0 receive 13	Received section trace octet 13	RO
2.78.7:0	J0 receive 12	Received section trace octet 12	RO
2.77.15:8	J0 receive 11	Received section trace octet 11	RO
2.77.7:0	J0 receive 10	Received section trace octet 10	RO
2.76.15:8	J0 receive 9	Received section trace octet 9	RO
2.76.7:0	J0 receive 8	Received section trace octet 8	RO
2.75.15:8	J0 receive 7	Received section trace octet 7	RO
2.75.7:0	J0 receive 6	Received section trace octet 6	RO
2.74.15:8	J0 receive 5	Received section trace octet 5	RO
2.74.7:0	J0 receive 4	Received section trace octet 4	RO
2.73.15:8	J0 receive 3	Received section trace octet 3	RO
2.73.7:0	J0 receive 2	Received section trace octet 2	RO
2.72.15:8	J0 receive 1	Received section trace octet 1	RO
2.72.7:0	J0 receive 0	Received section trace octet 0	RO

[a]RO = Read only

The first received section trace octet is J0 receive 15. The last received section trace octet is J0 receive 0. The J0 receive octets allow a WIS receiver to verify its continued connection to the intended transmitter. The received section trace is described in 50.3.2.4.

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45.2.2.20 TimeSync WIS capability (Register 2.1800)

The TimeSync WIS capability register (see Table 45–116) indicates the capability of the WIS to report the transmit and receive data delay, stored in registers 2.1801 through 2.1804 and 2.1805 through 2.1808, respectively.

Table 45–116—TimeSync WIS capability

Bit(s)	Name	Description	R/W[a]
2.1800.15:2	Reserved	Value always 0	RO
2.1800.1	TimeSync transmit path data delay	1 = WIS provides information on transmit path data delay in registers 2.1801 through 2.1804 0 = WIS does not provide information on transmit path data delay	RO
2.1800.0	TimeSync receive path data delay	1 = WIS provides information on receive path data delay in registers 2.1805 through 2.1808 0 = WIS does not provide information on receive path data delay	RO

[a]RO = Read only

45.2.2.21 TimeSync WIS transmit path data delay (Registers 2.1801, 2.1802, 2.1803, 2.1804)

The TimeSync WIS transmit path data delay register contains the maximum (Registers 2.1801, 2.1802, see Table 45–117) and minimum (Registers 2.1803, 2.1804, see Table 45–117) values of the transmit path data delay. The transmit path data delay is expressed in units of ns. The values contained in these registers are valid when the link is established, as indicated by bit 2 in Register 1.1 (see 45.2.1.2.4).

Table 45–117—TimeSync WIS transmit path data delay register

Bit(s)	Name	Description	R/W[a]
2.1801.15:0	Maximum WIS transmit path data delay, lower	WIS_delay_TX_max [15:0]	RO, MW
2.1802.15:0	Maximum WIS transmit path data delay, upper	WIS_delay_TX_max [31:16]	RO, MW
2.1803.15:0	Minimum WIS transmit path data delay, lower	WIS_delay_TX_min [15:0]	RO, MW
2.1804.15:0	Minimum WIS transmit path data delay, upper	WIS_delay_TX_min [31:16]	RO, MW

[a]RO = Read only, MW = Multi-word

45.2.2.22 TimeSync WIS receive path data delay (Registers 2.1805, 2.1806, 2.1807, 2.1808)

The TimeSync WIS receive path data delay register contains the maximum (Registers 2.1805, 2.1806, see Table 45–118) and minimum (Registers 2.1807, 2.1808, see Table 45–118) values of the receive path data delay. The receive path data delay is expressed in units of ns. The values contained in these registers are valid when the link is established, as indicated by bit 2 in Register 1.1 (see 45.2.1.2.4).

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Table 45–118—TimeSync WIS receive path data delay register

Bit(s)	Name	Description	R/W[a]
2.1805.15:0	Maximum WIS receive path data delay, lower	WIS_delay_RX_max [15:0]	RO, MW
2.1806.15:0	Maximum WIS receive path data delay, upper	WIS_delay_RX_max [31:16]	RO, MW
2.1807.15:0	Minimum WIS receive path data delay, lower	WIS_delay_RX_min [15:0]	RO, MW
2.1808.15:0	Minimum WIS receive path data delay, upper	WIS_delay_RX_min [31:16]	RO, MW

[a]RO = Read only, MW = Multi-word

45.2.3 PCS registers

The assignment of registers in the PCS is shown in Table 45–119.

Table 45–119—PCS registers

Register address	Register name	Subclause
3.0	PCS control 1	45.2.3.1
3.1	PCS status 1	45.2.3.2
3.2, 3.3	PCS device identifier	45.2.3.3
3.4	PCS speed ability	45.2.3.4
3.5, 3.6	PCS devices in package	45.2.3.5
3.7	PCS control 2	45.2.3.6
3.8	PCS status 2	45.2.3.7
3.9 through 3.13	Reserved	
3.14, 3.15	PCS package identifier	45.2.3.8
3.16 through 3.19	Reserved	
3.20	EEE control and capability	45.2.3.9
3.21	Reserved	
3.22	EEE wake error counter	45.2.3.10
3.23	Reserved	
3.24	10GBASE-X PCS status	45.2.3.11
3.25	10GBASE-X PCS test control	45.2.3.12
3.26 through 3.31	Reserved	
3.32	BASE-R and 10GBASE-T PCS status 1	45.2.3.13
3.33	BASE-R and 10GBASE-T PCS status 2	45.2.3.14
3.34 through 3.37	10GBASE-R PCS test pattern seed A	45.2.3.15
3.38 through 3.41	10GBASE-R PCS test pattern seed B	45.2.3.16
3.42	BASE-R PCS test pattern control	45.2.3.17
3.43	BASE-R PCS test pattern error counter	45.2.3.18

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Table 45–119—PCS registers *(continued)*

Register address	Register name	Subclause
3.44	BER high order counter	45.2.3.19
3.45	Errored blocks high order counter	45.2.3.20
3.46 through 3.49	Reserved	
3.50 through 3.53	Multi-lane BASE-R PCS alignment status 1 through 4	45.2.3.21
3.54 through 3.59	Reserved	
3.60	10P/2B capability	45.2.3.25
3.61	10P/2B PCS control	45.2.3.26
3.62, 3.63	10P/2B PME available	45.2.3.27
3.64, 3.65	10P/2B PME aggregate	45.2.3.28
3.66	10P/2B PAF RX error counter	45.2.3.29
3.67	10P/2B PAF small fragment counter	45.2.3.30
3.68	10P/2B PAF large fragments counter	45.2.3.31
3.69	10P/2B PAF overflow counter	45.2.3.32
3.70	10P/2B PAF bad fragments counter	45.2.3.33
3.71	10P/2B PAF lost fragments counter	45.2.3.34
3.72	10P/2B PAF lost starts of fragments counter	45.2.3.35
3.73	10P/2B PAF lost ends of fragments counter	45.2.3.36
3.74	10GBASE-PR and 10/1GBASE-PRX FEC ability	45.2.3.37
3.75	10GBASE-PR and 10/1GBASE-PRX FEC control	45.2.3.38
3.76, 3.77	10/1GBASE-PRX and 10GBASE-PR corrected FEC codewords counter	45.2.3.39
3.78, 3.79	10/1GBASE-PRX and 10GBASE-PR uncorrected FEC codewords counter	45.2.3.40
3.80	10GBASE-PR and 10/1GBASE-PRX BER monitor timer control	45.2.3.41
3.81	10GBASE-PR and 10/1GBASE-PRX BER monitor status	45.2.3.42
3.82	10GBASE-PR and 10/1GBASE-PRX BER monitor threshold control	45.2.3.43
3.83 through 3.199	Reserved	
3.200 through 3.219	BIP error counters, lanes 0 through 19	45.2.3.44
3.220 through 3.399	Reserved	
3.400 through 3.419	PCS lane mapping registers, lanes 0 through 19	45.2.3.46
3.420 through 3.1799	Reserved	
3.1800	TimeSync PCS capability	45.2.3.48
3.1801 through 3.1804	TimeSync PCS transmit path data delay	45.2.3.49
3.1805 through 3.1808	TimeSync PCS receive path data delay	45.2.3.50
3.1809 through 3.32767	Reserved	
3.32 768 through 3.65 535	Vendor specific	

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45.2.3.1 PCS control 1 register (Register 3.0)

The assignment of bits in the PCS control 1 register is shown in Table 45–120. The default value for each bit of the PCS control 1 register should be chosen so that the initial state of the device upon power up or reset is a normal operational state without management intervention.

Table 45–120—PCS control 1 register bit definitions

Bit(s)	Name	Description	R/W[a]
3.0.15	Reset	1 = PCS reset 0 = Normal operation	R/W SC
3.0.14	Loopback	1 = Enable loopback mode 0 = Disable loopback mode	R/W
3.0.13	Speed selection	13 6 1 1 = bits 5:2 select speed 0 x = unspecified x 0 = unspecified	R/W
3.0.12	Reserved	Value always 0	RO
3.0.11	Low power	1 = Low-power mode 0 = Normal operation	R/W
3.0.10	Clock stop enable	1 = The PHY may stop the clock during LPI 0 = Clock not stoppable	R/W
3.0.9:7	Reserved	Value always 0	RO
3.0.6	Speed selection	13 6 1 1 = bits 5:2 select speed 0 x = unspecified x 0 = unspecified	R/W
3.0.5:2	Speed selection	5 4 3 2 1 x x x = Reserved 0 1 1 x = Reserved 0 1 0 1 = Reserved 0 1 0 0 = 100 Gb/s 0 0 1 1 = 40 Gb/s 0 0 1 0 = 10/1 Gb/s 0 0 0 1 = 10PASS-TS/2BASE-TL 0 0 0 0 = 10 Gb/s	R/W
3.0.1:0	Reserved	Value always 0	RO

[a]RO = Read only, R/W = Read/Write, SC = Self-clearing

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45.2.3.1.1 Reset (3.0.15)

Resetting a PCS is accomplished by setting bit 3.0.15 to a one. This action shall set all PCS registers to their default states. As a consequence, this action may change the internal state of the PCS and the state of the physical link. This action may also initiate a reset in any other MMDs that are instantiated in the same package. This bit is self-clearing, and a PCS shall return a value of one in bit 3.0.15 when a reset is in progress and a value of zero otherwise. A PCS is not required to accept a write transaction to any of its

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registers until the reset process is completed. The reset process shall be completed within 0.5 s from the setting of bit 3.0.15. During a reset, a PCS shall respond to reads from register bits 3.0.15 and 3.8.15:14. All other register bits should be ignored.

NOTE—This operation may interrupt data communication.

45.2.3.1.2 Loopback (3.0.14)

When the 10GBASE-T or the 10GBASE-R mode of operation is selected for the PCS using the PCS type selection field (3.7.2:0), the PCS shall be placed in a loopback mode of operation when bit 3.0.14 is set to a one. When bit 3.0.14 is set to a one, the 10GBASE-R or 10GBASE-T PCS shall accept data on the transmit path and return it on the receive path. The specific behavior of the 10GBASE-R PCS during loopback is specified in 49.2. The specific behavior for the 10GBASE-T PCS during loopback is specified in 55.3.7.3. For all other port types, the PCS loopback functionality is not applicable and writes to this bit shall be ignored and reads from this bit shall return a value of zero.

The default value of bit 3.0.14 is zero.

NOTE—The signal path through the PCS that is exercised in the loopback mode of operation is implementation specific, but it is recommended that the signal path encompass as much of the PCS circuitry as is practical. The intention of providing this loopback mode of operation is to permit a diagnostic or self-test function to perform the transmission and reception of a PDU, thus testing the transmit and receive data paths. Other loopback signal paths may be enabled using loopback controls within other MMDs.

45.2.3.1.3 Low power (3.0.11)

A PCS may be placed into a low-power mode by setting bit 3.0.11 to a one. This action may also initiate a low-power mode in any other MMDs that are instantiated in the same package. The low-power mode is exited by resetting the PCS. The behavior of the PCS in transition to and from the low-power mode is implementation specific and any interface signals should not be relied upon. While in the low-power mode, the device shall, as a minimum, respond to management transactions necessary to exit the low-power mode. The default value of bit 3.0.11 is zero.

45.2.3.1.4 Clock stop enable (3.0.10)

If bit 3.0.10 is set to 1 then the PHY may stop the receive xMII clock while it is signaling LPI otherwise it shall keep the clock active. If the PHY does not support EEE capability or is not able to stop the receive clock then this bit has no effect (see 22.2.2.2, 35.2.2.10, and 46.3.2.4).

45.2.3.1.5 Speed selection (3.0.13, 3.0.6, 3.0.5:2)

Speed selection bits 3.0.13 and 3.0.6 shall both be written as a one. Any attempt to change the bits to an invalid setting shall be ignored. These two bits are set to one in order to make them compatible with Clause 22.

The speed of the PCS may be selected using bits 5 through 2. The speed abilities of the PCS are advertised in the PCS speed ability register. A PCS may ignore writes to the PCS speed selection bits that select speeds it has not advertised in the PCS speed ability register. It is the responsibility of the STA entity to ensure that mutually acceptable speeds are applied consistently across all the MMDs on a particular PHY.

The PCS speed selection defaults to a supported ability.

The speed selection bits 3.0.5:2, when set to 0001, select the use of the 10PASS-TS and 2BASE-TL PCS.

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45.2.3.2 PCS status 1 register (Register 3.1)

The assignment of bits in the PCS status 1 register is shown in Table 45–121. All the bits in the PCS status 1 register are read only; a write to the PCS status 1 register shall have no effect.

Table 45–121—PCS status 1 register bit definitions

Bit(s)	Name	Description	R/W[a]
3.1.15:12	Reserved	Value always 0	RO
3.1.11	Tx LPI received	1 = Tx PCS has received LPI 0 = LPI not received	RO/LH
3.1.10	Rx LPI received	1 = Rx PCS has received LPI 0 = LPI not received	RO/LH
3.1.9	Tx LPI indication	1 = Tx PCS is currently receiving LPI 0 = PCS is not currently receiving LPI	RO
3.1.8	Rx LPI indication	1 = Rx PCS is currently receiving LPI 0 = PCS is not currently receiving LPI	RO
3.1.7	Fault	1 = Fault condition detected 0 = No fault condition detected	RO
3.1.6	Clock stop capable	1 = The MAC may stop the clock during LPI 0 = Clock not stoppable	RO
3.1.5:3	Reserved	Value always 0	RO
3.1.2	PCS receive link status	1 = PCS receive link up 0 = PCS receive link down	RO/LL
3.1.1	Low-power ability	1 = PCS supports low-power mode 0 = PCS does not support low-power mode	RO
3.1.0	Reserved	Value always 0	RO

[a]RO = Read only, LL = Latching low, LH = Latching high

45.2.3.2.1 Transmit LPI received (3.1.11)

When read as a one, bit 3.1.11 indicates that the transmit PCS has received LPI signaling one or more times since the register was last read. When read as a zero, bit 3.1.11 indicates that the PCS has not received LPI signaling. This bit shall be implemented with latching high behavior.

45.2.3.2.2 Receive LPI received (3.1.10)

When read as a one, bit 3.1.10 indicates that the receive PCS has received LPI signaling one or more times since the register was last read. When read as a zero, bit 3.1.10 indicates that the PCS has not received LPI signaling. This bit shall be implemented with latching high behavior.

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45.2.3.2.3 Transmit LPI indication (3.1.9)

When read as a one, bit 3.1.9 indicates that the transmit PCS is currently receiving LPI signals. When read as a zero, bit 3.1.9 indicates that the PCS is not currently receiving LPI signals. The behavior if read during a state transition is undefined.

45.2.3.2.4 Receive LPI indication (3.1.8)

When read as a one, bit 3.1.8 indicates that the receive PCS is currently receiving LPI signals. When read as a zero, bit 3.1.8 indicates that the PCS is not currently receiving LPI signals. The behavior if read during a state transition is undefined.

45.2.3.2.5 Fault (3.1.7)

When read as a one, bit 3.1.7 indicates that the PCS has detected a fault condition on either the transmit or receive paths. When read as a zero, bit 3.1.7 indicates that the PCS has not detected a fault condition. For 10 Gb/s operation, bit 3.1.7 is read as a one when either of the fault bits (3.8.11, 3.8.10) located in register 3.8 are read as a one. For 10BASE-TS or 2BASE-TL operation, this bit shall become a one when any 10P/2B PCS registers indicate a fault (see 45.2.3.29 through 45.2.3.36).

45.2.3.2.6 Clock stop capable (3.1.6)

If bit 3.1.6 is set to one then the RS may stop the transmit xMII clock while it is signaling LPI otherwise it shall keep the clock active. If the RS does not support EEE capability or is not able to stop the transmit clock then this bit has no effect (see 22.2.2.6, 35.2.2.6, and 46.3.2.4).

45.2.3.2.7 PCS receive link status (3.1.2)

When read as a one, bit 3.1.2 indicates that the PCS receive link is up. When read as a zero, bit 3.1.2 indicates that the PCS receive link is down. When a 10/40/100GBASE-R, 10GBASE-W, or 10GBASE-T mode of operation is selected for the PCS using the PCS type selection field (3.7.2:0), this bit is a latching low version of bit 3.32.12. When a 10GBASE-X mode of operation is selected for the PCS using the PCS type selection field (3.7.2:0), this bit is a latching low version of bit 3.24.12. The receive link status bit shall be implemented with latching low behavior.

45.2.3.2.8 Low-power ability (3.1.1)

When read as a one, bit 3.1.1 indicates that the PCS supports the low-power feature. When read as a zero, bit 3.1.1 indicates that the PCS does not support the low-power feature. If a PCS supports the low-power feature then it is controlled using the low-power bit 3.0.11.

45.2.3.3 PCS device identifier (Registers 3.2 and 3.3)

Registers 3.2 and 3.3 provide a 32-bit value, which may constitute a unique identifier for a particular type of PCS. The identifier shall be composed of the 3rd through 24th bits of the Organizationally Unique Identifier (OUI) assigned to the device manufacturer by the IEEE, plus a six-bit model number, plus a four-bit revision number. A PCS may return a value of zero in each of the 32 bits of the PCS device identifier.

The format of the PCS device identifier is specified in 22.2.4.3.1.

45.2.3.4 PCS speed ability (Register 3.4)

The assignment of bits in the PCS speed ability register is shown in Table 45–122.

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Table 45–122—PCS speed ability register bit definitions

Bit(s)	Name	Description	R/W[a]
3.4.15:4	Reserved for future speeds	Value always 0	RO
3.4.3	100G capable	1 = PCS is capable of operating at 100 Gb/s 0 = PCS is not capable of operating at 100 Gb/s	RO
3.4.2	40G capable	1 = PCS is capable of operating at 40 Gb/s 0 = PCS is not capable of operating at 40 Gb/s	RO
3.4.1	10PASS-TS/2BASE-TL capable	1 = PCS is capable of operating as the 10P/2B PCS 0 = PCS is not capable of operating as the 10P/2B PCS	RO
3.4.0	10G capable	1 = PCS is capable of operating at 10 Gb/s 0 = PCS is not capable of operating at 10 Gb/s	RO

[a]RO = Read only

45.2.3.4.1 10G capable (3.4.0)

When read as a one, bit 3.4.0 indicates that the PCS is able to operate at a data rate of 10 Gb/s. When read as a zero, bit 3.4.0 indicates that the PCS is not able to operate at a data rate of 10 Gb/s.

45.2.3.4.2 10PASS-TS/2BASE-TL capable

When read as a one, this bit indicates that the PCS is able to operate as the 10PASS-TS/2BASE-TL PCS, as specified in Clause 61.

45.2.3.4.3 40G capable (3.4.2)

When read as a one, bit 3.4.2 indicates that the PCS is able to operate at a data rate of 40 Gb/s. When read as a zero, bit 3.4.2 indicates that the PCS is not able to operate at a data rate of 40 Gb/s.

45.2.3.4.4 100G capable (3.4.3)

When read as a one, bit 3.4.3 indicates that the PCS is able to operate at a data rate of 100 Gb/s. When read as a zero, bit 3.4.3 indicates that the PCS is not able to operate at a data rate of 100 Gb/s.

45.2.3.5 PCS devices in package (Registers 3.5 and 3.6)

The PCS devices in package registers are defined in Table 45–2.

45.2.3.6 PCS control 2 register (Register 3.7)

The assignment of bits in the PCS control 2 register is shown in Table 45–123. The default value for each bit of the PCS control 2 register should be chosen so that the initial state of the device upon power up or reset is a normal operational state without management intervention.

45.2.3.6.1 PCS type selection (3.7.2:0)

The PCS type shall be selected using bits 2 through 0. The PCS type abilities of the PCS are advertised in bits 3.8.5:0. A PCS shall ignore writes to the PCS type selection bits that select PCS types it has not advertised in the PCS status 2 register. It is the responsibility of the STA entity to ensure that mutually

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Table 45–123—PCS control 2 register bit definitions

Bit(s)	Name	Description	R/W[a]
3.7.15:3	Reserved	Value always 0	RO
3.7.2:0	PCS type selection	2 1 0 1 1 x = reserved 1 0 1 = Select 100GBASE-R PCS type 1 0 0 = Select 40GBASE-R PCS type 0 1 1 = Select 10GBASE-T PCS type 0 1 0 = Select 10GBASE-W PCS type 0 0 1 = Select 10GBASE-X PCS type 0 0 0 = Select 10GBASE-R PCS type	R/W

[a]RO = Read only, R/W = Read/Write

acceptable MMD types are applied consistently across all the MMDs on a particular PHY. The PCS type selection defaults to a supported ability.

45.2.3.7 PCS status 2 register (Register 3.8)

The assignment of bits in the PCS status 2 register is shown in Table 45–124. All the bits in the PCS status 2 register are read only; a write to the PCS status 2 register shall have no effect.

Table 45–124—PCS status 2 register bit definitions

Bit(s)	Name	Description	R/W[a]
3.8.15:14	Device present	15 14 1 0 = Device responding at this address 1 1 = No device responding at this address 0 1 = No device responding at this address 0 0 = No device responding at this address	RO
3.8.13:12	Reserved	Value always 0	RO
3.8.11	Transmit fault	1 = Fault condition on transmit path 0 = No fault condition on transmit path	RO/LH
3.8.10	Receive fault	1 = Fault condition on the receive path 0 = No fault condition on the receive path	RO/LH
3.8.9:6	Reserved	Value always 0	RO
3.8.5	100GBASE-R capable	1 = PCS is able to support 100GBASE-R PCS type 0 = PCS is not able to support 100GBASE-R PCS type	RO
3.8.4	40GBASE-R capable	1 = PCS is able to support 40GBASE-R PCS type 0 = PCS is not able to support 40GBASE-R PCS type	RO
3.8.3	10GBASE-T capable	1 = PCS is able to support 10GBASE-T PCS type 0 = PCS is not able to support 10GBASE-T PCS type	RO
3.8.2	10GBASE-W capable	1 = PCS is able to support 10GBASE-W PCS type 0 = PCS is not able to support 10GBASE-W PCS type	RO

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Table 45–124—PCS status 2 register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
3.8.1	10GBASE-X capable	1 = PCS is able to support 10GBASE-X PCS type 0 = PCS is not able to support 10GBASE-X PCS type	RO
3.8.0	10GBASE-R capable	1 = PCS is able to support 10GBASE-R PCS types 0 = PCS is not able to support 10GBASE-R PCS types	RO

[a]RO = Read only, LH = Latching high

45.2.3.7.1 Device present (3.8.15:14)

When read as <10>, bits 3.8.15:14 indicate that a device is present and responding at this register address. When read as anything other than <10>, bits 3.8.15:14 indicate that no device is present at this address or that the device is not functioning properly.

45.2.3.7.2 Transmit fault (3.8.11)

When read as a one, bit 3.8.11 indicates that the PCS has detected a fault condition on the transmit path. When read as a zero, bit 3.8.11 indicates that the PCS has not detected a fault condition on the transmit path. The transmit fault bit shall be implemented with latching high behavior.

The default value of bit 3.8.11 is zero.

45.2.3.7.3 Receive fault (3.8.10)

When read as a one, bit 3.8.10 indicates that the PCS has detected a fault condition on the receive path. When read as a zero, bit 3.8.10 indicates that the PCS has not detected a fault condition on the receive path. The receive fault bit shall be implemented with latching high behavior.

The default value of bit 3.8.10 is zero.

45.2.3.7.4 100GBASE-R capable (3.8.5)

When read as a one, bit 3.8.5 indicates that the PCS is able to support the 100GBASE-R PCS type. When read as a zero, bit 3.8.5 indicates that the PCS is not able to support the 100GBASE-R PCS type.

45.2.3.7.5 40GBASE-R capable (3.8.4)

When read as a one, bit 3.8.4 indicates that the PCS is able to support the 40GBASE-R PCS type. When read as a zero, bit 3.8.4 indicates that the PCS is not able to support the 40GBASE-R PCS type.

45.2.3.7.6 10GBASE-T capable (3.8.3)

When read as a one, bit 3.8.3 indicates that the PCS is able to support the 10GBASE-T PCS type. When read as a zero, bit 3.8.3 indicates that the PCS is not able to support the 10GBASE-T PCS type.

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45.2.3.7.7 10GBASE-W capable (3.8.2)

When read as a one, bit 3.8.2 indicates that the 64B/66B PCS is able to support operation in a 10GBASE-W PHY (that is, supports operation with a WIS). When read as a zero, bit 3.8.2 indicates that the 64B/66B PCS is not able to support operation with a WIS in a 10GBASE-W PHY.

NOTE—This bit does not indicate that the PCS is performing the functionality contained in the WIS. This bit indicates whether the 64B/66B PCS would be able to support a WIS if it were to be attached.

45.2.3.7.8 10GBASE-X capable (3.8.1)

When read as a one, bit 3.8.1 indicates that the PCS is able to support the 10GBASE-X PCS type. When read as a zero, bit 3.8.1 indicates that the PCS is not able to support the 10GBASE-X PCS type.

45.2.3.7.9 10GBASE-R capable (3.8.0)

When read as a one, bit 3.8.0 indicates that the PCS is able to support operation in a 10GBASE-R PHY. When read as a zero, bit 3.8.0 indicates that the PCS is not able to support operation in a 10GBASE-R PHY.

45.2.3.8 PCS package identifier (Registers 3.14 and 3.15)

Registers 3.14 and 3.15 provide a 32-bit value, which may constitute a unique identifier for a particular type of package that the PCS is instantiated within. The identifier shall be composed of the 3rd through 24th bits of the Organizationally Unique Identifier (OUI) assigned to the package manufacturer by the IEEE, plus a six-bit model number, plus a four-bit revision number. A PCS may return a value of zero in each of the 32 bits of the PCS package identifier.

A non-zero package identifier may be returned by one or more MMDs in the same package. The package identifier may be the same as the device identifier.

The format of the package identifier is specified in 22.2.4.3.1.

45.2.3.9 EEE control and capability (Register 3.20)

This register is used to indicate the capability of the PCS to support EEE functions for each PHY type. The assignment of bits in the EEE capability register is shown in Table 45–125.

Table 45–125—EEE control and capability register bit definitions

Bit(s)	Name	Description	R/W[a]
3.20.15:14	Reserved	Value always 0	RO
3.20.13	100GBASE-R deep sleep	1 = EEE deep sleep is supported for 100GBASE-R 0 = EEE deep sleep is not supported for 100GBASE-R	RO
3.20.12	100GBASE-R fast wake	1 = EEE fast wake is supported for 100GBASE-R 0 = EEE fast wake is not supported for 100GBASE-R	RO
3.20.11:10	Reserved	Value always 0	RO
3.20.9	40GBASE-R deep sleep	1 = EEE deep sleep is supported for 40GBASE-R 0 = EEE deep sleep is not supported for 40GBASE-R	RO
3.20.8	40GBASE-R fast wake	1 = EEE fast wake is supported for 40GBASE-R 0 = EEE fast wake is not supported for 40GBASE-R	RO

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Table 45–125—EEE control and capability register bit definitions *(continued)*

3.20.7	Reserved	Value always 0	RO
3.20.6	10GBASE-KR EEE	1 = EEE is supported for 10GBASE-KR 0 = EEE is not supported for 10GBASE-KR	RO
3.20.5	10GBASE-KX4 EEE	1 = EEE is supported for 10GBASE-KX4 0 = EEE is not supported for 10GBASE-KX4	RO
3.20.4	1000BASE-KX EEE	1 = EEE is supported for 1000BASE-KX 0 = EEE is not supported for 1000BASE-KX	RO
3.20.3	10GBASE-T EEE	1 = EEE is supported for 10GBASE-T 0 = EEE is not supported for 10GBASE-T	RO
3.20.2	1000BASE-T EEE	1 = EEE is supported for 1000BASE-T 0 = EEE is not supported for 1000BASE-T	RO
3.20.1	100BASE-TX EEE	1 = EEE is supported for 100BASE-TX 0 = EEE is not supported for 100BASE-TX	RO
3.20.0	LPI_FW	1 = Fast wake mode is used for LPI function 0 = Deep sleep is used for LPI function	R/W

[a]R/W = Read/Write, RO = Read only

45.2.3.9.1 100GBASE-R EEE deep sleep supported (3.20.13)

If the PCS supports EEE deep sleep operation for 100GBASE-R, this bit shall be set to a one; otherwise this bit shall be set to a zero.

45.2.3.9.2 100GBASE-R EEE fast wake supported (3.20.12)

If the PCS supports EEE fast wake operation for 100GBASE-R, this bit shall be set to a one; otherwise this bit shall be set to a zero.

45.2.3.9.3 40GBASE-R EEE deep sleep supported (3.20.9)

If the PCS supports EEE deep sleep operation for 40GBASE-R, as defined in 78.1, this bit shall be set to a one; otherwise this bit shall be set to a zero.

45.2.3.9.4 40GBASE-R EEE fast wake supported (3.20.8)

If the PCS supports EEE fast wake operation for 40GBASE-R, as defined in 78.1, this bit shall be set to a one; otherwise this bit shall be set to a zero.

45.2.3.9.5 10GBASE-KR EEE supported (3.20.6)

If the device supports EEE operation for 10GBASE-KR as defined in 72.1, this bit shall be set to one.

45.2.3.9.6 10GBASE-KX4 EEE supported (3.20.5)

If the device supports EEE operation for 10GBASE-KX4 as defined in 71.2, this bit shall be set to one.

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45.2.3.9.7 1000BASE-KX EEE supported (3.20.4)

If the device supports EEE operation for 1000BASE-KX as defined in 70.1, this bit shall be set to one.

45.2.3.9.8 10GBASE-T EEE supported (3.20.3)

If the device supports EEE operation for 10GBASE-T as defined in 55.1.3.3, this bit shall be set to one.

45.2.3.9.9 1000BASE-T EEE supported (3.20.2)

If the device supports EEE operation for 1000BASE-T as defined in 40.1.3, this bit shall be set to one.

45.2.3.9.10 100BASE-TX EEE supported (3.20.1)

If the device supports EEE operation for 100BASE-TX as defined in 24.1.1, this bit shall be set to one.

45.2.3.9.11 LPI_FW (3.20.0)

If the device supports fast wake as defined in 78.5, this bit selects fast wake or deep sleep operation. Setting 3.20.0 to one selects fast wake, setting to zero selects deep sleep. This bit is ignored by devices that do not support fast wake, and this bit defaults to one for devices that support fast wake.

45.2.3.10 EEE wake error counter (Register 3.22)

This register is used by PHY types that support EEE to count wake time faults where the PHY fails to complete its normal wake sequence within the time required for the specific PHY type. The definition of the fault event to be counted is defined for each PHY and may occur during a refresh or a wake-up as defined by the PHY. This 16-bit counter shall be reset to all zeros when the EEE wake error counter is read by the management function or upon execution of the PCS reset. This counter shall be held at all ones in the case of overflow.

45.2.3.11 10GBASE-X PCS status register (Register 3.24)

The assignment of bits in the 10GBASE-X PCS status register is shown in Table 45–126. All the bits in the 10GBASE-X PCS status register are read only; a write to the 10GBASE-X PCS status register shall have no effect. A PCS device that does not implement 10GBASE-X shall return a zero for all bits in the 10GBASE-X PCS status register. It is the responsibility of the STA management entity to ensure that a port type is supported by all MMDs before interrogating any of its status bits.

Table 45–126—10GBASE-X PCS status register bit definitions

Bit(s)	Name	Description	R/W[a]
3.24.15:13	Reserved	Value always 0	RO
3.24.12	10GBASE-X lane alignment status	1 = 10GBASE-X PCS receive lanes aligned 0 = 10GBASE-X PCS receive lanes not aligned	RO
3.24.11	Pattern testing ability	1 = 10GBASE-X PCS is able to generate test patterns 0 = 10GBASE-X PCS is not able to generate test patterns	RO
3.24.10:4	Reserved	Value always 0	RO

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Table 45–126—10GBASE-X PCS status register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
3.24.3	Lane 3 sync	1 = Lane 3 is synchronized 0 = Lane 3 is not synchronized	RO
3.24.2	Lane 2 sync	1 = Lane 2 is synchronized 0 = Lane 2 is not synchronized	RO
3.24.1	Lane 1 sync	1 = Lane 1 is synchronized 0 = Lane 1 is not synchronized	RO
3.24.0	Lane 0 sync	1 = Lane 0 is synchronized 0 = Lane 0 is not synchronized	RO

[a]RO = Read only

45.2.3.11.1 10GBASE-X receive lane alignment status (3.24.12)

When read as a one, bit 3.24.12 indicates that the 10GBASE-X PCS has synchronized and aligned all four receive lanes. When read as a zero, bit 3.24.12 indicates that the 10GBASE-X PCS has not synchronized and aligned all four receive lanes.

45.2.3.11.2 Pattern testing ability (3.24.11)

When read as a one, bit 3.24.11 indicates that the 10GBASE-X PCS is able to generate test patterns. When read as a zero, bit 3.24.11 indicates that the 10GBASE-X PCS is not able to generate test patterns. If the 10GBASE-X PCS is able to generate test patterns, then the functionality is controlled using the transmit test-pattern enable bit in register 3.25.

45.2.3.11.3 Lane 3 sync (3.24.3)

When read as a one, bit 3.24.3 indicates that the 10GBASE-X PCS receive lane 3 is synchronized. When read as a zero, bit 3.24.3 indicates that the 10GBASE-X PCS receive lane 3 is not synchronized.

45.2.3.11.4 Lane 2 sync (3.24.2)

When read as a one, bit 3.24.2 indicates that the 10GBASE-X PCS receive lane 2 is synchronized. When read as a zero, bit 3.24.2 indicates that the 10GBASE-X PCS receive lane 2 is not synchronized.

45.2.3.11.5 Lane 1 sync (3.24.1)

When read as a one, bit 3.24.1 indicates that the 10GBASE-X PCS receive lane 1 is synchronized. When read as a zero, bit 3.24.1 indicates that the 10GBASE-X PCS receive lane 1 is not synchronized.

45.2.3.11.6 Lane 0 sync (3.24.0)

When read as a one, bit 3.24.0 indicates that the 10GBASE-X PCS receive lane 0 is synchronized. When read as a zero, bit 3.24.0 indicates that the 10GBASE-X PCS receive lane 0 is not synchronized.

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45.2.3.12 10GBASE-X PCS test control register (Register 3.25)

The assignment of bits in the 10GBASE-X PCS test control register is shown in Table 45–127. The default value for each bit of the 10GBASE-X PCS test control register should be chosen so that the initial state of the device upon power up or reset is a normal operational state without management intervention.

Table 45–127—10GBASE-X PCS test control register bit definitions

Bit(s)	Name	Description	R/W[a]
3.25.15:3	Reserved	Value always 0	RO
3.25.2	Transmit test-pattern enable	1 = Transmit test pattern enabled 0 = Transmit test pattern not enabled	R/W
3.25.1:0	Test pattern select	1 0 1 1 = Reserved 1 0 = Mixed-frequency test pattern 0 1 = Low-frequency test pattern 0 0 = High-frequency test pattern	R/W

[a]RO = Read only, R/W = Read/Write

45.2.3.12.1 Transmit test-pattern enable (3.25.2)

When bit 3.25.2 is set to a one, pattern testing is enabled on the transmit path. When bit 3.25.2 is set to a zero, pattern testing is disabled on the transmit path. Pattern testing is optional, and the ability of the 10GBASE-X PCS to generate test patterns is advertised by the pattern testing ability bit in register 3.24. A 10GBASE-X PCS that does not support the generation of test patterns shall ignore writes to this bit and always return a value of zero. The default of bit 3.25.2 is zero.

45.2.3.12.2 Test pattern select (3.25.1:0)

The test pattern to be used when pattern testing is enabled using bit 3.25.2 is selected using bits 3.25.1:0. When bits 3.25.1:0 are set to <10>, the mixed-frequency test pattern shall be selected for pattern testing. When bits 3.25.1:0 are set to <01>, the low-frequency test pattern shall be selected for pattern testing. When bits 3.25.1:0 are set to <00>, the high-frequency test pattern shall be selected for pattern testing. The test patterns are defined in Annex 48A.

45.2.3.13 BASE-R and 10GBASE-T PCS status 1 register (Register 3.32)

The assignment of bits in the BASE-R and 10GBASE-T PCS status 1 register is shown in Table 45–128. All the bits in the BASE-R and 10GBASE-T PCS status 1 register are read only; a write to the BASE-R and 10GBASE-T PCS status 1 register shall have no effect. A PCS device that does not implement BASE-R or the 10GBASE-T shall return a zero for all bits in the BASE-R and 10GBASE-T PCS status 1 register. It is the responsibility of the STA management entity to ensure that a port type is supported by all MMDs before interrogating any of its status bits. The contents of register 3.32 are undefined when the BASE-R PCS or the 10GBASE-T PCS is operating in seed test-pattern mode, PRBS31 test-pattern mode, or PRBS9 test-pattern mode.

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Table 45–128—BASE-R and 10GBASE-T PCS status 1 register bit definitions

Bit(s)	Name	Description	R/W[a]
3.32.15:13	Reserved	Value always 0	RO
3.32.12	BASE-R and 10GBASE-T receive link status	1 = BASE-R or 10GBASE-T PCS receive link up 0 = BASE-R or 10GBASE-T PCS receive link down	RO
3.32.11:4	Reserved	Value always 0	RO
3.32.3	10GBASE-R PRBS9 pattern testing ability	1 = PCS is able to support PRBS9 pattern testing 0 = PCS is not able to support PRBS9 pattern testing	RO
3.32.2	10GBASE-R PRBS31 pattern testing ability	1 = PCS is able to support PRBS31 pattern testing 0 = PCS is not able to support PRBS31 pattern testing	RO
3.32.1	BASE-R and 10GBASE-T PCS high BER	1 = BASE-R or 10GBASE-T PCS reporting a high BER 0 = BASE-R or 10GBASE-T PCS not reporting a high BER	RO
3.32.0	BASE-R and 10GBASE-T PCS block lock	1 = BASE-R or 10GBASE-T PCS locked to received blocks 0 = BASE-R or 10GBASE-T PCS not locked to received blocks	RO

[a]RO = Read only

45.2.3.13.1 BASE-R and 10GBASE-T receive link status (3.32.12)

When read as a one, bit 3.32.12 indicates that the PCS is in a fully operational state. When read as a zero, bit 3.32.12 indicates that the PCS is not fully operational. This bit is a reflection of the PCS_status variable defined in 49.2.14.1 for 10GBASE-R, in 55.3.6.1 for 10GBASE-T and in 82.3.1 for 40/100GBASE-R.

45.2.3.13.2 PRBS9 pattern testing ability (3.32.3)

When read as a one, bit 3.32.3 indicates that the PCS is able to support PRBS9 pattern testing of its transmitter. When read as a zero, bit 3.32.3 indicates that the PCS is not able to support PRBS9 pattern testing of its transmitter. If the PCS is able to support PRBS9 pattern testing of its transmitter then the pattern generation is controlled using bit 3.42.6.

45.2.3.13.3 PRBS31 pattern testing ability (3.32.2)

When read as a one, bit 3.32.2 indicates that the PCS is able to support PRBS31 pattern testing. When read as a zero, bit 3.32.2 indicates that the PCS is not able to support PRBS31 pattern testing. If the PCS is able to support PRBS31 pattern testing then the pattern generation and checking is controlled using bits 3.42.5:4.

45.2.3.13.4 BASE-R and 10GBASE-T PCS high BER (3.32.1)

For BASE-R, when read as a one, bit 3.32.1 indicates that the 64B/66B receiver is detecting a BER of $\geq 10^{-4}$. When read as a zero, bit 3.32.1 indicates that the 64B/66B receiver is detecting a BER of $< 10^{-4}$. This bit is a direct reflection of the state of the hi_ber variable in the 64B/66B state diagram and is defined in 49.2.13.2.2 for 10GBASE-R and in 82.2.19.2.2 for 40/100GBASE-R.

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For 10GBASE-T, when read as a one, bit 3.32.1 indicates that the 64B/65B receiver is detecting a BER of ≥ 10^{-4}. When read as a zero, bit 3.32.1 indicates that the 64B/65B receiver is detecting a BER of < 10^{-4}. This bit is a direct reflection of the state of the hi_lfer variable in the 64B/65B state diagram and is defined in 55.3.6.1.

45.2.3.13.5 BASE-R and 10GBASE-T PCS block lock (3.32.0)

When read as a one, bit 3.32.0 indicates that the 64B/66B receiver for BASE-R or the 64B/65B receiver for the 10GBASE-T has block lock. When read as a zero, bit 3.32.0 indicates that the 64B/66B receiver for BASE-R or the 64B/65B receiver for the 10GBASE-T has not achieved block lock. This bit is a direct reflection of the state of the block_lock variable in the 64B/66B state diagram and is defined in 49.2.13.2.2 for 10GBASE-R and in 82.2.19.2.2 for 40/100GBASE-R. For the 10GBASE-T PCS the block_lock variable in the 64B/65B state diagram is defined in 55.3.2.3. For a multi-lane PCS, this bit indicates that the receiver has both block lock and alignment for all lanes and is identical to 3.50.12 (see 45.2.3.21.1).

45.2.3.14 BASE-R and 10GBASE-T PCS status 2 register (Register 3.33)

The assignment of bits in the BASE-R and 10GBASE-T PCS status 2 register is shown in Table 45–129. All the bits in the BASE-R and 10GBASE-T PCS status 2 register are read only; a write to the BASE-R and 10GBASE-T PCS status 2 register shall have no effect. A PCS device that does not implement BASE-R or 10GBASE-T shall return a zero for all bits in the BASE-R and 10GBASE-T PCS status 2 register. It is the responsibility of the STA management entity to ensure that a port type is supported by all MMDs before interrogating any of its status bits. The contents of register 3.33 are undefined when the BASE-R or the 10GBASE-T PCS is operating seed test-pattern mode, PRBS31 test-pattern mode, or PRBS9 test-pattern mode.

Table 45–129—BASE-R and 10GBASE-T PCS status 2 register bit definitions

Bit(s)	Name	Description	R/W[a]
3.33.15	Latched block lock	1 = BASE-R or 10GBASE-T PCS has block lock 0 = BASE-R or 10GBASE-T PCS does not have block lock	RO/LL
3.33.14	Latched high BER	1 = BASE-R or 10GBASE-T PCS has reported a high BER 0 = BASE-R or 10GBASE-T PCS has not reported a high BER	RO/LH
3.33.13:8	BER	BER counter	RO/NR
3.33.7:0	Errored blocks	Errored blocks counter	RO/NR

[a]RO = Read only, LL = Latching low, LH = Latching high, NR = Non Roll-over

45.2.3.14.1 Latched block lock (3.33.15)

When read as a one, bit 3.33.15 indicates that the 10/40/100GBASE-R or the 10GBASE-T PCS has achieved block lock. When read as a zero, bit 3.33.15 indicates that the 10/40/100GBASE-R or the 10GBASE-T PCS has lost block lock.

The latched block lock bit shall be implemented with latching low behavior.

This bit is a latching low version of the 10/40/100GBASE-R and 10GBASE-T PCS block lock status bit (3.32.0).

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45.2.3.14.2 Latched high BER (3.33.14)

When read as a one, bit 3.33.14 indicates that the 10/40/100GBASE-R or the 10GBASE-T PCS has detected a high BER. When read as a zero, bit 3.33.14 indicates that the 10/40/100GBASE-R or the 10GBASE-T PCS has not detected a high BER.

The latched high BER bit shall be implemented with latching high behavior.

This bit is a latching high version of the 10/40/100GBASE-R and 10GBASE-T PCS high BER status bit (3.32.1).

45.2.3.14.3 BER (3.33.13:8)

The BER counter is a six bit count as defined by the ber_count variable in 49.2.14.2 and 82.2.19.2.4 for 10/40/100GBASE-R and defined by the lfer_count variable in 55.3.6.2 for 10GBASE-T. These bits shall be reset to all zeros when the BASE-R and 10GBASE-T PCS status 2 register is read by the management function or upon execution of the PCS reset. If the BER high order counter, 3.44 (see 45.2.3.19) is not implemented then these bits shall be held at all ones in the case of overflow.

45.2.3.14.4 Errored blocks (3.33.7:0)

The errored blocks counter is an eight bit count defined by the errored_block_count counter specified in 49.2.14.2 for 10GBASE-R, in 82.3.1 for 40/100GBASE-R and defined by the errored_block_count variable in 55.3.6.2 for 10GBASE-T. These bits shall be reset to all zeros when the errored blocks count is read by the management function or upon execution of the PCS reset. If the Errored blocks high order counter, 3.45 (see 45.2.3.20) is not implemented then these bits shall be held at all ones in the case of overflow.

45.2.3.15 10GBASE-R PCS test pattern seed A (Registers 3.34 through 3.37)

The assignment of bits in the 10GBASE-R PCS test pattern seed A registers is shown in Table 45–130. This register is only required when the 10GBASE-R capability is supported. If both 10GBASE-R and 10GBASE-W capability is supported, then this register may either ignore writes and return zeros for reads when in 10GBASE-W mode or may function as defined for 10GBASE-R. For each seed register, seed bits are assigned to register bits in order with the lowest numbered seed bit for that register being assigned to register bit 0.

Table 45–130—10GBASE-R PCS test pattern seed A 0-3 register bit definitions

Bit(s)	Name	Description	R/W[a]
3.37.15:10	Reserved	Value always 0	RO
3.37.9:0	Test pattern seed A 3	Test pattern seed A bits 48-57	R/W
3.36.15:0	Test pattern seed A 2	Test pattern seed A bits 32-47	R/W
3.35.15:0	Test pattern seed A 1	Test pattern seed A bits 16-31	R/W
3.34.15:0	Test pattern seed A 0	Test pattern seed A bits 0-15	R/W

[a]RO = Read only, R/W = Read/Write

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The A seed for the pseudo random test pattern is held in registers 3.34 through 3.37. The test-pattern methodology is described in 49.2.8.

45.2.3.16 10GBASE-R PCS test pattern seed B (Registers 3.38 through 3.41)

The assignment of bits in the 10GBASE-R PCS test pattern seed B registers is shown in Table 45–131. This register is only required when the 10GBASE-R capability is supported. If both 10GBASE-R and 10GBASE-W capability is supported, then this register may either ignore writes and return zeros for reads when in 10GBASE-W mode or may function as defined for 10GBASE-R. For each seed register, seed bits are assigned to register bits in order with the lowest numbered seed bit for that register being assigned to register bit 0.

Table 45–131—10GBASE-R PCS test pattern seed B 0-3 register bit definitions

Bit(s)	Name	Description	R/W[a]
3.41.15:10	Reserved	Value always 0	RO
3.41.9:0	Test pattern seed B 3	Test pattern seed B bits 48-57	R/W
3.40.15:0	Test pattern seed B 2	Test pattern seed B bits 32-47	R/W
3.39.15:0	Test pattern seed B 1	Test pattern seed B bits 16-31	R/W
3.38.15:0	Test pattern seed B 0	Test pattern seed B bits 0-15	R/W

[a]RO = Read only, R/W = Read/Write

The B seed for the pseudo random test pattern is held in registers 3.38 through 3.41. The test-pattern methodology is described in 49.2.8.

45.2.3.17 BASE-R PCS test-pattern control register (Register 3.42)

The assignment of bits in the BASE-R PCS test-pattern control register is shown in Table 45–132. This register is only required when the BASE-R capability is supported. If both BASE-R and 10GBASE-W capability is supported, then this register may either ignore writes and return zeros for reads when in 10GBASE-W mode or may function as defined for BASE-R. PRBS9, PRBS31, pseudo random, and square wave test patterns are defined for 10GBASE-R PCS only. Scrambled idle test patterns are defined for 40/100GBASE-R PCS only. The test-pattern methodology is described in 49.2.8 and 82.2.11.

Table 45–132—BASE-R PCS test-pattern control register bit definitions

Bit(s)	Name	Description	R/W[a]
3.42.15:8	Reserved	Value always 0	RO
3.42.7	Scrambled idle test-pattern enable	1 = Enable scrambled idle test-pattern mode 0 = Disable scrambled idle test-pattern mode	R/W
3.42.6	10GBASE-R PRBS9 transmit test-pattern enable	1 = Enable PRBS9 test-pattern mode on the transmit path 0 = Disable PRBS9 test-pattern mode on the transmit path	R/W

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Table 45–132—BASE-R PCS test-pattern control register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
3.42.5	10GBASE-R PRBS31 receive test-pattern enable	1 = Enable PRBS31 test-pattern mode on the receive path 0 = Disable PRBS31 test-pattern mode on the receive path	R/W
3.42.4	10GBASE-R PRBS31 transmit test-pattern enable	1 = Enable PRBS31 test-pattern mode on the transmit path 0 = Disable PRBS31 test-pattern mode on the transmit path	R/W
3.42.3	Transmit test-pattern enable	1 = Enable transmit test pattern 0 = Disable transmit test pattern	R/W
3.42.2	Receive test-pattern enable	1 = Enable receive test-pattern testing 0 = Disable receive test-pattern testing	R/W
3.42.1	Test-pattern select	1 = Square wave test pattern 0 = Pseudo random test pattern	R/W
3.42.0	Data pattern select	1 = Zeros data pattern 0 = LF data pattern	R/W

[a]RO = Read only, R/W = Read/Write

45.2.3.17.1 Scrambled idle test-pattern enable (3.42.7)

When bit 3.42.7 is set to a one, scrambled idle pattern testing is enabled. When bit 3.42.7 is set to zero, scrambled idle pattern testing is disabled.

The default value for bit 3.42.3 is zero.

45.2.3.17.2 10GBASE-R PRBS9 transmit test-pattern enable (3.42.6)

If the PCS supports the optional PRBS9 pattern testing (indicated by bit 3.32.3), the mandatory transmit test-pattern enable bit (3.42.3) is not one, and the optional PRBS31 transmit test-pattern enable bit (3.42.4) is not one, then when bit 3.42.6 is set to one the PCS shall transmit PRBS9. When bit 3.42.6 is set to zero, the PCS shall not generate PRBS9. The PRBS9 test-pattern is specified in 68.6.1. The behavior of the PCS when in PRBS9 test-pattern mode is specified in Clause 49.

45.2.3.17.3 10GBASE-R PRBS31 receive test-pattern enable (3.42.5)

If the PCS supports the optional PRBS31 pattern testing advertised in bit 3.32.2 and the mandatory receive test-pattern enable bit (3.42.2) is not one, setting bit 3.42.5 to a one shall set the receive path of the PCS into the PRBS31 test-pattern mode. The number of errors received during a PRBS31 pattern test are recorded in register 3.43. Setting bit 3.42.5 to a zero shall disable the PRBS31 test-pattern mode on the receive path of the PCS. The behavior of the PCS when in PRBS31 test-pattern mode is specified in Clause 49.

45.2.3.17.4 10GBASE-R PRBS31 transmit test-pattern enable (3.42.4)

If the PCS supports the optional PRBS31 pattern testing advertised in bit 3.32.2 and the mandatory transmit test-pattern enable bit (3.42.3) is not one, then setting bit 3.42.4 to a one shall set the transmit path of the PCS into the PRBS31 test-pattern mode. Setting bit 3.42.4 to a zero shall disable the PRBS31 test-pattern mode on the transmit path of the PCS. The behavior of the PCS when in PRBS31 test-pattern mode is specified in Clause 49.

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45.2.3.17.5 Transmit test-pattern enable (3.42.3)

When bit 3.42.3 is set to a one, pattern testing is enabled on the transmit path. When bit 3.42.3 is set to a zero, pattern testing is disabled on the transmit path.

The default value for bit 3.42.3 is zero.

45.2.3.17.6 Receive test-pattern enable (3.42.2)

When bit 3.42.2 is set to a one, pattern testing is enabled on the receive path. When bit 3.42.2 is set to a zero, pattern testing is disabled on the receive path.

The default value for bit 3.42.2 is zero.

45.2.3.17.7 Test-pattern select (3.42.1)

When bit 3.42.1 is set to a one, the square wave test pattern is used for pattern testing. When bit 3.42.1 is set to a zero, the pseudo random test pattern is used for pattern testing.

The default value for bit 3.42.1 is zero.

45.2.3.17.8 Data pattern select (3.42.0)

When bit 3.42.0 is set to a one, the zeros data pattern is used for pattern testing. When bit 3.42.0 is set to a zero, the LF data pattern is used for pattern testing.

The default value for bit 3.42.0 is zero.

45.2.3.18 BASE-R PCS test-pattern error counter register (Register 3.43)

The assignment of bits in the BASE-R PCS test-pattern error counter register is shown in Table 45–133. This register is only required when the BASE-R capability is supported. If both BASE-R and 10GBASE-W capability is supported, then this register may either ignore writes and return zeros for reads when in 10GBASE-W mode, or may function as defined for BASE-R.

Table 45–133—BASE-R PCS test-pattern error counter register bit definitions

Bit(s)	Name	Description	R/W[a]
3.43.15:0	Test-pattern error counter	Error counter	RO

[a]RO = Read only

The test-pattern error counter is a sixteen bit counter that contains the number of errors received during a pattern test. These bits shall be reset to all zeros when the test-pattern error counter is read by the management function or upon execution of the PCS reset. These bits shall be held at all ones in the case of overflow. The test-pattern methodology is described in 49.2.12 and 82.2.11. This counter will count either block errors or bit errors dependent on the test mode (see 49.2.12).

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45.2.3.19 BER high order counter (Register 3.44)

The assignment of bits in the BER high order counter register is shown in Table 45–134. This register is mandatory when the 40/100GBASE-R capability is supported and optional for other PHY types that implement register 3.33.

Table 45–134—BER high order counter register bit definitions

Bit(s)	Name	Description	R/W[a]
3.44.15:0	BER high order	Bits 21:6 of BER counter	RO

[a]RO = Read only

Bits 15:0 of this register are concatenated with bits 13:8 of register 3.33 (see 45.2.3.14) to read the value of a twenty-two bit BER counter. When registers 3.44 and 3.33 are used to read the 22-bit counter value, the register 3.33 is read first (indicating the lower 6 bits). The remaining 16 bits shall be latched when register 3.33 is read and reads to register 3.44 return the latched value. The counter continues to function as defined in 45.2.3.14.3 regardless of the state of the latched register. The 22-bit counter shall be reset to all zeros when register 3.33 is read or upon PCS reset. The 22-bit counter shall be held at all ones in the case of overflow.

45.2.3.20 Errored blocks high order counter (Register 3.45)

The assignment of bits in the Errored blocks high order counter register is shown in Table 45–135. This register is mandatory when the 40/100GBASE-R capability is supported and optional for other PHY types that implement register 3.33. If this register is implemented then bit 3.45.15 shall be set to 1.

Table 45–135—Errored blocks high order counter register bit definitions

Bit(s)	Name	Description	R/W[a]
3.45.15	High order counter present	Always reads as 1 if this register is implemented	RO
3.45.14	Reserved	Value always 0	RO
3.45.13:0	Errored blocks high order	Bits 21:8 of errored blocks counter	RO

[a]RO = Read only

Bits 13:0 of this register are concatenated with bits 7:0 of register 3.33 (see 45.2.3.14) to read the value of a twenty-two bit errored blocks counter. When registers 3.45 and 3.33 are used to read the 22-bit counter value, the register 3.33 is read first (indicating the lower 8 bits). The remaining 14 bits shall be latched when register 3.33 is read and reads to register 3.45 return the latched value. The counter continues to function as defined in 45.2.3.14.4 regardless of the state of the latched register. The 22-bit counter shall be reset to all zeros when register 3.33 is read or upon PCS reset. The 22-bit counter shall be held at all ones in the case of overflow.

45.2.3.21 Multi-lane BASE-R PCS alignment status 1 register (Register 3.50)

The assignment of bits in the multi-lane BASE-R PCS alignment status 1 register is shown in Table 45–136. All the bits in the multi-lane BASE-R PCS alignment status 1 register are read only; a write to the multi-lane

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BASE-R PCS alignment status 1 register shall have no effect. A PCS device that does not implement multi-lane BASE-R PCS shall return a zero for all bits in the multi-lane BASE-R PCS alignment status 1 register. A device that implements multi-lane BASE-R PCS shall return a zero for all bits in the multi-lane BASE-R PCS alignment status 1 register that are not required for the PCS configuration. It is the responsibility of the STA management entity to ensure that a port type is supported by all MMDs before interrogating any of its status bits.

Table 45–136—Multi-lane BASE-R PCS alignment status 1 register bit definitions

Bit(s)	Name	Description	R/W[a]
3.50.15:13	Reserved	Value always 0	RO
3.50.12	PCS lane alignment status	1 = PCS receive lanes locked and aligned 0 = PCS receive lanes not locked and aligned	RO
3.50.11:8	Reserved	Value always 0	RO
3.50.7	Block 7 lock	1 = Lane 7 is locked 0 = Lane 7 is not locked	RO
3.50.6	Block 6 lock	1 = Lane 6 is locked 0 = Lane 6 is not locked	RO
3.50.5	Block 5 lock	1 = Lane 5 is locked 0 = Lane 5 is not locked	RO
3.50.4	Block 4 lock	1 = Lane 4 is locked 0 = Lane 4 is not locked	RO
3.50.3	Block 3 lock	1 = Lane 3 is locked 0 = Lane 3 is not locked	RO
3.50.2	Block 2 lock	1 = Lane 2 is locked 0 = Lane 2 is not locked	RO
3.50.1	Block 1 lock	1 = Lane 1 is locked 0 = Lane 1 is not locked	RO
3.50.0	Block 0 lock	1 = Lane 0 is locked 0 = Lane 0 is not locked	RO

[a]RO = Read only

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45.2.3.21.1 Multi-lane BASE-R PCS alignment status (3.50.12)

When read as a one, bit 3.50.12 indicates that the PCS has locked and aligned all receive lanes. When read as a zero, bit 3.50.12 indicates that the PCS has not locked and aligned all receive lanes.

45.2.3.21.2 Block 7 lock (3.50.7)

When read as a one, bit 3.50.7 indicates that the PCS receiver has achieved block lock for service interface lane 7. When read as a zero, bit 3.50.7 indicates that the PCS receiver lane 7 has not achieved block lock. This bit reflects the state of block_lock[7] (see 82.2.19.2.2).

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45.2.3.21.3 Block 6 lock (3.50.6)

When read as a one, bit 3.50.6 indicates that the PCS receiver has achieved block lock for service interface lane 6. When read as a zero, bit 3.50.6 indicates that the PCS receiver lane 6 has not achieved block lock. This bit reflects the state of block_lock[6] (see 82.2.19.2.2).

45.2.3.21.4 Block 5 lock (3.50.5)

When read as a one, bit 3.50.5 indicates that the PCS receiver has achieved block lock for service interface lane 5. When read as a zero, bit 3.50.5 indicates that the PCS receiver lane 5 has not achieved block lock. This bit reflects the state of block_lock[5] (see 82.2.19.2.2).

45.2.3.21.5 Block 4 lock (3.50.4)

When read as a one, bit 3.50.4 indicates that the PCS receiver has achieved block lock for service interface lane 4. When read as a zero, bit 3.50.4 indicates that the PCS receiver lane 4 has not achieved block lock. This bit reflects the state of block_lock[4] (see 82.2.19.2.2).

45.2.3.21.6 Block 3 lock (3.50.3)

When read as a one, bit 3.50.3 indicates that the PCS receiver has achieved block lock for service interface lane 3. When read as a zero, bit 3.50.3 indicates that the PCS receiver lane 3 has not achieved block lock. This bit reflects the state of block_lock[3] (see 82.2.19.2.2).

45.2.3.21.7 Block 2 lock (3.50.2)

When read as a one, bit 3.50.2 indicates that the PCS receiver has achieved block lock for service interface lane 2. When read as a zero, bit 3.50.2 indicates that the PCS receiver lane 2 has not achieved block lock. This bit reflects the state of block_lock[2] (see 82.2.19.2.2).

45.2.3.21.8 Block 1 lock (3.50.1)

When read as a one, bit 3.50.1 indicates that the PCS receiver has achieved block lock for service interface lane 1. When read as a zero, bit 3.50.1 indicates that the PCS receiver lane 1 has not achieved block lock. This bit reflects the state of block_lock[1] (see 82.2.19.2.2).

45.2.3.21.9 Block 0 lock (3.50.0)

When read as a one, bit 3.50.0 indicates that the PCS receiver has achieved block lock for service interface lane 0. When read as a zero, bit 3.50.0 indicates that the PCS receiver lane 0 has not achieved block lock. This bit reflects the state of block_lock[0] (see 82.2.19.2.2).

45.2.3.22 Multi-lane BASE-R PCS alignment status 2 register (Register 3.51)

The assignment of bits in the multi-lane BASE-R PCS alignment status 2 register is shown in Table 45–137. All the bits in the multi-lane BASE-R PCS alignment status 2 register are read only; a write to the multi-lane BASE-R PCS alignment status 2 register shall have no effect. A PCS device that does not implement multi-lane BASE-R PCS shall return a zero for all bits in the multi-lane BASE-R PCS alignment status 2 register. A device that implements multi-lane BASE-R PCS shall return a zero for all bits in the multi-lane BASE-R PCS alignment status 2 register that are not required for the PCS configuration. It is the responsibility of the STA management entity to ensure that a port type is supported by all MMDs before interrogating any of its status bits.

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Table 45–137—Multi-lane BASE-R PCS alignment status 2 register bit definitions

Bit(s)	Name	Description	R/W[a]
3.51.15:12	Reserved	Value always 0	RO
3.51.11	Block 19 lock	1 = Lane 19 is locked 0 = Lane 19 is not locked	RO
3.51.10	Block 18 lock	1 = Lane 18 is locked 0 = Lane 18 is not locked	RO
3.51.9	Block 17 lock	1 = Lane 17 is locked 0 = Lane 17 is not locked	RO
3.51.8	Block 16 lock	1 = Lane 16 is locked 0 = Lane 16 is not locked	RO
3.51.7	Block 15 lock	1 = Lane 15 is locked 0 = Lane 15 is not locked	RO
3.51.6	Block 14 lock	1 = Lane 14 is locked 0 = Lane 14 is not locked	RO
3.51.5	Block 13 lock	1 = Lane 13 is locked 0 = Lane 13 is not locked	RO
3.51.4	Block 12 lock	1 = Lane 12 is locked 0 = Lane 12 is not locked	RO
3.51.3	Block 11 lock	1 = Lane 11 is locked 0 = Lane 11 is not locked	RO
3.51.2	Block 10 lock	1 = Lane 10 is locked 0 = Lane 10 is not locked	RO
3.51.1	Block 9 lock	1 = Lane 9 is locked 0 = Lane 9 is not locked	RO
3.51.0	Block 8 lock	1 = Lane 8 is locked 0 = Lane 8 is not locked	RO

[a]RO = Read only

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45.2.3.22.1 Block 19 lock (3.51.11)

When read as a one, bit 3.51.11 indicates that the PCS receiver has achieved block lock for service interface lane 19. When read as a zero, bit 3.51.11 indicates that the PCS receiver lane 19 has not achieved block lock. This bit reflects the state of block_lock[19] (see 82.2.19.2.2).

45.2.3.22.2 Block 18 lock (3.51.10)

When read as a one, bit 3.51.10 indicates that the PCS receiver has achieved block lock for service interface lane 18. When read as a zero, bit 3.51.10 indicates that the PCS receiver lane 18 has not achieved block lock This bit reflects the state of block_lock[18] (see 82.2.19.2.2).

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45.2.3.22.3 Block 17 lock (3.51.9)

When read as a one, bit 3.51.9 indicates that the PCS receiver has achieved block lock for service interface lane 17. When read as a zero, bit 3.51.9 indicates that the PCS receiver lane 17 has not achieved block lock This bit reflects the state of block_lock[17] (see 82.2.19.2.2).

45.2.3.22.4 Block 16 lock (3.51.8)

When read as a one, bit 3.51.8 indicates that the PCS receiver has achieved block lock for service interface lane 16. When read as a zero, bit 3.51.8 indicates that the PCS receiver lane 16 has not achieved block lock This bit reflects the state of block_lock[16] (see 82.2.19.2.2).

45.2.3.22.5 Block 15 lock (3.51.7)

When read as a one, bit 3.51.7 indicates that the PCS receiver has achieved block lock for service interface lane 15. When read as a zero, bit 3.51.7 indicates that the PCS receiver lane 15 has not achieved block lock This bit reflects the state of block_lock[15] (see 82.2.19.2.2).

45.2.3.22.6 Block 14 lock (3.51.6)

When read as a one, bit 3.51.6 indicates that the PCS receiver has achieved block lock for service interface lane 14. When read as a zero, bit 3.51.6 indicates that the PCS receiver lane 14 has not achieved block lock This bit reflects the state of block_lock[14] (see 82.2.19.2.2).

45.2.3.22.7 Block 13 lock (3.51.5)

When read as a one, bit 3.51.5 indicates that the PCS receiver has achieved block lock for service interface lane 13. When read as a zero, bit 3.51.5 indicates that the PCS receiver lane 13 has not achieved block lock This bit reflects the state of block_lock[13] (see 82.2.19.2.2).

45.2.3.22.8 Block 12 lock (3.51.4)

When read as a one, bit 3.51.4 indicates that the PCS receiver has achieved block lock for service interface lane 12. When read as a zero, bit 3.51.4 indicates that the PCS receiver lane 12 has not achieved block lock This bit reflects the state of block_lock[12] (see 82.2.19.2.2).

45.2.3.22.9 Block 11 lock (3.51.3)

When read as a one, bit 3.51.3 indicates that the PCS receiver has achieved block lock for service interface lane 11. When read as a zero, bit 3.51.3 indicates that the PCS receiver lane 11 has not achieved block lock This bit reflects the state of block_lock[11] (see 82.2.19.2.2).

45.2.3.22.10 Block 10 lock (3.51.2)

When read as a one, bit 3.51.2 indicates that the PCS receiver has achieved block lock for service interface lane 10. When read as a zero, bit 3.51.2 indicates that the PCS receiver lane 10 has not achieved block lock This bit reflects the state of block_lock[10] (see 82.2.19.2.2).

45.2.3.22.11 Block 9 lock (3.51.1)

When read as a one, bit 3.51.1 indicates that the PCS receiver has achieved block lock for service interface lane 9. When read as a zero, bit 3.51.1 indicates that the PCS receiver lane 9 has not achieved block lock This bit reflects the state of block_lock[9] (see 82.2.19.2.2).

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45.2.3.22.12 Block 8 lock (3.51.0)

When read as a one, bit 3.51.0 indicates that the PCS receiver has achieved block lock for service interface lane 8. When read as a zero, bit 3.51.0 indicates that the PCS receiver lane 8 has not achieved block lock This bit reflects the state of block_lock[8] (see 82.2.19.2.2).

45.2.3.23 Multi-lane BASE-R PCS alignment status 3 register (Register 3.52)

The assignment of bits in the multi-lane BASE-R PCS alignment status 3 register is shown in Table 45–138. All the bits in the multi-lane BASE-R PCS alignment status 3 register are read only; a write to the multi-lane BASE-R PCS alignment status 3 register shall have no effect. A PCS device that does not implement multi-lane BASE-R PCS shall return a zero for all bits in the multi-lane BASE-R PCS alignment status 3 register. A device that implements multi-lane BASE-R PCS shall return a zero for all bits in the multi-lane BASE-R PCS alignment status 3 register that are not required for the PCS configuration. It is the responsibility of the STA management entity to ensure that a port type is supported by all MMDs before interrogating any of its status bits.

Table 45–138—Multi-lane BASE-R PCS alignment status 3 register bit definitions

Bit(s)	Name	Description	R/W[a]
3.52.15:8	Reserved	Value always 0	RO
3.52.7	Lane 7 aligned	1 = Lane 7 alignment marker is locked 0 = Lane 7 alignment marker is not locked	RO
3.52.6	Lane 6 aligned	1 = Lane 6 alignment marker is locked 0 = Lane 6 alignment marker is not locked	RO
3.52.5	Lane 5 aligned	1 = Lane 5 alignment marker is locked 0 = Lane 5 alignment marker is not locked	RO
3.52.4	Lane 4 aligned	1 = Lane 4 alignment marker is locked 0 = Lane 4 alignment marker is not locked	RO
3.52.3	Lane 3 aligned	1 = Lane 3 alignment marker is locked 0 = Lane 3 alignment marker is not locked	RO
3.52.2	Lane 2 aligned	1 = Lane 2 alignment marker is locked 0 = Lane 2 alignment marker is not locked	RO
3.52.1	Lane 1 aligned	1 = Lane 1 alignment marker is locked 0 = Lane 1 alignment marker is not locked	RO
3.52.0	Lane 0 aligned	1 = Lane 0 alignment marker is locked 0 = Lane 0 alignment marker is not locked	RO

[a]RO = Read only

45.2.3.23.1 Lane 7 aligned (3.52.7)

When read as a one, bit 3.52.7 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 7. When read as a zero, bit 3.52.7 indicates that the PCS receiver lane 7 has not achieved alignment marker lock. This bit reflects the state of am_lock[7] (see 82.2.19.2.2).

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45.2.3.23.2 Lane 6 aligned (3.52.6)

When read as a one, bit 3.52.6 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 6. When read as a zero, bit 3.52.6 indicates that the PCS receiver lane 6 has not achieved alignment marker lock. This bit reflects the state of am_lock[6] (see 82.2.19.2.2).

45.2.3.23.3 Lane 5 aligned (3.52.5)

When read as a one, bit 3.52.5 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 5. When read as a zero, bit 3.52.5 indicates that the PCS receiver lane 5 has not achieved alignment marker lock. This bit reflects the state of am_lock[5] (see 82.2.19.2.2).

45.2.3.23.4 Lane 4 aligned (3.52.4)

When read as a one, bit 3.52.4 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 4. When read as a zero, bit 3.52.4 indicates that the PCS receiver lane 4 has not achieved alignment marker lock. This bit reflects the state of am_lock[4] (see 82.2.19.2.2).

45.2.3.23.5 Lane 3 aligned (3.52.3)

When read as a one, bit 3.52.3 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 3. When read as a zero, bit 3.52.3 indicates that the PCS receiver lane 3 has not achieved alignment marker lock. This bit reflects the state of am_lock[3] (see 82.2.19.2.2).

45.2.3.23.6 Lane 2 aligned (3.52.2)

When read as a one, bit 3.52.2 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 2. When read as a zero, bit 3.52.2 indicates that the PCS receiver lane 2 has not achieved alignment marker lock. This bit reflects the state of am_lock[2] (see 82.2.19.2.2).

45.2.3.23.7 Lane 1 aligned (3.52.1)

When read as a one, bit 3.52.1 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 1. When read as a zero, bit 3.52.1 indicates that the PCS receiver lane 1 has not achieved alignment marker lock. This bit reflects the state of am_lock[1] (see 82.2.19.2.2).

45.2.3.23.8 Lane 0 aligned (3.52.0)

When read as a one, bit 3.52.0 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 0. When read as a zero, bit 3.52.0 indicates that the PCS receiver lane 0 has not achieved alignment marker lock. This bit reflects the state of am_lock[0] (see 82.2.19.2.2).

45.2.3.24 Multi-lane BASE-R PCS alignment status 4 register (Register 3.53)

The assignment of bits in the multi-lane BASE-R PCS alignment status 4 register is shown in Table 45–139. All the bits in the multi-lane BASE-R PCS alignment status 4 register are read only; a write to the multi-lane BASE-R PCS alignment status 4 register shall have no effect. A PCS device that does not implement multi-lane BASE-R PCS shall return a zero for all bits in the multi-lane BASE-R PCS alignment status 4 register. A device that implements multi-lane BASE-R PCS shall return a zero for all bits in the multi-lane BASE-R PCS alignment status 4 register that are not required for the PCS configuration. It is the responsibility of the STA management entity to ensure that a port type is supported by all MMDs before interrogating any of its status bits.

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Table 45–139—Multi-lane BASE-R PCS alignment status 4 register bit definitions

Bit(s)	Name	Description	R/W[a]
3.53.15:12	Reserved	Value always 0	RO
3.53.11	Lane 19 aligned	1 = Lane 19 alignment marker is locked 0 = Lane 19 alignment marker is not locked	RO
3.53.10	Lane 18 aligned	1 = Lane 18 alignment marker is locked 0 = Lane 18 alignment marker is not locked	RO
3.53.9	Lane 17 aligned	1 = Lane 17 alignment marker is locked 0 = Lane 17 alignment marker is not locked	RO
3.53.8	Lane 16 aligned	1 = Lane 16 alignment marker is locked 0 = Lane 16 alignment marker is not locked	RO
3.53.7	Lane 15 aligned	1 = Lane 15 alignment marker is locked 0 = Lane 15 alignment marker is not locked	RO
3.53.6	Lane 14 aligned	1 = Lane 14 alignment marker is locked 0 = Lane 14 alignment marker is not locked	RO
3.53.5	Lane 13 aligned	1 = Lane 13 alignment marker is locked 0 = Lane 13 alignment marker is not locked	RO
3.53.4	Lane 12 aligned	1 = Lane 12 alignment marker is locked 0 = Lane 12 alignment marker is not locked	RO
3.53.3	Lane 11 aligned	1 = Lane 11 alignment marker is locked 0 = Lane 11 alignment marker is not locked	RO
3.53.2	Lane 10 aligned	1 = Lane 10 alignment marker is locked 0 = Lane 10 alignment marker is not locked	RO
3.53.1	Lane 9 aligned	1 = Lane 9 alignment marker is locked 0 = Lane 9 alignment marker is not locked	RO
3.53.0	Lane 8 aligned	1 = Lane 8 alignment marker is locked 0 = Lane 8 alignment marker is not locked	RO

[a]RO = Read only

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45.2.3.24.1 Lane 19 aligned (3.53.11)

When read as a one, bit 3.53.11 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 19. When read as a zero, bit 3.53.11 indicates that the PCS receiver lane 19 has not achieved alignment marker lock. This bit reflects the state of am_lock[19] (see 82.2.19.2.2).

45.2.3.24.2 Lane 18 aligned (3.53.10)

When read as a one, bit 3.53.10 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 18. When read as a zero, bit 3.53.10 indicates that the PCS receiver lane 18 has not achieved alignment marker lock. This bit reflects the state of am_lock[18] (see 82.2.19.2.2).

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45.2.3.24.3 Lane 17 aligned (3.53.9)

When read as a one, bit 3.53.9 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 17. When read as a zero, bit 3.53.9 indicates that the PCS receiver lane 17 has not achieved alignment marker lock. This bit reflects the state of am_lock[17] (see 82.2.19.2.2).

45.2.3.24.4 Lane 16 aligned (3.53.8)

When read as a one, bit 3.53.8 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 16. When read as a zero, bit 3.53.8 indicates that the PCS receiver lane 16 has not achieved alignment marker lock. This bit reflects the state of am_lock[16] (see 82.2.19.2.2).

45.2.3.24.5 Lane 15 aligned (3.53.7)

When read as a one, bit 3.53.7 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 15. When read as a zero, bit 3.53.7 indicates that the PCS receiver lane 15 has not achieved alignment marker lock. This bit reflects the state of am_lock[15] (see 82.2.19.2.2).

45.2.3.24.6 Lane 14 aligned (3.53.6)

When read as a one, bit 3.53.6 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 14. When read as a zero, bit 3.53.6 indicates that the PCS receiver lane 14 has not achieved alignment marker lock. This bit reflects the state of am_lock[14] (see 82.2.19.2.2).

45.2.3.24.7 Lane 13 aligned (3.53.5)

When read as a one, bit 3.53.5 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 13. When read as a zero, bit 3.53.5 indicates that the PCS receiver lane 13 has not achieved alignment marker lock. This bit reflects the state of am_lock[13] (see 82.2.19.2.2).

45.2.3.24.8 Lane 12 aligned (3.53.4)

When read as a one, bit 3.53.4 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 12. When read as a zero, bit 3.53.4 indicates that the PCS receiver lane 12 has not achieved alignment marker lock. This bit reflects the state of am_lock[12] (see 82.2.19.2.2).

45.2.3.24.9 Lane 11 aligned (3.53.3)

When read as a one, bit 3.53.3 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 11. When read as a zero, bit 3.53.3 indicates that the PCS receiver lane 11 has not achieved alignment marker lock. This bit reflects the state of am_lock[11] (see 82.2.19.2.2).

45.2.3.24.10 Lane 10 aligned (3.53.2)

When read as a one, bit 3.53.2 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 10. When read as a zero, bit 3.53.2 indicates that the PCS receiver lane 10 has not achieved alignment marker lock. This bit reflects the state of am_lock[10] (see 82.2.19.2.2).

45.2.3.24.11 Lane 9 aligned (3.53.1)

When read as a one, bit 3.53.1 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 9. When read as a zero, bit 3.53.1 indicates that the PCS receiver lane 9 has not achieved alignment marker lock. This bit reflects the state of am_lock[9] (see 82.2.19.2.2).

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45.2.3.24.12 Lane 8 aligned (3.53.0)

When read as a one, bit 3.53.8 indicates that the PCS receiver has achieved alignment marker lock for service interface lane 0. When read as a zero, bit 3.53.8 indicates that the PCS receiver lane 0 has not achieved alignment marker lock. This bit reflects the state of am_lock[8] (see 82.2.19.2.2).

45.2.3.25 10P/2B capability register (3.60)

The 10P/2B capability register reports which functions are supported by the PCS. This register is present at the PCS layer for each PHY. The bit definitions of the 10P/2B capability register are shown in Table 45–140.

Table 45–140—10P/2B capability register bit definitions

Bit(s)	Name	Description	R/W[a]
3.60.15:13	Reserved	Value always 0	RO
3.60.12	PAF available	1 = PAF supported 0 = PAF not supported	RO
3.60.11	Remote PAF supported	1 = link partner supports PAF 0 = link partner does not support PAF	RO
3.60.10:0	Reserved	Value always 0	RO

[a]RO = Read only

45.2.3.25.1 PAF available (3.60.12)

This bit indicates that the PHY supports the PME aggregation function. The PHY sets this bit to a one when the capability is supported and zero otherwise. This bit reflects the signal PAF_available in 61.2.3.

45.2.3.25.2 Remote PAF supported (3.60.11)

This bit indicates that the remote link-partner PHY supports the PME aggregation function. The PHY sets this bit to a one when the capability is supported and zero otherwise. This bit does not accurately report the capability of the remote PCS until a remote discovery operation has been completed by the -O PHY. In this case, this bit is set if the "Ethernet bonding" NPar(2) bit is set in the capabilities exchange message received from the other device. See 61.4.7, which discusses use of G.994.1 to access remote registers.

45.2.3.26 10P/2B PCS control register (Register 3.61)

The assignment of bits in the 10P/2B PCS control register is shown in Table 45–141.

Table 45–141—10B/2B PCS control register bit definitions

Bit(s)	Name	Description	R/W[a]
3.61.15	MII receive during transmit	1 = MII can TX/RX simultaneously 0 = MII cannot TX/RX simultaneously (default)	R/W
3.61.14	TX_EN and CRS infer a collision	1 = MII uses TX_EN and CRS to infer a collision 0 = MII uses COL to indicate a collision (default)	R/W

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Table 45–141—10B/2B PCS control register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
3.61.13:1	Reserved	Value always 0	RO
3.61.0	PAF enable	1 = use PAF 0 = do not use PAF	O: R/W R: RO

[a]R/W = Read/Write, RO = Read only

45.2.3.26.1 MII receive during transmit (3.61.15)

This register bit is used to tell the PHY-MAC rate matching function if the MAC is capable of receiving frames from the PHY while the MAC is transmitting (i.e., sending frames to the PHY). The variable tx_rx_simultaneously for the PHY-MAC Rate-Matching function takes on the value of this bit as defined in 61.2.3.

45.2.3.26.2 TX_EN and CRS infer a collision (3.61.14)

This bit is set by the STA to tell the MAC-PHY rate matching function that the MAC-PHY interface does not have a separate collision signal but instead infers a collision when TX_EN and CRS are asserted simultaneously. The variable crs_and_tx_en_infer_col in the PHY-MAC Rate-Matching function takes on the value of this bit as in 61.2.3. This bit will default to a supported mode, and writes to unsupported modes will be ignored.

45.2.3.26.3 PAF enable (3.61.0)

Setting this bit to a one shall activate the PME aggregation function of the PCS when the link is established. Writes to this bit while link is up or initializing (see 45.2.1.15) or if the PAF is not supported shall be ignored. When link is established, handshake indicates the use of PAF to the -R PHY. This bit reflects the signal PAF_enable in 61.2.3.

45.2.3.27 10P/2B PME available (Registers 3.62 and 3.63)

The 10P/2B PME available registers are used to indicate which PMEs in the aggregation group are available to be attached to the queried PCS. A PME is marked as unavailable if the PME does not support PME aggregation or if the PME is currently marked to be aggregated with another PMD. For a device that does not support aggregation of multiple PMEs, a single bit of this register shall be set to one and all other bits cleared to zero.

These registers may be writeable for -R ports. For PMEs that may be accessed through more than one MII, the availability is limited such that no PME may be mapped to more than one MII prior to enabling the links. In this case, the reset state of the 10P/2B PME available registers shall reflect the capabilities of the device, the management entity should reset appropriate bits to meet the restriction described.

If the -R device is not capable of aggregating PMEs to multiple MIIs then these registers may be read only.

The 10P/2B PME available register shall be available per PCS. For example, a package implementing four PMEs and one MII would have only one set of 10P/2B PME available registers, addressed by a read or write to 3.62 and 3.63 on any of those PHYs.

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For more information, see 61.2.2.8.3.

The assignment of bits in the 10P/2B PME available registers is shown in Table 45–142.

Table 45–142—10P/2B PME available register bit definitions

Bit(s)	Name	Description	R/W[a]
3.62.15:0	PME [p = 31:16] available	For each bit in the sequence: 1 = PME[p] is available for aggregating 0 = PME[p] is unavailable	O: RO R: R/W
3.63.15:0	PME [p = 15:0] available	For each bit in the sequence: 1 = PME[p] is available for aggregating 0 = PME[p] is unavailable	O: RO R: R/W

[a]RO = Read only, R/W = Read/Write

45.2.3.28 10P/2B PME aggregate registers (Registers 3.64 and 3.65)

The 10P/2B PME aggregate registers are used to select PMEs for aggregation. Attempts to activate aggregation with an unavailable PME (see 45.2.3.27) are ignored. The PCS shall use PME aggregation if one or more bits are set to a one and if PME aggregation is supported.

The 10P/2B PME aggregate register shall be available per PCS. For example, a package implementing four PMEs and one MII would have only one set of 10P/2B PME aggregate registers, accessed by a read or write to 3.64, 3.65 on any of those PHYs.

Upon MMD reset, these registers shall be reset to all zeros.

For more information, see 61.2.2.8.3.

The assignment of bits for the 10P/2B PME aggregate registers is shown in Table 45–143.

Table 45–143—10P/2B PME aggregate register bit definitions

Bit(s)	Name	Description	R/W[a]
3.64.15:0	Aggregate with PME [p = 31:16]	For each bit in the sequence: 1 = activate aggregation with PME[p] 0 = deactivate aggregation with PME[p]	R/W
3.65.15:0	Aggregate with PME [p = 15:0]	For each bit in the sequence: 1 = activate aggregation with PME[p] 0 = deactivate aggregation with PME[p]	R/W

[a]R/W = Read/Write

45.2.3.29 10P/2B PAF RX error register (Register 3.66)

The 10P/2B PAF RX error register is a 16 bit counter that contains the number of fragments that have been received across the gamma interface with RxErr asserted. The corresponding signal, TC_PAF_RxErrorReceived, is defined in 61.2.3. This counter is inactive when the PAF is unsupported or

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disabled. Upon disabling the PAF, the register retains its previous value. These bits shall be reset to all zeros when the 10P/2B PAF RX error register is read by the management function or upon execution of the MMD reset. These bits shall be held at all ones in the case of overflow. The assignment of bits in the 10P/2B PAF RX error register is shown in Table 45–144.

Table 45–144—10P/2B PAF RX error register bit definitions

Bit(s)	Name	Description	R/W[a]
3.66.15:0	PAF RX errors[15:0]	The bytes of the counter	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.3.30 10P/2B PAF small fragments register (Register 3.67)

The 10P/2B PAF small fragments register is a 16 bit counter that contains the number of small fragments that have been received across the gamma interface. The corresponding signal, TC_PAF_FragmentTooSmall, is defined in 61.2.3. These bits shall be reset to all zeros when the register is read by the management function or upon execution of the MMD reset. This counter is inactive when the PAF is unsupported or disabled. Upon disabling the PAF, the register retains its previous value. These bits shall be held at all ones in the case of overflow. The assignment of bits in the 10P/2B PAF small fragment register is shown in Table 45–145.

Table 45–145—10P/2B PAF small fragments register bit definitions

Bit(s)	Name	Description	R/W[a]
3.67.15:0	PAF small fragments[15:0]	The bytes of the counter	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.3.31 10P/2B PAF large fragments register (Register 3.68)

The 10P/2B PAF large fragments register is a 16 bit counter that contains the number of large fragments that have been received across the gamma interface. The corresponding signal, TC_PAF_FragmentTooLarge, is defined in 61.2.3. These bits shall be reset to all zeros when the register is read by the management function or upon execution of the MMD reset. This counter is inactive when the PAF is unsupported or disabled. Upon disabling the PAF, the register retains its previous value. These bits shall be held at all ones in the case of overflow. The assignment of bits in the 10P/2B PAF large fragments register is shown in Table 45–146.

Table 45–146—10P/2B PAF large fragments register bit definitions

Bit(s)	Name	Description	R/W[a]
3.68.15:0	PAF large fragments[15:0]	The bytes of the counter	RO, NR

[a]RO = Read only, NR = Non Roll-over

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45.2.3.32 10P/2B PAF overflow register (Register 3.69)

The 10P/2B PAF overflow register is a 16 bit counter that contains the number of fragments that have been received across the gamma interface which would have caused the receive buffer to overflow. The corresponding signal, TC_PAF_Overflow, is defined in 61.2.3. These bits shall be reset to all zeros when the register is read by the management function or upon execution of the MMD reset. This counter is inactive when the PAF is unsupported or disabled. Upon disabling the PAF, the register retains its previous value. These bits shall be held at all ones in the case of overflow. The assignment of bits in the 10P/2B PAF overflow register is shown in Table 45–147.

Table 45–147—10P/2B PAF overflow register bit definitions

Bit(s)	Name	Description	R/W[a]
3.69.15:0	PAF overflow fragments[15:0]	The bytes of the counter	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.3.33 10P/2B PAF bad fragments register (Register 3.70)

The 10P/2B PAF bad fragments register is a 16 bit counter that contains the number of bad fragments that have been received across the gamma interface. The corresponding signal, TC_PAF_BadFragmentReceived, is defined in 61.2.3. These bits shall be reset to all zeros when the register is read by the management function or upon execution of the MMD reset. This counter is inactive when the PAF is unsupported or disabled. Upon disabling the PAF, the register retains its previous value. These bits shall be held at all ones in the case of overflow. The assignment of bits in the 10P/2B PAF bad fragments register is shown in Table 45–148.

Table 45–148—P10P/2B AF bad fragments register bit definitions

Bit(s)	Name	Description	R/W[a]
3.70.15:0	PAF bad fragments[15:0]	The bytes of the counter	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.3.34 10P/2B PAF lost fragments register (Register 3.71)

The 10P/2B PAF lost fragments register is a 16 bit counter that contains the number of gaps in the sequence of fragments that have been received across the gamma interface. The corresponding signal, TC_PAF_LostFragment, is defined in 61.2.3.

These bits shall be reset to all zeros when the register is read by the management function or upon execution of the MMD reset. This counter is inactive when the PAF is unsupported or disabled. Upon disabling the PAF, the register retains its previous value. These bits shall be held at all ones in the case of overflow. The assignment of bits in the 10P/2B PAF lost fragments register is shown in Table 45–149.

Table 45–149—10P/2B PAF lost fragments register bit definitions

Bit(s)	Name	Description	R/W[a]
3.71.15:0	PAF lost fragments[15:0]	The bytes of the counter	RO, NR

[a]RO = Read only, NR = Non Roll-over

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45.2.3.35 10P/2B PAF lost starts of fragments register (Register 3.72)

The 10P/2B PAF lost starts of fragments register is a 16-bit counter that contains the number of missing start of fragment indicators expected by the frame assembly function. The corresponding signal, TC_PAF_LostStart, is defined in 61.2.3. These bits shall be reset to all zeros when the register is read by the management function or upon execution of the MMD reset. This counter is inactive when the PAF is unsupported or disabled. Upon disabling the PAF, the register retains its previous value. These bits shall be held at all ones in the case of overflow. The assignment of bits in the 10P/2B PAF lost starts of fragments register is shown in Table 45–150.

Table 45–150—10P/2B PAF lost starts of fragments register bit definitions

Bit(s)	Name	Description	R/W[a]
3.72.15:0	PAF lost starts of fragments[15:0]	The bytes of the counter	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.3.36 10P/2B PAF lost ends of fragments register (Register 3.73)

The 10P/2B PAF lost ends of fragments register is a 16 bit counter that contains the number of missing end of fragment indicators expected by the frame assembly function. The corresponding signal, TC_PAF_LostEnd, is defined in 61.2.3. These bits shall be reset to all zeros when the register is read by the management function or upon execution of the MMD reset. This counter is inactive when the PAF is unsupported or disabled. Upon disabling the PAF, the register retains its previous value. These bits shall be held at all ones in the case of overflow. The assignment of bits in the 10P/2B PAF lost ends of fragments register is shown in Table 45–151.

Table 45–151—10P/2B PAF lost ends of fragments register bit definitions

Bit(s)	Name	Description	R/W[a]
3.73.15:0	PAF lost ends of fragments[15:0]	The bytes of the counter	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.3.37 10GBASE-PR and 10/1GBASE-PRX FEC ability register (Register 3.74)

The assignment of bits in the 10GBASE-PR and 10/1GBASE-PRX FEC ability register is shown in Table 45–152.

Table 45–152—10GBASE-PR and 10/1GBASE-PRX FEC ability register bit definitions

Bit(s)	Name	Description	R/W[a]
3.74.15:1	Reserved	Value always 0	RO
3.74.0	10 Gb/s FEC ability	A read of 1 in this bit indicates that the PCS supports the 10/1GBASE-PRX or 10GBASE-PR 10 Gb/s FEC (always reads as 1 for 10/1GBASE-PRX or 10GBASE-PR).	RO

[a]RO = Read only

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45.2.3.38 10GBASE-PR and 10/1GBASE-PRX FEC control register (Register 3.75)

The assignment of bits in the 10GBASE-PR FEC control register is shown in Table 45–153.

Table 45–153—10GBASE-PR and 10/1GBASE-PRX FEC control register bit definitions

Bit(s)	Name	Description	R/W[a]
3.75.15:2	Reserved	Value always 0	RO
3.75.1	Enable FEC error indication	A write of 1 to this bit configures the 10 Gb/s FEC decoder to indicate uncorrectable codeword errors to the higher layer. In a 10/1GBASE-PRX OLT, this bit is undefined.	R/W
3.75.0	10 Gb/s FEC enable	Always reads as 1 for 10/1GBASE-PRX or 10GBASE-PR since 10 Gb/s FEC is always enabled.	RO

[a]RO = Read only, R/W = Read/Write

45.2.3.38.1 FEC enable error indication (3.75.1)

This bit instructs the 10 Gb/s FEC decoder component of the 10GBASE-PR and 10/1GBASE-PRX PCS to indicate decoding errors to the upper layers (see 45.2.3.38 and 76.3.3.3).

When written as a one, the receiving PCS invalidates 66 bit blocks received in uncorrectable FEC codewords. As a consequence, the receiving MAC discards any packet which includes data that was received in an uncorrectable FEC codeword (even though the packet itself might or might not contain errors).

When written as a zero, the receiving PCS does not modify 66 bit blocks received in uncorrectable FEC codewords. As a consequence, the receiving MAC performs regular processing on a packet that includes data that was received in an uncorrectable FEC codeword (though the packet itself may contain errors which might or might not be detected by the MAC FCS)

45.2.3.38.2 10 Gb/s FEC Enable (3.75.0)

This bit indicates whether 10 Gb/s FEC is enabled in the 10GBASE-PR and 10/1GBASE-PRX PCS and always reads as one.

The register for enabling and disabling forward error correction in the 10/1GBASE-PRX upstream is specified in 45.2.8.3.

45.2.3.39 10/1GBASE-PRX and 10GBASE-PR corrected FEC codewords counter (Register 3.76, 3.77)

The assignment of bits in the 10/1GBASE-PRX and 10GBASE-PR corrected FEC codewords counter register is shown in Table 45–154. See 76.3.3.3.2 for a definition of this counter. These bits shall be reset to

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all zeros when the register is read by the management function or upon PCS reset. These bits shall be held at all ones in the case of overflow.

Table 45–154—10GBASE-PR corrected FEC codewords counter register bit definitions

Bit(s)	Name	Description	R/W[a]
3.76.15:0	corrected FEC codewords lower	corrected_FEC_codewords_counter[15:0]	RO, MW, NR
3.77.15:0	corrected FEC codewords upper	corrected_FEC_codewords_counter[31:16]	RO, MW, NR

[a]RO = Read only, MW = Multi-word, NR = Non Roll-over

45.2.3.40 10/1GBASE-PRX and 10GBASE-PR uncorrected FEC codewords counter (Register 3.78, 3.79)

The assignment of bits in the 10/1GBASE-PRX and 10GBASE-PR uncorrected FEC codewords counter register is shown in Table 45–155. See 76.3.3.3.2 for a definition of this counter. These bits shall be reset to all zeros when the register is read by the management function or upon PCS reset. These bits shall be held at all ones in the case of overflow.

Table 45–155—10GBASE-PR uncorrected FEC codewords counter register bit definitions

Bit(s)	Name	Description	R/W[a]
3.78.15:0	uncorrected FEC codewords lower	uncorrected_FEC_codewords_counter[15:0]	RO, MW, NR
3.79.15:0	uncorrected FEC codewords lower	uncorrected_FEC_codewords_counter[32:16]	RO, MW, NR

[a]RO = Read only, MW = Multi-word, NR = Non Roll-over

45.2.3.41 10GBASE-PR and 10/1GBASE-PRX BER monitor timer control register (Register 3.80)

The assignment of bits in the 10GBASE-PR and 10/1GBASE-PRX BER monitor timer control register is shown in Table 45–156. This register is defined only when 10GBASE-PR or 10/1GBASE-PRX ONU capability is supported. The 10G-EPON BER monitor is described in 76.3.3.4.

Table 45–156—10GBASE-PR and 10/1GBASE-PRX BER monitor timer control register bit definitions

Bit(s)	Name	Description	R/W[a]
3.80.7:0	10G-EPON BER monitor timer	Duration (in units of 5 microseconds) of the timer used by the 10G-EPON BER monitor function. Default value is 25 (i.e., 125 microseconds). A value of 0 indicates that the BER monitor function is disabled.	R/W

[a]R/W = Read/Write

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45.2.3.42 10GBASE-PR and 10/1GBASE-PRX BER monitor status (Register 3.81)

The assignment of bits in the 10GBASE-PR and 10/1GBASE-PRX BER monitor status register is shown in Table 45–157. This register is defined only when 10GBASE-PR or 10/1GBASE-PRX ONU capability is supported.

Table 45–157—10GBASE-PR and 10/1GBASE-PRX BER monitor status register bit definitions

Bit(s)	Name	Description	R/W[a]
3.81.7:2	Reserved	Value always 0	RO
3.81.1	Latched high BER	1 = 10GBASE-PR or 10/1GBASE-PRX PCS reported a high BER. 0 = 10GBASE-PR or 10/1GBASE-PRX PCS did not report a high BER.	RO, LH
3.81.0	high BER	1 = 10GBASE-PR or 10/1GBASE-PRX PCS reporting a high BER. 0 = 10GBASE-PR or 10/1GBASE-PRX PCS not reporting a high BER.	RO

[a]RO Read only, LH = Latching high

45.2.3.42.1 10GBASE-PR and 10/1GBASE-PRX PCS high BER (3.81.0)

In the 10GBASE-PR and 10/1GBASE-PRX PCS, when read as a one, bit 3.81.0 indicates that the receiver is detecting a BER greater than the configurable threshold (high BER state). When read as a zero, bit 3.81.0 indicates that the receiver is detecting a BER lower than the configurable threshold (low BER state). This bit mirrors the state of the hi_ber variable, defined in 76.3.3.4.

45.2.3.42.2 10GBASE-PR and 10/1GBASE-PRX PCS latched high BER (3.81.1)

In the 10GBASE-PR and 10/1GBASE-PRX PCS, when read as a one, bit 3.81.1 indicates that the receiver detected a BER greater than the configurable threshold (high BER state). When read as a zero, bit 3.81.1 indicates that the receiver detected BER lower than the configurable threshold (low BER state).

This bit is a latching high version of the 10GBASE-PR and 10/1GBASE-PRX high BER status bit (3.81.0).

45.2.3.43 10GBASE-PR and 10/1GBASE-PRX BER monitor threshold control (Register 3.82)

The assignment of bits in the 10GBASE-PR and 10/1GBASE-PRX BER monitor threshold control register is shown in Table 45–158. This register is defined only when 10GBASE-PR or 10/1GBASE-PRX ONU capability is supported. The 10G-EPON BER monitor is described in 76.3.3.4.

Table 45–158—10GBASE-PR and 10/1GBASE-PRX BER monitor threshold control register bit definitions

Bit(s)	Name	Description	R/W[a]
3.82.15:0	10G-EPON BER monitor threshold	Number of sync header errors within a timer interval that triggers a high BER condition for the 10G-EPON BER monitor function. Default value is 1600. A value of 0 indicates that the BER monitor function is disabled.	R/W

[a]R/W = Read/Write

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45.2.3.44 BIP error counter lane 0 (Register 3.200)

The assignment of bits in the BIP error counter lane 0 is shown in Table 45–159. The multi-lane PCS described in Clause 82 calculates a BIP value for each PCS lane (see 82.2.8, 82.2.15). Errors detected in PCS lane 0 are counted and shown in register 3.200.15:0. The 16-bit counter shall be reset to all zeros when register 3.200 is read or upon PCS reset. The 16-bit counter shall be held at all ones in the case of overflow.

Table 45–159—BIP error counter, lane 0 register bit definitions

Bit(s)	Name	Description	R/W[a]
3.200.15:0	BIP error counter, lane 0	Errors detected by BIP in PCS lane 0	RO

[a]RO = Read only

45.2.3.45 BIP error counter, lanes 1 through 19 (Registers 3.201 through 3.219)

The behavior of the BIP error counters, lanes 1 through 19 is identical to that described for PCS lane 0 in 45.2.3.44. Errors detected in each PCS lane are counted and shown in register bits 15:0 in the corresponding register. PCS lane 1 is shown in register 3.201; PCS lane 2 is shown in register 3.202; through register 3.219 for PCS lane 19.

45.2.3.46 Lane 0 mapping register (Register 3.400)

The assignment of bits in the Lane 0 mapping register is shown in Table 45–160. When the multi-lane PCS described in Clause 82 detects and locks the alignment marker for service interface lane 0, the detected PCS lane number is recorded in this register. The contents of the Lane 0 mapping register is valid when Lane 0 aligned bit (3.52.0) is set to one and is invalid otherwise.

Table 45–160—Lane 0 mapping register bit definitions

Bit(s)	Name	Description	R/W[a]
3.400.15:5	Reserved	Value always 0	RO
3.400.4:0	Lane 0 mapping	PCS lane received in service interface lane 0	RO

[a]RO = Read only

45.2.3.47 Lanes 1 through 19 mapping registers (Registers 3.401 through 3.419)

The definition of lanes 1 through 19 mapping registers is identical to that described for lane 0 in 45.2.3.46. The lane mapping for lane 1 is in register 3.401; lane 2 is in register 3.402; etc.

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45.2.3.48 TimeSync PCS capability (Register 3.1800)

The TimeSync PCS capability register (see Table 45–161) indicates the capability of the PCS to report the transmit and receive data delay, stored in registers 3.1801 through 3.1804 and 3.1805 through 3.1808, respectively.

Table 45–161—TimeSync PCS capability

Bit(s)	Name	Description	R/W[a]
3.1800.15:2	Reserved	Value always 0	RO
3.1800.1	TimeSync transmit path data delay	1 = PCS provides information on transmit path data delay in registers 3.1801 through 3.1804 0 = PCS does not provide information on transmit path data delay	RO
3.1800.0	TimeSync receive path data delay	1 = PCS provides information on receive path data delay in registers 3.1805 through 3.1808 0 = PCS does not provide information on receive path data delay	RO

[a]RO = Read only

45.2.3.49 TimeSync PCS transmit path data delay (Registers 3.1801, 3.1802, 3.1803, 3.1804)

The TimeSync PCS transmit path data delay register contains the maximum (Registers 3.1801, 3.1802, see Table 45–162) and minimum (Registers 3.1803, 3.1804, see Table 45–162) values of the transmit path data delay. The transmit path data delay is expressed in units of ns. The values contained in these registers are valid when the link is established, as indicated by bit 2.1 in Register 1.1 (see 45.2.1.2.4).

Table 45–162—TimeSync PCS transmit path data delay register

Bit(s)	Name	Description	R/W[a]
3.1801.15:0	Maximum PCS transmit path data delay, lower	PCS_delay_TX_max [15:0]	RO, MW
3.1802.15:0	Maximum PCS transmit path data delay, upper	PCS_delay_TX_max [31:16]	RO, MW
3.1803.15:0	Minimum PCS transmit path data delay, lower	PCS_delay_TX_min [15:0]	RO, MW
3.1804.15:0	Minimum PCS transmit path data delay, upper	PCS_delay_TX_min [31:16]	RO, MW

[a]RO = Read only, MW = Multi-word

45.2.3.50 TimeSync PCS receive path data delay (Registers 3.1805, 3.1806, 3.1807, 3.1808)

The TimeSync PCS receive path data delay register contains the maximum (Registers 3.1805, 3.1806, see Table 45–163) and minimum (Registers 3.1807, 3.1808, see Table 45–163) values of the receive path data

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delay. The receive path data delay is expressed in units of ns. The values contained in these registers are valid when the link is established, as indicated by bit 2 in Register 1.1 (see 45.2.1.2.4).

Table 45–163—TimeSync PCS receive path data delay register

Bit(s)	Name	Description	R/W[a]
3.1805.15:0	Maximum PCS receive path data delay, lower	PCS_delay_RX_max [15:0]	RO, MW
3.1806.15:0	Maximum PCS receive path data delay, upper	PCS_delay_RX_max [31:16]	RO, MW
3.1807.15:0	Minimum PCS receive path data delay, lower	PCS_delay_RX_min [15:0]	RO, MW
3.1808.15:0	Minimum PCS receive path data delay, upper	PCS_delay_RX_min [31:16]	RO, MW

[a]RO = Read only, MW = Multi-word

45.2.4 PHY XS registers

The assignment of registers in the PHY XS is shown in Table 45–164.

Table 45–164—PHY XS registers

Register address	Register name	Subclause
4.0	PHY XS control 1	45.2.4.1
4.1	PHY XS status 1	45.2.4.2
4.2, 4.3	PHY XS device identifier	45.2.4.3
4.4	PHY XS speed ability	45.2.4.4
4.5, 4.6	PHY XS devices in package	45.2.4.5
4.7	Reserved	
4.8	PHY XS status 2	45.2.4.6
4.9 through 4.13	Reserved	
4.14, 4.15	PHY XS package identifier	45.2.4.7
4.16 through 4.19	Reserved	
4.20	EEE capability	45.2.4.8
4.21	Reserved	
4.22	EEE wake error counter	45.2.4.9
4.23	Reserved	
4.24	10G PHY XGXS lane status	45.2.4.10
4.25	10G PHY XGXS test control	45.2.4.11
4.26 through 4.1799	Reserved	
4.1800	TimeSync PHY XS capability	45.2.4.12
4.1801 through 4.1804	TimeSync PHY XS transmit path data delay	45.2.4.13
4.1805 through 4.1808	TimeSync PHY XS receive path data delay	45.2.4.14

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Table 45–164—PHY XS registers *(continued)*

Register address	Register name	Subclause
4.1809 through 4.32767	Reserved	
4.32 768 through 4.65 535	Vendor specific	

45.2.4.1 PHY XS control 1 register (Register 4.0)

The assignment of bits in the PHY XS control 1 register is shown in Table 45–165. The default value for each bit of the PHY XS control 1 register should be chosen so that the initial state of the device upon power up or reset is a normal operational state without management intervention.

Table 45–165—PHY XS control 1 register bit definitions

Bit(s)	Name	Description	R/W[a]
4.0.15	Reset	1 = PHY XS reset 0 = Normal operation	R/W SC
4.0.14	Loopback	1 = Enable loopback mode 0 = Disable loopback mode	R/W
4.0.13	Speed selection	1 = Operation at 10 Gb/s and above 0 = Unspecified	R/W
4.0.12	Reserved	Value always 0	RO
4.0.11	Low power	1 = Low-power mode 0 = Normal operation	R/W
4.0.10	Clock stop enable	1 = The PHY XS may stop the clock during LPI 0 = Clock not stoppable	R/W
4.0.9	XAUI stop enable	1 = The PHY XS may stop XAUI signals during LPI 0 = XAUI not stoppable	R/W
4.0.8:7	Reserved	Value always 0	RO
4.0.6	Speed selection	1 = Operation at 10 Gb/s and above 0 = Unspecified	R/W
4.0.5:2	Speed selection	5 4 3 2 1 x x x = Reserved x 1 x x = Reserved x x 1 x = Reserved 0 0 0 1 = Reserved 0 0 0 0 = 10 Gb/s	R/W
4.0.1:0	Reserved	Value always 0	RO

[a]R/W = Read/Write, SC = Self-clearing, RO = Read only

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45.2.4.1.1 Reset (4.0.15)

Resetting a PHY XS is accomplished by setting bit 4.0.15 to a one. This action shall set all PHY XS registers to their default states. As a consequence, this action may change the internal state of the PHY XS and the state of the physical link. This action may also initiate a reset in any other MMDs that are instantiated in the same package. This bit is self-clearing, and a PHY XS shall return a value of one in bit 4.0.15 when a reset is in progress and a value of zero otherwise. A PHY XS is not required to accept a write transaction to any of its registers until the reset process is completed. The reset process shall be completed within 0.5 s from the setting of bit 4.0.15. During a reset, a PHY XS shall respond to reads from register bits 4.0.15 and 4.8.15:14. All other register bits should be ignored.

NOTE—This operation may interrupt data communication.

45.2.4.1.2 Loopback (4.0.14)

The PHY XS shall be placed in a loopback mode of operation when bit 4.0.14 is set to a one. When bit 4.0.14 is set to a one, the PHY XS shall accept data on the receive path and return it on the transmit path. The direction of the loopback path for the PHY XS is opposite to all other MMD loopbacks.

The loopback function is optional. A device's ability to perform the loopback function is advertised in the loopback ability bit of the related speed-dependent status register. A PHY XS that is unable to perform the loopback function shall ignore writes to this bit and return a value of zero when read. For 10 Gb/s operation, the loopback functionality is detailed in 48.3.3 and the loopback ability bit is specified in the 10G PHY XGXS Lane status register.

The default value of bit 4.0.14 is zero.

NOTE—The signal path through the PHY XS that is exercised in the loopback mode of operation is implementation specific, but it is recommended that the signal path encompass as much of the PHY XS circuitry as is practical. The intention of providing this loopback mode of operation is to permit a diagnostic or self-test function to perform the transmission and reception of a PDU, thus testing the transmit and receive data paths. Other loopback signal paths may be enabled using loopback controls within other MMDs.

45.2.4.1.3 Low power (4.0.11)

A PHY XS may be placed into a low-power mode by setting bit 4.0.11 to a one. This action may also initiate a low-power mode in any other MMDs that are instantiated in the same package. The low-power mode is exited by resetting the PHY XS. The behavior of the PHY XS in transition to and from the low-power mode is implementation specific and any interface signals should not be relied upon. While in the low-power mode, the device shall, as a minimum, respond to management transactions necessary to exit the low-power mode. The default value of bit 4.0.11 is zero.

45.2.4.1.4 Clock stop enable (4.0.10)

If bit 4.0.10 is set to 1, then the PHY XS may stop the transmit direction xMII clock while it is signaling LPI, otherwise it shall keep the clock active. If the PHY XS does not support EEE capability or is not able to stop the transmit clock, then this bit has no effect (see 46.3.2.4).

45.2.4.1.5 XAUI stop enable (4.0.9)

If bit 4.0.9 is set to 1, then the PHY XS may stop signaling on the XAUI in the receive direction during LPI, otherwise the PHY XS shall keep the XAUI signals active. If the PHY XS does not support EEE capability or is not able to stop the receive path XAUI signals, then this bit has no effect.

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45.2.4.1.6 Speed selection (4.0.13, 4.0.6, 4.0.5:2)

Speed selection bits 4.0.13 and 4.0.6 shall both be written as a one. Any attempt to change the bits to an invalid setting shall be ignored. These two bits are set to one in order to make them compatible with Clause 22.

The speed of the PHY XS may be selected using bits 5 through 2. The speed abilities of the PHY XS are advertised in the PHY XS speed ability register. A PHY XS may ignore writes to the PHY XS speed selection bits that select speeds it has not advertised in the PHY XS speed ability register. It is the responsibility of the STA entity to ensure that mutually acceptable speeds are applied consistently across all the MMDs on a particular PHY.

The PHY XS speed selection defaults to a supported ability.

45.2.4.2 PHY XS status 1 register (Register 4.1)

The assignment of bits in the PHY XS status 1 register is shown in Table 45–166. All the bits in the PHY XS status 1 register are read only; a write to the PHY XS status 1 register shall have no effect.

Table 45–166—PHY XS status 1 register bit definitions

Bit(s)	Name	Description	R/W[a]
4.1.15:12	Reserved	Value always 0	RO
4.1.11	Tx LPI received	1 = Tx PHY XS has received LPI 0 = LPI not received	RO/LH
4.1.10	Rx LPI received	1 = Rx PHY XS has received LPI 0 = LPI not received	RO/LH
4.1.9	Tx LPI indication	1 = Tx PHY XS is currently receiving LPI 0 = PCS is not currently receiving LPI	RO
4.1.8	Rx LPI indication	1 = Rx PHY XS is currently receiving LPI 0 = PCS is not currently receiving LPI	RO
4.1.7	Fault	1 = Fault condition detected 0 = No fault condition detected	RO
4.1.6	Clock stop capable	1 = The attached PHY may stop the clock during LPI 0 = Clock not stoppable	RO
4.1.5:3	Reserved	Value always 0	RO
4.1.2	PHY XS transmit link status	1 = The PHY XS transmit link is up 0 = The PHY XS transmit link is down	RO/LL
4.1.1	Low-power ability	1 = PHY XS supports low-power mode 0 = PHY XS does not support low-power mode	RO
4.1.0	Reserved	Value always 0	RO

[a]RO = Read only, LL = Latching low, LH = Latching high

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45.2.4.2.1 Transmit LPI received (4.1.11)

When read as a one, bit 4.1.11 indicates that the transmit PHY XS has received LPI signaling one or more times since the register was last read. When read as a zero, bit 4.1.11 indicates that the PHY XS has not received LPI signaling. This bit shall be implemented with latching high behavior.

45.2.4.2.2 Receive LPI received (4.1.10)

When read as a one, bit 4.1.10 indicates that the receive PHY XS has received LPI signaling one or more times since the register was last read. When read as a zero, bit 4.1.10 indicates that the PHY XS has not received LPI signaling. This bit shall be implemented with latching high behavior.

45.2.4.2.3 Transmit LPI indication (4.1.9)

When read as a one, bit 4.1.9 indicates that the transmit PHY XS is currently receiving LPI signals. When read as a zero, bit 4.1.9 indicates that the PHY XS is not currently receiving LPI signals. The behavior if read during a state transition is undefined.

45.2.4.2.4 Receive LPI indication (4.1.8)

When read as a one, bit 4.1.8 indicates that the receive PHY XS is currently receiving LPI signals. When read as a zero, bit 4.1.8 indicates that the PHY XS is not currently receiving LPI signals. The behavior if read during a state transition is undefined.

45.2.4.2.5 Fault (4.1.7)

When read as a one, bit 4.1.7 indicates that the PHY XS has detected a fault condition on either the transmit or receive paths. When read as a zero, bit 4.1.7 indicates that the PHY XS has not detected a fault condition. Bit 4.1.7 is set to a one when either of the fault bits (4.8.11, 4.8.10) located in register 4.8 are set to a one.

45.2.4.2.6 Clock stop capable (4.1.6)

If bit 4.1.6 is set to one then the PHY XS is indicating that the attached PHY is permitted to stop the receive direction xMII clock while it is signaling LPI. If the bit is set to zero then the PHY XS is indicating that the attached PHY is not permitted to stop the receive xMII clock while it is signaling LPI. If the attached PHY does not support EEE capability or is not able to stop the receive direction xMII clock then this bit has no effect (see 46.3.2.4).

45.2.4.2.7 PHY XS transmit link status (4.1.2)

When read as a one, bit 4.1.2 indicates that the PHY XS transmit link is aligned. When read as a zero, bit 4.1.2 indicates that the PHY XS transmit link is not aligned. The transmit link status bit shall be implemented with latching low behavior.

For 10 Gb/s operation, bit 4.1.2 is a latching low version of bit 4.24.12.

45.2.4.2.8 Low-power ability (4.1.1)

When read as a one, bit 4.1.1 indicates that the PHY XS supports the low-power feature. When read as a zero, bit 4.1.1 indicates that the PHY XS does not support the low-power feature. If a PHY XS supports the low-power feature then it is controlled using the low-power bit in the PHY XS control register.

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45.2.4.3 PHY XS device identifier (Registers 4.2 and 4.3)

Registers 4.2 and 4.3 provide a 32-bit value, which may constitute a unique identifier for a PHY XS. The identifier shall be composed of the 3rd through 24th bits of the Organizationally Unique Identifier (OUI) assigned to the device manufacturer by the IEEE, plus a six-bit model number, plus a four-bit revision number. A PHY XS may return a value of zero in each of the 32 bits of the PHY XS device identifier.

The format of the PHY XS device identifier is specified in 22.2.4.3.1.

45.2.4.4 PHY XS speed ability (Register 4.4)

The assignment of bits in the PHY XS speed ability register is shown in Table 45–167.

Table 45–167—PHY XS speed ability register bit definitions

Bit(s)	Name	Description	R/W[a]
4.4.15:1	Reserved for future speeds	Value always 0	RO
4.4.0	10G capable	1 = PHY XS is capable of operating at 10 Gb/s 0 = PHY XS is not capable of operating at 10 Gb/s	RO

[a]RO = Read only

45.2.4.4.1 10G capable (4.4.0)

When read as a one, bit 4.4.0 indicates that the PHY XS is able to operate at a data rate of 10 Gb/s. When read as a zero, bit 4.4.0 indicates that the PHY XS is not able to operate at a data rate of 10 Gb/s.

45.2.4.5 PHY XS devices in package (Registers 4.5 and 4.6)

The PHY XS devices in package registers are defined in Table 45–2.

45.2.4.6 PHY XS status 2 register (Register 4.8)

The assignment of bits in the PHY XS status 2 register is shown in Table 45–168. All the bits in the PHY XS status 2 register are read only; a write to the PHY XS status 2 register shall have no effect.

Table 45–168—PHY XS status 2 register bit definitions

Bit(s)	Name	Description	R/W[a]
4.8.15:14	Device present	15 14 1 0 = Device responding at this address 1 1 = No device responding at this address 0 1 = No device responding at this address 0 0 = No device responding at this address	RO
4.8.13:12	Reserved	Value always 0	RO
4.8.11	Transmit fault	1 = Fault condition on transmit path 0 = No fault condition on transmit path	RO/LH

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Table 45–168—PHY XS status 2 register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
4.8.10	Receive fault	1 = Fault condition on receive path 0 = No fault condition on receive path	RO/LH
4.8.9:0	Reserved	Value always 0	RO

[a]RO = Read only, LH = Latching high

45.2.4.6.1 Device present (4.8.15:14)

When read as <10>, bits 4.8.15:14 indicate that a device is present and responding at this register address. When read as anything other than <10>, bits 4.8.15:14 indicate that no device is present at this register address or that the device is not functioning properly.

45.2.4.6.2 Transmit fault (4.8.11)

When read as a one, bit 4.8.11 indicates that the PHY XS has detected a fault condition on the transmit path. When read as a zero, bit 4.8.11 indicates that the PHY XS has not detected a fault condition on the transmit path. The transmit fault bit shall be implemented with latching high behavior.

The default value for bit 4.8.11 is zero.

45.2.4.6.3 Receive fault (4.8.10)

When read as a one, bit 4.8.10 indicates that the PHY XS has detected a fault condition on the receive path. When read as a zero, bit 4.8.10 indicates that the PHY XS has not detected a fault condition on the receive path. The receive fault bit shall be implemented with latching high behavior.

The default value of bit 4.8.10 is zero.

45.2.4.7 PHY XS package identifier (Registers 4.14 and 4.15)

Registers 4.14 and 4.15 provide a 32-bit value, which may constitute a unique identifier for a particular type of package that the PHY XS is instantiated within. The identifier shall be composed of the 3rd through 24th bits of the Organizationally Unique Identifier (OUI) assigned to the package manufacturer by the IEEE, plus a six-bit model number, plus a four-bit revision number. A PHY XS may return a value of zero in each of the 32 bits of the PHY XS package identifier.

A non-zero package identifier may be returned by one or more MMDs in the same package. The package identifier may be the same as the device identifier.

The format of the PHY XS package identifier is specified in 22.2.4.3.1.

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45.2.4.8 EEE capability (Register 4.20)

This register is used to indicate the capability of the PHY XS to support EEE functions. The assignment of bits in the EEE capability register is shown in Table 45–169.

Table 45–169—EEE capability register bit definitions

Bit(s)	Name	Description	R/W[a]
4.20.15:5	Reserved	Value always 0	RO
4.20.4	PHY XS EEE	1 = EEE is supported for PHY XS 0 = EEE is not supported for PHY XS	RO
4.20.3:1	Reserved	Value always 0	RO
4.20.0	XAUI stop capable	1 = The DTE XS may stop XAUI signals during LPI 0 = XAUI signals not stoppable	RO

[a] RO = Read only

45.2.4.8.1 PHY XS EEE supported (4.20.4)

If the device supports EEE operation for PHY XS as defined in 48.2, this bit shall be set to one.

45.2.4.8.2 XAUI stop capable (4.20.0)

If bit 4.20.0 is set to one, then the PHY XS is indicating that the attached DTE XS is permitted to stop transmitting XAUI signals during LPI. If the bit is set to zero then the PHY XS is indicating that the attached DTE XS is not permitted to stop transmitting XAUI signals during LPI. If the DTE XS does not support EEE capability or is not able to stop the transmit direction XAUI, then this bit has no effect.

45.2.4.9 EEE wake error counter (Register 4.22)

This register is used by PHY XS that support EEE to count wake time faults where the PHY XS fails to complete its normal wake sequence after a period of quiescence for XAUI transmit signals. The fault event to be counted may occur during a refresh or a wake-up. This 16-bit counter shall be reset to all zeros when the EEE wake error counter is read by the management function or upon execution of the PHY XS reset. This counter shall be held at all ones in the case of overflow.

45.2.4.10 10G PHY XGXS lane status register (Register 4.24)

The assignment of bits in the 10G PHY XGXS lane status register is shown in Table 45–170. All the bits in the 10G PHY XGXS lane status register are read only; a write to the 10G PHY XGXS lane status register shall have no effect.

45.2.4.10.1 PHY XGXS transmit lane alignment status (4.24.12)

When read as a one, bit 4.24.12 indicates that the PHY XGXS has synchronized and aligned all four transmit lanes. When read as a zero, bit 4.24.12 indicates that the PHY XGXS has not synchronized and aligned all four transmit lanes.

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Table 45–170—10G PHY XGXS lane status register bit definitions

Bit(s)	Name	Description	R/W[a]
4.24.15:13	Reserved	Value always 0	RO
4.24.12	PHY XGXS lane alignment status	1 = PHY XGXS transmit lanes aligned 0 = PHY XGXS transmit lanes not aligned	RO
4.24.11	Pattern testing ability	1 = PHY XGXS is able to generate test patterns 0 = PHY XGXS is not able to generate test patterns	RO
4.24.10	PHY XGXS loopback ability	1 = PHY XGXS has the ability to perform a loopback function 0 = PHY XGXS does not have the ability to perform a loopback function	RO
4.24.9:4	Reserved	Value always 0	RO
4.24.3	Lane 3 sync	1 = Lane 3 is synchronized 0 = Lane 3 is not synchronized	RO
4.24.2	Lane 2 sync	1 = Lane 2 is synchronized 0 = Lane 2 is not synchronized	RO
4.24.1	Lane 1 sync	1 = Lane 1 is synchronized 0 = Lane 1 is not synchronized	RO
4.24.0	Lane 0 sync	1 = Lane 0 is synchronized 0 = Lane 0 is not synchronized	RO

[a]RO = Read only

45.2.4.10.2 Pattern testing ability (4.24.11)

When read as a one, bit 4.24.11 indicates that the 10G PHY XGXS is able to generate test patterns. When read as a zero, bit 4.24.11 indicates that the 10G PHY XGXS is not able to generate test patterns. If the 10G PHY XGXS is able to generate test patterns, then the functionality is controlled using the transmit test-pattern enable bit in register 4.25.

45.2.4.10.3 PHY XS loopback ability (4.24.10)

When read as a one, bit 4.24.10 indicates that the PHY XGXS is able to perform the loopback function. When read as a zero, bit 4.24.10 indicates that the PHY XGXS is not able to perform the loopback function. If a 10G PHY XGXS is able to perform the loopback function, then it is controlled using the PHY XGXS loopback bit 4.0.14.

45.2.4.10.4 Lane 3 sync (4.24.3)

When read as a one, bit 4.24.3 indicates that the 10G PHY XGXS transmit lane 3 is synchronized. When read as a zero, bit 4.24.3 indicates that the 10G PHY XGXS transmit lane 3 is not synchronized.

45.2.4.10.5 Lane 2 sync (4.24.2)

When read as a one, bit 4.24.2 indicates that the 10G PHY XGXS transmit lane 2 is synchronized. When read as a zero, bit 4.24.2 indicates that the 10G PHY XGXS transmit lane 2 is not synchronized.

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45.2.4.10.6 Lane 1 sync (4.24.1)

When read as a one, bit 4.24.1 indicates that the 10G PHY XGXS transmit lane 1 is synchronized. When read as a zero, bit 4.24.1 indicates that the 10G PHY XGXS transmit lane 1 is not synchronized.

45.2.4.10.7 Lane 0 sync (4.24.0)

When read as a one, bit 4.24.0 indicates that the 10G PHY XGXS transmit lane 0 is synchronized. When read as a zero, bit 4.24.0 indicates that the 10G PHY XGXS transmit lane 0 is not synchronized.

45.2.4.11 10G PHY XGXS test control register (Register 4.25)

The assignment of bits in the 10G PHY XGXS test control register is shown in Table 45–171. The default value for each bit of the 10G PHY XGXS test control register should be chosen so that the initial state of the device upon power up or reset is a normal operational state without management intervention.

Table 45–171—10G PHY XGXS test control register bit definitions

Bit(s)	Name	Description	R/W[a]
4.25.15:3	Reserved	Value always 0	RO
4.25.2	Receive test-pattern enable	1 = Receive test pattern enabled 0 = Receive test pattern not enabled	R/W
4.25.1:0	Test-pattern select	1 0 = Reserved 1 1 = Reserved 1 0 = Mixed-frequency test pattern 0 1 = Low-frequency test pattern 0 0 = High-frequency test pattern	R/W

[a]RO = Read only, R/W = Read/Write

45.2.4.11.1 10G PHY XGXS test-pattern enable (4.25.2)

When bit 4.25.2 is set to a one, pattern testing is enabled on the receive path. When bit 4.25.2 is set to a zero, pattern testing is disabled on the receive path. Pattern testing is optional, and the ability of the 10G PHY XGXS to generate test patterns is advertised by the pattern testing ability bit in register 4.24. A 10G PHY XGXS that does not support the generation of test patterns shall ignore writes to this bit and always return a value of zero. The default of bit 4.25.2 is zero.

45.2.4.11.2 10G PHY XGXS test-pattern select (4.25.1:0)

The test pattern to be used when pattern testing is enabled using bit 4.25.2 is selected using bits 4.25.1:0. When bits 4.25.1:0 are set to <10>, the mixed-frequency test pattern shall be selected for pattern testing. When bits 4.25.1:0 are set to <01>, the low-frequency test pattern shall be selected for pattern testing. When bits 4.25.1:0 are set to <00>, the high-frequency test pattern shall be selected for pattern testing. The test patterns are defined in Annex 48A.

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45.2.4.12 TimeSync PHY XS capability (Register 4.1800)

The TimeSync PHY XS capability register (see Table 45–172) indicates the capability of the PHY XS to report the transmit and receive data delay, stored in registers 4.1801 through 4.1804 and 4.1805 through 4.1808, respectively.

Table 45–172—TimeSync PHY XS capability

Bit(s)	Name	Description	R/W[a]
4.1800.15:2	Reserved	Value always 0	RO
4.1800.1	TimeSync transmit path data delay	1 = PHY XS provides information on transmit path data delay in registers 4.1801 through 4.1804 0 = PHY XS does not provide information on transmit path data delay	RO
4.1800.0	TimeSync receive path data delay	1 = PHY XS provides information on receive path data delay in registers 4.1805 through 4.1808 0 = PHY XS does not provide information on receive path data delay	RO

[a]RO = Read only

45.2.4.13 TimeSync PHY XS transmit path data delay (Registers 4.1801, 4.1802, 4.1803, 4.1804)

The TimeSync PHY XS transmit path data delay register contains the maximum (Registers 4.1801, 4.1802, see Table 45–173) and minimum (Registers 4.1803, 4.1804, see Table 45–173) values of the transmit path data delay. The transmit path data delay is expressed in units of ns. The values contained in these registers are valid when the link is established, as indicated by bit 2 in Register 1.1 (see 45.2.1.2.4).

Table 45–173—TimeSync PHY XS transmit path data delay register

Bit(s)	Name	Description	R/W[a]
4.1801.15:0	Maximum PHY XS transmit path data delay, lower	PHY_XS_delay_TX_max [15:0]	RO, MW
4.1802.15:0	Maximum PHY XS transmit path data delay, upper	PHY_XS_delay_TX_max [31:16]	RO, MW
4.1803.15:0	Minimum PHY XS transmit path data delay, lower	PHY_XS_delay_TX_min [15:0]	RO, MW
4.1804.15:0	Minimum PHY XS transmit path data delay, upper	PHY_XS_delay_TX_min [31:16]	RO, MW

[a]RO = Read only, MW = Multi-word

45.2.4.14 TimeSync PHY XS receive path data delay (Registers 4.1805, 4.1806, 4.1807, 4.1808)

The TimeSync PHY XS receive path data delay register contains the maximum (Registers 4.1805, 4.1806, see Table 45–174) and minimum (Registers 4.1807, 4.1808, see Table 45–174) values of the receive path data delay. The receive path data delay is expressed in units of ns. The values contained in these registers are valid when the link is established, as indicated by bit 2 in Register 1.1 (see 45.2.1.2.4).

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Table 45–174—TimeSync PHY XS receive path data delay register

Bit(s)	Name	Description	R/W[a]
4.1805.15:0	Maximum PHY XS receive path data delay, lower	PHY_XS_delay_RX_max [15:0]	RO, MW
4.1806.15:0	Maximum PHY XS receive path data delay, upper	PHY_XS_delay_RX_max [31:16]	RO, MW
4.1807.15:0	Minimum PHY XS receive path data delay, lower	PHY_XS_delay_RX_min [15:0]	RO, MW
4.1808.15:0	Minimum PHY XS receive path data delay, upper	PHY_XS_delay_RX_min [31:16]	RO, MW

[a]RO = Read only, MW = Multi-word

45.2.5 DTE XS registers

The assignment of registers in the DTE XS is shown in Table 45–175.

Table 45–175—DTE XS registers

Register address	Register name	Subclause
5.0	DTE XS control 1	45.2.5.1
5.1	DTE XS status 1	45.2.5.2
5.2, 5.3	DTE XS device identifier	45.2.5.3
5.4	DTE XS speed ability	45.2.5.4
5.5, 5.6	DTE XS devices in package	45.2.5.5
5.7	Reserved	
5.8	DTE XS status 2	45.2.5.6
5.9 through 5.13	Reserved	
5.14, 5.15	DTE XS package identifier	45.2.5.7
5.16 through 5.19	Reserved	
5.20	EEE capability	45.2.5.8
5.21	Reserved	
5.22	EEE wake error counter	45.2.5.9
5.23	Reserved	
5.24	10G DTE XGXS lane status	45.2.5.10
5.25	10G DTE XGXS test control	45.2.5.11

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Table 45–175—DTE XS registers *(continued)*

Register address	Register name	Subclause
5.26 through 5.1799	Reserved	
5.1800	TimeSync DTE XS capability	45.2.5.12
5.1801 through 5.1804	TimeSync DTE XS transmit path data delay	45.2.5.13
5.1805 through 5.1808	TimeSync DTE XS receive path data delay	45.2.5.14
5.1809 through 5.32767	Reserved	
5.32 768 through 5.65 535	Vendor specific	

45.2.5.1 DTE XS control 1 register (Register 5.0)

The assignment of bits in the DTE XS control 1 register is shown in Table 45–176. The default value for each bit of the DTE XS control 1 register should be chosen so that the initial state of the device upon power up or reset is a normal operational state without management intervention.

Table 45–176—DTE XS control 1 register bit definitions

Bit(s)	Name	Description	R/W[a]
5.0.15	Reset	1 = DTE XS reset 0 = Normal operation	R/W SC
5.0.14	Loopback	1 = Enable loopback mode 0 = Disable loopback mode	R/W
5.0.13	Speed selection	1 = Operation at 10 Gbp/s and above 0 = Unspecified	R/W
5.0.12	Reserved	Value always 0	RO
5.0.11	Low power	1 = Low-power mode 0 = Normal operation	R/W
5.0.10	Clock stop enable	1 = The DTE XS may stop the clock during LPI 0 = Clock not stoppable	R/W
5.0.9	XAUI stop enable	1 = The DTE XS may stop XAUI signals during LPI 0 = XAUI not stoppable	R/W
5.0.8:7	Reserved	Value always 0	RO
5.0.6	Speed selection	1 = Operation at 10 Gb/s and above 0 = Unspecified	R/W

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Table 45–176—DTE XS control 1 register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
5.0.5:2	Speed selection	5 4 3 2 1 x x x = Reserved x 1 x x = Reserved x x 1 x = Reserved 0 0 0 1 = Reserved 0 0 0 0 = 10 Gb/s	R/W
5.0.1:0	Reserved	Value always 0	RO

[a]R/W = Read/Write, SC = Self-clearing, RO = Read only

45.2.5.1.1 Reset (5.0.15)

Resetting a DTE XS is accomplished by setting bit 5.0.15 to a one. This action shall set all DTE XS registers to their default states. As a consequence, this action may change the internal state of the DTE XS and the state of the physical link. This action may also initiate a reset in any other MMDs that are instantiated in the same package. This bit is self-clearing, and a DTE XS shall return a value of one in bit 5.0.15 when a reset is in progress and a value of zero otherwise. A DTE XS is not required to accept a write transaction to any of its registers until the reset process is completed. The reset process shall be completed within 0.5 s from the setting of bit 5.0.15. During a reset, a DTE XS shall respond to reads to register bits 5.0.15 and 5.8.15:14. All other register bits should be ignored.

NOTE—This operation may interrupt data communication.

45.2.5.1.2 Loopback (5.0.14)

The DTE XS shall be placed in a loopback mode of operation when bit 5.0.14 is set to a one. When bit 5.0.14 is set to a one, the DTE XS shall accept data on the transmit path and return it on the receive path. For 10 Gb/s operation, the specific behavior of a DTE XS during loopback is specified in 48.3.3.

The default value of bit 5.0.14 is zero.

NOTE—The signal path through the DTE XS that is exercised in the loopback mode of operation is implementation specific, but it is recommended that the signal path encompass as much of the DTE XS circuitry as is practical. The intention of providing this loopback mode of operation is to permit a diagnostic or self-test function to perform the transmission and reception of a PDU, thus testing the transmit and receive data paths. Other loopback signal paths may be enabled using loopback controls within other MMDs.

45.2.5.1.3 Low power (5.0.11)

A DTE XS may be placed into a low-power mode by setting bit 5.0.11 to a one. This action may also initiate a low-power mode in any other MMDs that are instantiated in the same package. The low-power mode is exited by resetting the DTE XS. The behavior of the DTE XS in transition to and from the low-power mode is implementation specific and any interface signals should not be relied upon. While in the low-power mode, the device shall, as a minimum, respond to management transactions necessary to exit the low-power mode. The default value of bit 5.0.11 is zero.

45.2.5.1.4 Clock stop enable (5.0.10)

If bit 5.0.10 is set to 1, then the DTE XS may stop the receive xMII clock while it is signaling LPI, otherwise it shall keep the clock active. If the DTE XS does not support EEE capability or is not able to stop the receive clock, then this bit has no effect (see 46.3.2.4).

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45.2.5.1.5 XAUI stop enable (5.0.9)

If bit 5.0.9 is set to 1, then the DTE XS may stop signaling on the XAUI in the transmit direction during LPI, otherwise the DTE XS shall keep the XAUI signals active. If the DTE XS does not support EEE capability or is not able to stop the transmit path XAUI signals, then this bit has no effect.

45.2.5.1.6 Speed selection (5.0.13, 5.0.6, 5.0.5:2)

Speed selection bits 5.0.13 and 5.0.6 shall both be written as a one. Any attempt to change the bits to an invalid setting shall be ignored. These two bits are set to one in order to make them compatible with Clause 22.

The speed of the DTE XS may be selected using bits 5 through 2. The speed abilities of the DTE XS are advertised in the DTE XS speed ability register. A DTE XS may ignore writes to the DTE XS speed selection bits that select speeds it has not advertised in the DTE XS speed ability register. It is the responsibility of the STA entity to ensure that mutually acceptable speeds are applied consistently across all the MMDs on a particular PHY.

The DTE XS speed selection defaults to a supported ability.

45.2.5.2 DTE XS status 1 register (Register 5.1)

The assignment of bits in the DTE XS status 1 register is shown in Table 45–177. All the bits in the DTE XS status 1 register are read only; a write to the DTE XS status 1 register shall have no effect.

Table 45–177—DTE XS status 1 register bit definitions

Bit(s)	Name	Description	R/W[a]
5.1.15:12	Reserved	Value always 0	RO
5.1.11	Tx LPI received	1 = Tx PCS has received LPI 0 = LPI not received	RO/LH
5.1.10	Rx LPI received	1 = Rx PCS has received LPI 0 = LPI not received	RO/LH
5.1.9	Tx LPI indication	1 = Tx PCS is currently receiving LPI 0 = PCS is not currently receiving LPI	RO
5.1.8	Rx LPI indication	1 = Rx PCS is currently receiving LPI 0 = PCS is not currently receiving LPI	RO
5.1.7	Fault	1 = Fault condition detected 0 = No fault condition detected	RO
5.1.6	Clock stop capable	1 = The MAC may stop the clock during LPI 0 = Clock not stoppable	RO
5.1.5:3	Reserved	Value always 0	RO
5.1.2	DTE XS receive link status	1 = The DTE XS receive link is up 0 = The DTE XS receive link is down	RO/LL

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Table 45–177—DTE XS status 1 register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
5.1.1	Low-power ability	1 = DTE XS supports low-power mode 0 = DTE XS does not support low-power mode	RO
5.1.0	Reserved	Value always 0	RO

[a]RO = Read only, LL = Latching low, LH = Latching high

45.2.5.2.1 Transmit LPI received (5.1.11)

When read as a one, bit 5.1.11 indicates that the transmit DTE XS has received LPI signaling one or more times since the register was last read. When read as a zero, bit 5.1.11 indicates that the DTE XS has not received LPI signaling. This bit shall be implemented with latching high behavior.

45.2.5.2.2 Receive LPI received (5.1.10)

When read as a one, bit 5.1.10 indicates that the receive DTE XS has received LPI signaling one or more times since the register was last read. When read as a zero, bit 5.1.10 indicates that the DTE XS has not received LPI signaling. This bit shall be implemented with latching high behavior.

45.2.5.2.3 Transmit LPI indication (5.1.9)

When read as a one, bit 5.1.9 indicates that the transmit DTE XS is currently receiving LPI signals. When read as a zero, bit 5.1.9 indicates that the DTE XS is not currently receiving LPI signals. The behavior if read during a state transition is undefined.

45.2.5.2.4 Receive LPI indication (5.1.8)

When read as a one, bit 5.1.8 indicates that the receive DTE XS is currently receiving LPI signals. When read as a zero, bit 5.1.8 indicates that the DTE XS is not currently receiving LPI signals. The behavior if read during a state transition is undefined.

45.2.5.2.5 Fault (5.1.7)

When read as a one, bit 5.1.7 indicates that the DTE XS has detected a fault condition on either the transmit or receive paths. When read as a zero, bit 5.1.7 indicates that the DTE XS has not detected a fault condition. Bit 5.1.7 is set to a one when either of the fault bits (5.8.11, 5.8.10) located in register 5.8 are set to a one.

45.2.5.2.6 Clock stop capable (5.1.6)

If bit 5.1.6 is set to one, then the DTE XS is indicating that the attached RS is permitted to stop the transmit xMII clock while it is signaling LPI. If the bit is set to zero, then the DTE XS is indicating that the attached RS is not permitted to stop the transmit xMII clock while it is signaling LPI. If the RS does not support EEE capability or is not able to stop the transmit direction xMII clock, then this bit has no effect (see 46.3.2.4).

45.2.5.2.7 DTE XS receive link status (5.1.2)

When read as a one, bit 5.1.2 indicates that the DTE XS receive link is aligned. When read as a zero, bit 5.1.2 indicates that the DTE XS receive link is not aligned. The receive link status bit shall be implemented with latching low behavior.

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For 10 Gb/s operation, this bit is a latching low version of bit 5.24.12.

45.2.5.2.8 Low-power ability (5.1.1)

When read as a one, bit 5.1.1 indicates that the DTE XS supports the low-power feature. When read as a zero, bit 5.1.1 indicates that the DTE XS does not support the low-power feature. If a DTE XS supports the low-power feature then it is controlled using the low-power bit in the DTE XS control register.

45.2.5.3 DTE XS device identifier (Registers 5.2 and 5.3)

Registers 5.2 and 5.3 provide a 32-bit value, which may constitute a unique identifier for a DTE XS. The identifier shall be composed of the 3rd through 24th bits of the Organizationally Unique Identifier (OUI) assigned to the device manufacturer by the IEEE, plus a six-bit model number, plus a four-bit revision number. A DTE XS may return a value of zero in each of the 32 bits of the DTE XS device identifier.

The format of the DTE XS device identifier is specified in 22.2.4.3.1.

45.2.5.4 DTE XS speed ability (Register 5.4)

The assignment of bits in the DTE XS speed ability register is shown in Table 45–178.

Table 45–178— DTE XS speed ability register bit definitions

Bit(s)	Name	Description	R/W[a]
5.4.15:1	Reserved for future speeds	Value always 0	RO
5.4.0	10G capable	1 = DTE XS is capable of operating at 10 Gb/s 0 = DTE XS is not capable of operating at 10 Gb/s	RO

[a]RO = Read only

45.2.5.4.1 10G capable (5.4.0)

When read as a one, bit 5.4.0 indicates that the DTE XS is able to operate at a data rate of 10 Gb/s. When read as a zero, bit 5.4.0 indicates that the DTE XS is not able to operate at a data rate of 10 Gb/s.

45.2.5.5 DTE XS devices in package (Registers 5.5 and 5.6)

The DTE XS devices in package registers are defined in Table 45–2.

45.2.5.6 DTE XS status 2 register (Register 5.8)

The assignment of bits in the DTE XS status 2 register is shown in Table 45–179. All the bits in the DTE XS status 2 register are read only; a write to the DTE XS status 2 register shall have no effect.

45.2.5.6.1 Device present (5.8.15:14)

When read as <10>, bits 5.8.15:14 indicate that a device is present and responding at this register address. When read as anything other than <10>, bits 5.8.15:14 indicate that no device is present at this register address or that the device is not functioning properly.

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Table 45–179—DTE XS status 2 register bit definitions

Bit(s)	Name	Description	R/W[a]
5.8.15:14	Device present	15 14 1 0 = Device responding at this address 1 1 = No device responding at this address 0 1 = No device responding at this address 0 0 = No device responding at this address	RO
5.8.13:12	Reserved	Value always 0	RO
5.8.11	Transmit fault	1 = Fault condition on transmit path 0 = No fault condition on transmit path	RO/LH
5.8.10	Receive fault	1 = Fault condition on receive path 0 = No fault condition on receive path	RO/LH
5.8.9:0	Reserved	Value always 0	RO

[a]RO = Read only, LH = Latching high

45.2.5.6.2 Transmit fault (5.8.11)

When read as a one, bit 5.8.11 indicates that the DTE XS has detected a fault condition on the transmit path. When read as a zero, bit 5.8.11 indicates that the DTE XS has not detected a fault condition on the transmit path. The transmit fault bit shall be implemented with latching high behavior.

The default value of bit 5.8.11 is zero.

45.2.5.6.3 Receive fault (5.8.10)

When read as a one, bit 5.8.10 indicates that the DTE XS has detected a fault condition on the receive path. When read as a zero, bit 5.8.10 indicates that the DTE XS has not detected a fault condition on the receive path. The receive fault bit shall be implemented with latching high behavior.

The default value of bit 5.8.10 is zero.

45.2.5.7 DTE XS package identifier (Registers 5.14 and 5.15)

Registers 5.14 and 5.15 provide a 32-bit value, which may constitute a unique identifier for a particular type of package that the DTE XS is instantiated within. The identifier shall be composed of the 3rd through 24th bits of the Organizationally Unique Identifier (OUI) assigned to the package manufacturer by the IEEE, plus a six-bit model number, plus a four-bit revision number. A DTE XS may return a value of zero in each of the 32 bits of the DTE XS package identifier.

A non-zero package identifier may be returned by one or more MMDs in the same package. The package identifier may be the same as the device identifier.

The format of the DTE XS package identifier is specified in 22.2.4.3.1.

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45.2.5.8 EEE capability (Register 5.20)

This register is used to indicate the capability of the DTE XS to support EEE functions. The assignment of bits in the EEE capability register is shown in Table 45–180.

Table 45–180—EEE capability register bit definitions

Bit(s)	Name	Description	R/W[a]
5.20.15:5	Reserved	Value always 0	RO
5.20.4	DTE XS EEE	1 = EEE is supported for DTE XS 0 = EEE is not supported for DTE XS	RO
5.20.3:1	Reserved	Value always 0	RO
5.20.0	XAUI stop capable	1 = The PHY XS may stop XAUI signals during LPI 0 = XAUI signals not stoppable	RO

[a] RO = Read only

45.2.5.8.1 PHY XS EEE supported (5.20.4)

If the device supports EEE operation for DTE XS as defined in 48.2, this bit shall be set to one.

45.2.5.8.2 XAUI stop capable (5.20.0)

If bit 5.20.0 is set to one, then the DTE XS is indicating that the attached PHY XS is permitted to stop signaling the XAUI in the receive direction during LPI. If the bit is set to zero, then the DTE XS is indicating that the attached PHY XS is not permitted to stop signaling the XAUI in the receive direction during LPI. If the PHY XS does not support EEE capability or is not able to stop the receive direction XAUI, then this bit has no effect.

45.2.5.9 EEE wake error counter (Register 5.22)

This register is used by DTE XS that support EEE to count wake time faults where the DTE XS fails to complete its normal wake sequence after a period of quiescence for XAUI receive signals. The fault event to be counted may occur during a refresh or a wake-up. This 16-bit counter shall be reset to all zeros when the EEE wake error counter is read by the management function or upon execution of the DTE XS reset. This counter shall be held at all ones in the case of overflow.

45.2.5.10 10G DTE XGXS lane status register (Register 5.24)

The assignment of bits in the 10G DTE XGXS lane status register is shown in Table 45–181. All the bits in the 10G DTE XGXS lane status register are read only; a write to the 10G DTE XGXS lane status register shall have no effect.

45.2.5.10.1 DTE XGXS receive lane alignment status (5.24.12)

When read as a one, bit 5.24.12 indicates that the DTE XGXS has synchronized and aligned all four receive lanes. When read as a zero, bit 5.24.12 indicates that the DTE XGXS has not synchronized and aligned all four receive lanes.

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Table 45–181—10G DTE XGXS lane status register bit definitions

Bit(s)	Name	Description	R/W[a]
5.24.15:13	Reserved	Value always 0	RO
5.24.12	DTE XGXS lane alignment status	1 = DTE XGXS receive lanes aligned 0 = DTE XGXS receive lanes not aligned	RO
5.24.11	Pattern testing ability	1 = DTE XGXS is able to generate test patterns 0 = DTE XGXS is not able to generate test patterns	RO
5.24.10	Ignored	Value 0 or 1, writes ignored	RO
5.24.9:4	Reserved	Value always 0	RO
5.24.3	Lane 3 sync	1 = Lane 3 is synchronized 0 = Lane 3 is not synchronized	RO
5.24.2	Lane 2 sync	1 = Lane 2 is synchronized 0 = Lane 2 is not synchronized	RO
5.24.1	Lane 1 sync	1 = Lane 1 is synchronized 0 = Lane 1 is not synchronized	RO
5.24.0	Lane 0 sync	1 = Lane 0 is synchronized 0 = Lane 0 is not synchronized	RO

[a]RO = Read only

45.2.5.10.2 Pattern testing ability (5.24.11)

When read as a one, bit 5.24.11 indicates that the 10G DTE XGXS is able to generate test patterns. When read as a zero, bit 5.24.11 indicates that the 10G DTE XGXS is not able to generate test patterns. If the 10G DTE XGXS is able to generate test patterns then the functionality is controlled using the transmit test-pattern enable bit in register 5.25.

45.2.5.10.3 Ignored (5.24.10)

So that a single device can implement either register 4.24 or register 5.24, bit 5.24.10 can return either a one or a zero and should be ignored.

45.2.5.10.4 Lane 3 sync (5.24.3)

When read as a one, bit 5.24.3 indicates that the XGXS receive lane 3 is synchronized. When read as a zero, bit 5.24.3 indicates that the XGXS receive lane 3 is not synchronized.

45.2.5.10.5 Lane 2 sync (5.24.2)

When read as a one, bit 5.24.2 indicates that the XGXS receive lane 2 is synchronized. When read as a zero, bit 5.24.2 indicates that the XGXS receive lane 2 is not synchronized.

45.2.5.10.6 Lane 1 sync (5.24.1)

When read as a one, bit 5.24.1 indicates that the XGXS receive lane 1 is synchronized. When read as a zero, bit 5.24.1 indicates that the XGXS receive lane 1 is not synchronized.

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45.2.5.10.7 Lane 0 sync (5.24.0)

When read as a one, bit 5.24.0 indicates that the XGXS receive lane 0 is synchronized. When read as a zero, bit 5.24.0 indicates that the XGXS receive lane 0 is not synchronized.

45.2.5.11 10G DTE XGXS test control register (Register 5.25)

The assignment of bits in the 10G DTE XGXS test control register is shown in Table 45–182. The default value for each bit of the 10G DTE XGXS test control register should be chosen so that the initial state of the device upon power up or reset is a normal operational state without management intervention.

Table 45–182—10G DTE XGXS test control register bit definitions

Bit(s)	Name	Description	R/W[a]
5.25.15:3	Reserved	Value always 0	RO
5.25.2	Transmit test-pattern enable	1 = Transmit test pattern enabled 0 = Transmit test pattern not enabled	R/W
5.25.1:0	Test-pattern select	1 0 1 1 = Reserved 1 0 = Mixed-frequency test pattern 0 1 = Low-frequency test pattern 0 0 = High-frequency test pattern	R/W

[a]RO = Read only, R/W = Read/Write

45.2.5.11.1 10G DTE XGXS test-pattern enable (5.25.2)

When bit 5.25.2 is set to a one, pattern testing is enabled on the transmit path. When bit 5.25.2 is set to a zero, pattern testing is disabled on the transmit path. Pattern testing is optional, and the ability of the 10G DTE XGXS to generate test patterns is advertised by the pattern testing ability bit in register 5.24. A 10G DTE XGXS that does not support the generation of test patterns shall ignore writes to this bit and always return a value of zero. The default of bit 5.25.2 is zero.

45.2.5.11.2 10G DTE XGXS test-pattern select (5.25.1:0)

The test pattern to be used when pattern testing is enabled using bit 5.25.2 is selected using bits 5.25.1:0. When bits 5.25.1:0 are set to <10>, the mixed-frequency test pattern shall be selected for pattern testing. When bits 5.25.1:0 are set to <01>, the low-frequency test pattern shall be selected for pattern testing. When bits 5.25.1:0 are set to <00>, the high-frequency test pattern shall be selected for pattern testing. The test patterns are defined in Annex 48A.

45.2.5.12 TimeSync DTE XS capability (Register 5.1800)

The TimeSync DTE XS capability register (see Table 45–183) indicates the capability of the DTE XS to report the transmit and receive data delay, stored in registers 5.1801 through 5.1804 and 5.1805 through 5.1808, respectively

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Table 45–183—TimeSync DTE XS capability

Bit(s)	Name	Description	R/W[a]
5.1800.15:2	Reserved	Value always 0	RO
5.1800.1	TimeSync transmit path data delay	1 = DTE XS provides information on transmit path data delay in registers 5.1801 through 5.1804 0 = DTE XS does not provide information on transmit path data delay	RO
5.1800.0	TimeSync receive path data delay	1 = DTE XS provides information on receive path data delay in registers 5.1805 through 5.1808 0 = DTE XS does not provide information on receive path data delay	RO

[a]RO = Read only

45.2.5.13 TimeSync DTE XS transmit path data delay (Registers 5.1801, 5.1802, 5.1803, 5.1804)

The TimeSync DTE XS transmit path data delay register contains the maximum (Registers 5.1801, 5.1802, see Table 45–184) and minimum (Registers 5.1803, 5.1804, see Table 45–184) values of the transmit path data delay. The transmit path data delay is expressed in units of ns. The values contained in these registers are valid when the link is established, as indicated by bit 2 in Register 1.1 (see 45.2.1.2.4).

Table 45–184—TimeSync DTE XS transmit path data delay register

Bit(s)	Name	Description	R/W[a]
5.1801.15:0	Maximum DTE XS transmit path data delay, lower	DTE_XS_delay_TX_max [15:0]	RO, MW
5.1802.15:0	Maximum DTE XS transmit path data delay, upper	DTE_XS_delay_TX_max [31:16]	RO, MW
5.1803.15:0	Minimum DTE XS transmit path data delay, lower	DTE_XS_delay_TX_min [15:0]	RO, MW
5.1804.15:0	Minimum DTE XS transmit path data delay, upper	DTE_XS_delay_TX_min [31:16]	RO, MW

[a]RO = Read only, MW = Multi-word

45.2.5.14 TimeSync DTE XS receive path data delay (Registers 5.1805, 5.1806, 5.1807, 5.1808)

The TimeSync DTE XS receive path data delay register contains the maximum (Registers 5.1805, 5.1806, see Table 45–185) and minimum (Registers 5.1807, 5.1808, see Table 45–185) values of the receive path data delay. The receive path data delay is expressed in units of ns. The values contained in these registers are valid when the link is established, as indicated by bit 2 in Register 1.1 (see 45.2.1.2.4).

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Table 45–185—TimeSync DTE XS receive path data delay register

Bit(s)	Name	Description	R/W[a]
5.1805.15:0	Maximum DTE XS receive path data delay, lower	DTE_XS_delay_RX_max [15:0]	RO, MW
5.1806.15:0	Maximum DTE XS receive path data delay, upper	DTE_XS_delay_RX_max [31:16]	RO, MW
5.1807.15:0	Minimum DTE XS receive path data delay, lower	DTE_XS_delay_RX_min [15:0]	RO, MW
5.1808.15:0	Minimum DTE XS receive path data delay, upper	DTE_XS_delay_RX_min [31:16]	RO, MW

[a]RO = Read only, MW = Multi-word

45.2.6 TC registers

The assignment of registers in the TC MMD is shown in Table 45–186.

Table 45–186—TC registers

Register address	Register name	Subclause
6.0	TC control	45.2.6.1
6.1	Reserved	
6.2, 6.3	TC device identifier	45.2.6.2
6.4	TC speed ability	45.2.6.3
6.5, 6.6	TC devices in package	45.2.6.4
6.7 through 6.13	Reserved	
6.14, 6.15	TC package identifier	45.2.6.5
6.16	10P/2B aggregation discovery control[a]	45.2.6.6
6.17	10P/2B aggregation and discovery status[a]	45.2.6.7
6.18, 6.19, 6.20	10P/2B aggregation discovery code[a]	45.2.6.8
6.21	10P/2B link partner PME aggregate control[a]	45.2.6.9
6.22, 6.23	10P/2B link partner PME aggregate data[a]	45.2.6.10
6.24	10P/2B TC CRC error counter	45.2.6.11
6.25, 6.26	10P/2B TPS-TC coding violations counter	45.2.6.12
6.27	10P/2B TC indications	45.2.6.13
6.28 through 6.1799	Reserved	
6.1800	TimeSync TC capability	45.2.6.14

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Table 45–186—TC registers *(continued)*

Register address	Register name	Subclause
6.1801 through 6.1804	TimeSync TC transmit path data delay	45.2.6.15
6.1805 through 6.1808	TimeSync TC receive path data delay	45.2.6.16
6.1809 through 6.32767	Reserved	
6.32 768 through 6.65 535	Vendor specific	

[a]Register is defined only for -O port types and is reserved for -R ports

45.2.6.1 TC control register (Register 6.0)

The assignment of bits in the TC control register is shown in Table 45–187. The default value for each bit of the TC control register has been chosen so that the initial state of the device upon power up or completion of reset is a normal operational state without management intervention.

Table 45–187—TC control register bit definitions

Bit(s)	Name	Description	R/W[a]
6.0.15	Reset	1 = TC reset 0 = Normal operation	R/W SC
6.0.14	Reserved	Value always 0	RO
6.0.13	Speed selection	13 6 1 1 = bits 5:2 select speed 0 x = unspecified x 0 = unspecified	R/W
6.0.12:7	Reserved	Value always 0	RO
6.0.6	Speed selection	13 6 1 1 = bits 5:2 select speed 0 x = unspecified x 0 = unspecified	R/W
6.0.5:2	Speed selection	5 4 3 2 1 x x x = Reserved x 1 x x = Reserved x x 1 x = Reserved 0 0 0 1 = 10PASS-TS/2BASE-TL 0 0 0 0 = Reserved	R/W
6.0.1:0	Reserved	Value always 0	RO

[a]R/W = Read/Write, SC = Self-clearing, RO = Read only

45.2.6.1.1 Reset (6.0.15)

Resetting a TC is accomplished by setting bit 6.0.15 to a one. This action shall set all TC registers to their default states. As a consequence, this action may change the internal state of the TC and the state of the physical link. This action may also initiate a reset in any other MMDs that are instantiated in the same

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package. This bit is self-clearing, and a TC shall return a value of one in bit 6.0.15 when a reset is in progress; otherwise, it shall return a value of zero. A TC is not required to accept a write transaction to any of its registers until the reset process is completed. The control and management interface shall be restored to operation within 0.5 s from the setting of bit 6.0.15. During a reset, a TC shall respond to reads from register bit 6.0.15.

NOTE—This operation may interrupt data communication. The data path of a TC, depending on type and temperature, may take many seconds to run at optimum error ratio after exiting from reset.

45.2.6.1.2 Speed selection (6.0.13, 6.0.6, 6.0.5:2)

Speed selection bits 6.0.13 and 6.0.6 shall both be written as a one. Any attempt to change the bits to an invalid setting shall be ignored. These two bits are set to one in order to make them compatible with Clause 22.

The operating mode of the TC may be selected using bits 5 through 2. The abilities of the TC are advertised in the TC speed ability register. A TC may ignore writes to the TC speed selection bits that select speeds it has not advertised in the TC speed ability register. It is the responsibility of the STA entity to ensure that mutually acceptable speeds are applied consistently across all the MMDs on a particular PHY.

The speed selection bits 6.0.5:2, when set to 0001, select the use of the 10PASS-TS and 2BASE-TL TC.

The TC speed selection defaults to a supported ability.

45.2.6.2 TC device identifier (Registers 6.2 and 6.3)

Registers 6.2 and 6.3 provide a 32-bit value, which may constitute a unique identifier for a particular type of TC. The identifier shall be composed of the 3rd through 24th bits of the Organizationally Unique Identifier (OUI) assigned to the device manufacturer by the IEEE, plus a six-bit model number, plus a four-bit revision number. A TC may return a value of zero in each of the 32 bits of the TC device identifier.

The format of the TC device identifier is specified in 22.2.4.3.1.

45.2.6.3 TC speed ability (Register 6.4)

The assignment of bits in the TC speed ability register is shown in Table 45–188.

Table 45–188—TC speed ability register bit definitions

Bit(s)	Name	Description	R/W[a]
6.4.15:1	Reserved for future speeds	Value always 0	RO
6.4.1	10PASS-TS/2BASE-TL capable	1 = TC is capable of operating as the 10P/2B TC 0 = TC is not capable of operating as the 10P/2B TC	RO
6.4.0	Reserved	Value always 0	RO

[a]RO = Read only

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45.2.6.3.1 10PASS-TS/2BASE-TL capable (6.4.1)

When read as a one, this bit indicates that the TC is able to operate as the 10PASS-TS/2BASE-TL TC, as specified in Clause 61.

45.2.6.4 TC devices in package registers (Registers 6.5, 6.6)

The TC devices in package registers are defined in Table 45–2.

45.2.6.5 TC package identifier registers (Registers 6.14, 6.15)

Registers 6.14 and 6.15 provide a 32-bit value, which may constitute a unique identifier for a particular type of package that the TC MMD is instantiated within. The identifier shall be composed of the 3rd through 24th bits of the Organizationally Unique Identifier (OUI) assigned to the package manufacturer by the IEEE, plus a six-bit model number, plus a four-bit revision number. A TC may return a value of zero in each of the 32 bits of the package identifier.

A non-zero package identifier may be returned by one or more MMDs in the same package. The package identifier may be the same as the device identifier.

The format of the package identifier is specified in 22.2.4.3.1.

45.2.6.6 10P/2B aggregation discovery control register (Register 6.16)

The 10P/2B aggregation discovery control register allows the STA of an -O port to determine the aggregation capabilities of an -R link-partner.

The 10P/2B aggregation discovery control register shall be implemented as a unique register for each TC MMD in a package. For example, a package implementing four PHYs would have four independent instances of the 10P/2B aggregation discovery control register, accessed by a read or write to each PHY.

For information on the encoding of this function on the physical link, see 61.4.7.

This register is defined for -O port subtypes only. The register bit definitions for the 10P/2B aggregation discovery control register are shown in Table 45–189.

Table 45–189—10P/2B aggregation discovery control register bit definitions

Bit(s)	Name	Description	R/W[a]
6.16.15:2	Reserved	Value always 0	RO
6.16.1:0	Discovery operation	01 = Ready (default) 00 = Set if clear 11 = Clear if same 10 = Get	R/W

[a]RO = Read only, R/W = Read/Write

45.2.6.6.1 Discovery operation (6.16.1:0)

The Discovery operation bits are used to query and manipulate the remote discovery register. The remote discover register is not a Clause 45 object, but a variable of the PME aggregation PCS function on -R ports.

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The Discovery operation makes use of G.994.1 handshaking messages, therefore valid only when the link status is down (i.e., neither Initializing nor Up). Attempts to perform an operation while the link is Initializing or Up shall be ignored.

The default state of these bits is "Ready". The bits shall indicate "Ready" any time the PME aggregation function is capable of performing an operation on the remote discovery register. If PAF is not supported, the discovery operation bits shall indicate "Ready" and ignore writes. These bits shall return to the "Ready" state upon MMD Reset.

If the STA sets the bits to "Get," the PME aggregation function queries the remote discovery register and returns its contents to the aggregation discovery code register.

If the STA sets the bits to "Set if clear," the PME aggregation function passes a message to the -R PCS instructing it to set the remote discovery register to the contents of the aggregation discovery code register, but only if the remote discovery register is all zeros.

If the STA sets the bits to "Clear if same," the PME aggregation function passes a message to the -R PCS instructing it to clear the remote discovery register, but only if the contents of the remote discovery register currently match the contents of the aggregation discovery code register.

While the requested operation is in progress, the PHY maintains the operation value in the bits. After the operation is complete, the PHY shall set the bits to indicate "Ready". If the operation does not complete within a 255 second time-out, the discovery operation result bit (6.17.0) will be set to "1" (operation unsuccessful), and the discovery operation bits will be set to "Ready".

45.2.6.7 10P/2B aggregation and discovery status register (Register 6.17)

The 10P/2B aggregation and discovery status register is defined for -O port subtypes only.

The assignment of bits in the 10P/2B aggregation and discovery status register is shown in Table 45–190.

Table 45–190—10P/2B aggregation and discovery status register bit definitions

Bit(s)	Name	Description	R/W[a]
6.17.15:2	Reserved	Value always 0	RO
6.17.1	Link partner aggregate operation result	1 = operation unsuccessful 0 = operation completed successfully (default)	RO, LH
6.17.0	Discovery operation result	1 = operation unsuccessful 0 = discovery operation completed successfully (default)	RO, LH

[a]RO = Read only, LH = Latching high

45.2.6.7.1 Link partner aggregate operation result (6.17.1)

When a link partner aggregate operation is complete, the PHY sets this bit to indicate the result of the operation. A "1" indicates that the operation could not be completed. This may be for a variety of reasons:

a) PMA/PMD link status is initializing or up.
b) The link partner is not present or not responding.

If PAF is not supported, this bit shall remain set to zero.

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45.2.6.7.2 Discovery operation result (6.17.0)

When a discovery operation is complete, the PHY sets this bit to indicate the result of the operation. A "1" indicates that the operation could not be completed. This may be for a variety of reasons:

a) PMA/PMD link status is initializing or up.
b) A "Set if clear" operation was requested but the remote discovery register was not clear.
c) A "Clear if same" operation was requested but the remote discovery register did not match the aggregation discovery code register.
d) The link partner is not present or not responding.

If PAF is not supported, this bit shall read as zero.

45.2.6.8 10P/2B aggregation discovery code (Registers 6.18, 6.19, 6.20)

The 10P/2B aggregation discovery code registers store the value of the remote_discovery_register exchanged with the -R link partner.

This register is defined for -O port subtypes only.

These registers shall be implemented as unique registers for each TC MMD in a package. For example, a package implementing four TCs would have four independent instances of the 10P/2B aggregation discovery code registers, accessed by a read or write to each PHY.

For information on the encoding of this function on the physical link, please see 61.4.7.

The assignment of bits for the 10P/2B aggregation discovery code registers are shown in Table 45–191.

Table 45–191—10P/2B aggregation discovery code bit definitions

Bit(s)	Name	Description	R/W[a]
6.18.15:0	Code [47:32]	The two most significant octets of the aggregation discovery code	R/W
6.19.15:0	Code [31:16]	The two middle octets of the aggregation discovery code	R/W
6.20.15:0	Code [15:0]	The two least significant octets of the aggregation discovery code	R/W

[a]R/W = Read/Write

45.2.6.9 10P/2B link partner PME aggregate control register (Register 6.21)

The 10P/2B link partner PME aggregate control register allows the STA of an -O port to read and write the remote PME_Aggregate_register (see 61.2.2.8.3).

The 10P/2B link partner PME aggregate control register shall be implemented as a unique register for each TC MMD in a package. For example, a package implementing four TCs would have four independent instances of the 10P/2B link partner PME aggregate control register, accessed by a read or write to each PHY.

This register is defined for -O port subtypes only.

The register bit definitions for the 10P/2B link partner PME aggregate control register are shown in Table 45–192.

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Table 45–192—10P/2B link partner PME aggregate control register bit definitions

Bit(s)	Name	Description	R/W[a]
6.21.15:2	Reserved	Value always 0	RO
6.21.1:0	Link partner aggregate operation	01 = Ready (default) 00 = Set 11 = invalid 10 = Get	R/W

[a]RO = Read only, R/W = Read/Write

45.2.6.9.1 Link partner aggregate operation (6.21.1:0)

The Link partner aggregate operation bits are used to query and manipulate the remote PME_Aggregate_register. This operation makes use of G.994.1 handshaking messages and therefore must be performed only when the link status is down (i.e., neither Initializing nor Up). Attempts to perform an operation while the link is Initializing or Up shall be ignored.

The default state of these bits is "Ready." The bits shall indicate "Ready" any time the PME aggregation function is capable of performing an operation on the remote PME_Aggregate_register. If PAF is not supported, the link partner aggregate operation bits shall indicate "Ready," ignore writes. These bits shall return to the "Ready" state upon MMD Reset.

If the STA sets the bits to "Get," the PME aggregation function queries the remote PME_Aggregate_register and returns its contents to the 10P/2B link partner PME aggregate data register (see 45.2.6.10).

If the STA sets the bits to "Set," the PME aggregation function passes a message to the -R PCS instructing it to set the bit location in the remote PME_Aggregate_register corresponding to the TC on which the message was received to the contents of bit 0 of the 10P/2B link partner PME aggregate data register.

While the requested operation is in progress, the PHY maintains the operation value in the bits. After the operation is complete, the PHY shall set the bits to indicate "Ready".

45.2.6.10 10P/2B link partner PME aggregate data (Registers 6.22, 6.23)

The 10P/2B link partner PME aggregate data registers store the data for the link partner aggregate operation. This register either contains the result of a "Get" operation, the data sent in a "Set" operation, or all zeros following an MMD reset.

These registers are defined for -O port subtypes only.

These registers shall be implemented as unique registers for each TC MMD in a package. For example, a package implementing four TCs would have four independent instances of the registers, accessed by a read or write to each PHY.

The assignment of bits for the 10P/2B link partner PME aggregate data registers are shown in Table 45–193.

Table 45–193—10P/2B link partner PME aggregate data registers bit definitions

Bit(s)	Name	Description	R/W[a]
6.22.15:0	Data[31:16]	The two most significant octets of the link partner PME aggregate data	R/W
6.23.15:0	Data[15:0]	The two least significant octets of the link partner PME aggregate data	R/W

[a]R/W = Read/Write

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45.2.6.11 10P/2B TC CRC error register (Register 6.24)

The 10P/2B TC CRC error register is a 16 bit counter that contains the number of TC frames received with the TC_CRC_error primitive asserted, defined in 61.2.3. These bits shall be reset to all zeros when the register is read by the management function or upon execution of the MMD reset. These bits shall be held at all ones in the case of overflow. The assignment of bits in the 10P/2B TC CRC error register are shown in Table 45–194.

Table 45–194—10P/2B TC CRC error register bit definitions

Bit(s)	Name	Description	R/W[a]
6.24.15:0	CRC errors[15:0]	The bytes of the counter	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.6.12 10P/2B TPS-TC coding violations counter (Registers 6.25, 6.26)

The 10P/2B TPS-TC coding violations counter is a 32-bit counter that contains the number of 64/64-octet encapsulation errors, defined in 61.3.3.1. This counter increments for each 64/65-octet received with the TC_coding_error signal asserted. These bits shall be reset to all zeros when the register is read by the management function or upon execution of the MMD reset. These bits shall be held at all ones in the case of overflow. The assignment of bits in the 10P/2B TPS-TC coding violations counter are shown in Table 45–195.

Table 45–195—10P/2B TPS-TC coding violations counter bit definitions

Bit(s)	Name	Description	R/W[a]
6.25.15:0	Coding violations[31:16]	The high order bytes of the counter	RO, MW
6.26.15:0	Coding violations[15:0]	The low order bytes of the counter	RO, MW

[a]RO = Read only, MW = Multi-word

45.2.6.13 10P/2B TC indications register (Register 6.27)

The 10P/2B TC indications register reflects the state of the TC sync detect state diagram and the state of the link partner TC sync detect state diagram (if present) (see 61.3.3.5). The assignment of bits in the 10P/2B TC indications register is shown in Table 45–196.

Table 45–196—10P/2B TC indications register bit definitions

Bit(s)	Name	Description	R/W[a]
6.27.15:9	Reserved	Value always 0	RO
6.27.8	Local TC synchronized	1 = TC_synchronized is TRUE 0 = TC_synchronized is FALSE	RO
6.27.7:1	Reserved	Value always 0	RO
6.27.0	Remote TC synchronized	1 = remote_TC_out_of_sync is FALSE 0 = remote_TC_out_of_sync is TRUE	RO

[a]RO = Read only

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45.2.6.13.1 Local TC synchronized (6.27.8)

This bit is read as a one when the TC_synchronized variable in the TC sync detect state diagram is TRUE (see 61.3.3.8). In all other cases, this bit is read as zero.

45.2.6.13.2 Remote TC synchronized (6.27.0)

This bit is read as a one when the remote_TC_out_of_sync variable in the link partner TC sync detect state diagram is FALSE (see 61.3.3.8). In all other cases, this bit is read as zero.

45.2.6.14 TimeSync TC capability (Register 6.1800)

The TimeSync TC capability register (see Table 45–197) indicates the capability of the TC to report the transmit and receive data delay, stored in registers 6.1801 through 6.1804 and 6.1805 through 6.1808, respectively.

Table 45–197—TimeSync TC capability

Bit(s)	Name	Description	R/W[a]
6.1800.15:2	Reserved	Value always 0	RO
6.1800.1	TimeSync transmit path data delay	1 = TC provides information on transmit path data delay in registers 6.1801 through 6.1804 0 = TC does not provide information on transmit path data delay	RO
6.1800.0	TimeSync receive path data delay	1 = TC provides information on receive path data delay in registers 6.1805 through 6.1808 0 = TC does not provide information on receive path data delay	RO

[a]RO = Read only

45.2.6.15 TimeSync TC transmit path data delay (Registers 6.1801, 6.1802, 6.1803, 6.1804)

The TimeSync TC transmit path data delay register contains the maximum (Registers 6.1801, 6.1802, see Table 45–198) and minimum (Registers 6.1803, 6.1804, see Table 45–198) values of the transmit path data delay. The transmit path data delay is expressed in units of ns. The values contained in these registers are valid when the link is established, as indicated by bit 2 in Register 1.1 (see 45.2.1.2.4).

Table 45–198—TimeSync TC transmit path data delay register

Bit(s)	Name	Description	R/W[a]
6.1801.15:0	Maximum TC transmit path data delay, lower	TC_delay_TX_max [15:0]	RO, MW
6.1802.15:0	Maximum TC transmit path data delay, upper	TC_delay_TX_max [31:16]	RO, MW
6.1803.15:0	Minimum TC transmit path data delay, lower	TC_delay_TX_min [15:0]	RO, MW
6.1804.15:0	Minimum TC transmit path data delay, upper	TC_delay_TX_min [31:16]	RO, MW

[a]RO = Read only, MW = Multi-word

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45.2.6.16 TimeSync TC receive path data delay (Registers 6.1805, 6.1806, 6.1807, 6.1808)

The TimeSync TC receive path data delay register contains the maximum (Registers 6.1805, 6.1806, see Table 45–199) and minimum (Registers 6.1807, 6.1808, see Table 45–199) values of the receive path data delay. The receive path data delay is expressed in units of ns. The values contained in these registers are valid when the link is established, as indicated by bit 2 in Register 1.1 (see 45.2.1.2.4).

Table 45–199—TimeSync TC receive path data delay register

Bit(s)	Name	Description	R/W[a]
6.1805.15:0	Maximum TC receive path data delay, lower	TC_delay_RX_max [15:0]	RO, MW
6.1806.15:0	Maximum TC receive path data delay, upper	TC_delay_RX_max [31:16]	RO, MW
6.1807.15:0	Minimum TC receive path data delay, lower	TC_delay_RX_min [15:0]	RO, MW
6.1808.15:0	Minimum TC receive path data delay, upper	TC_delay_RX_min [31:16]	RO, MW

[a]RO = Read only, MW = Multi-word

45.2.7 Auto-Negotiation registers

The assignment of registers in the Auto-Negotiation (AN) MMD is shown in Table 45–200.

Table 45–200—Auto-Negotiation MMD registers

Register address	Register name	Subclause
7.0	AN control	45.2.7.1
7.1	AN status	45.2.7.2
7.2, 7.3	AN device identifier	45.2.7.3
7.4	Reserved	
7.5, 7.6	AN devices in package	45.2.7.4
7.7 through 7.13	Reserved	
7.14, 7.15	AN package identifier	45.2.7.5
7.16 through 7.18	AN advertisement	45.2.7.6
7.19 through 7.21	AN LP Base Page ability	45.2.7.7
7.22 through 7.24	AN XNP transmit	45.2.7.8
7.25 through 7.27	AN LP XNP ability	45.2.7.9
7.28 through 7.31	Reserved	
7.32	10GBASE-T AN control	45.2.7.10
7.33	10GBASE-T AN status	45.2.7.11
7.34 through 7.47	Reserved	
7.48	Backplane Ethernet, BASE-R copper status	45.2.7.12
7.49 through 7.59	Reserved	
7.60	EEE advertisement	45.2.7.13

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Table 45–200—Auto-Negotiation MMD registers *(continued)*

Register address	Register name	Subclause
7.61	EEE LP ability	45.2.7.14
7.62 through 7.32 767	Reserved	
7.32 768 through 7.65 535	Vendor specific	

45.2.7.1 AN control register (Register 7.0)

The assignment of bits in the AN control register is shown in Table 45–201. The default value for each bit of the AN control register has been chosen so that the initial state of the device upon power up or completion of reset is a normal operational state without management intervention.

Table 45–201—AN control register bit definitions

Bit(s)	Name	Description	R/W[a]
7.0.15	AN reset	1 = AN reset 0 = AN normal operation	R/W SC
7.0.14	Reserved	Value always 0	RO
7.0.13	Extended Next Page control	1 = Extended Next Pages are enabled 0 = Extended Next Pages are disabled	R/W
7.0.12	Auto-Negotiation enable	1 = enable Auto-Negotiation process 0 = disable Auto-Negotiation process	R/W
7.0.11:10	Reserved	Value always 0	RO
7.0.9	Restart Auto-Negotiation	1 = Restart Auto-Negotiation process 0 = Auto-Negotiation in process, disabled, or not supported	R/W SC
7.0.8:0	Reserved	Value always 0	RO

[a]R/W = Read/Write, SC = Self-clearing, RO = Read only

A device that supports multiple port types may implement both Clause 22 control register operation and Clause 45 control register operation. Some control functions have been duplicated in both definitions. The register bits to control these functions are simply echoed in both locations; any reads or writes to these bits behave identically whether made through the Clause 22 location or the Clause 45 location.

45.2.7.1.1 AN reset (7.0.15)

Resetting AN is accomplished by setting bit 7.0.15 to a one. This action shall set all AN registers to their default states. As a consequence, this action may change the internal state of AN and the state of the physical link. This action may also initiate a reset in any other MMDs that are instantiated in the same package. This bit is self-clearing, and AN shall return a value of one in bit 7.0.15 when a reset is in progress and a value of zero otherwise. AN is not required to accept a write transaction to any of its registers until the reset process is complete. The reset process shall be completed within 0.5 s from the setting of bit 7.0.15. During an AN reset, AN shall respond to reads from register bit 7.0.15. All other register bits should be ignored.

The default value for bit 7.0.15 is zero. See 22.2.4.1.1.

NOTE—This operation may interrupt data communication.

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45.2.7.1.2 Extended Next Page control (7.0.13)

When bit 7.0.13 is set to one, Extended Next Page(s) are exchanged if the device(s) is/are capable. If a device intends to enable the exchange of Extended Next Page, it shall set bit 7.0.13 to one. A device may choose not to exchange Extended Next Page by setting bit 7.0.13 to zero. The Extended Next Page function is defined in 28.2.3.4. Setting of this bit shall have no effect if Extended Next Page ability bit 7.16.12 is set to zero.

The default value for bit 7.0.13 is one if bit 7.16.12 is one. Otherwise, bit 7.0.13 defaults to zero.

45.2.7.1.3 Auto-Negotiation enable (7.0.12)

The Auto-Negotiation function shall be enabled by setting bit 7.0.12 to a one. If bit 7.0.12 is set to one, then speed selection bits 1.0.13, 1.0.6, and bits 1.0.5:2 in PHY control register 1 and PHY type selection bits 1.7.3:0 in PHY control register 2 shall have no effect on the link configuration, and the Auto-Negotiation process determines the link configuration. If bit 7.0.12 is cleared to zero, then bits 1.0.13, 1.0.6, and bits 1.0.5:2 in control register 1 and type selection bit 1.7.3:0 in control register 2 determines the link configuration regardless of the prior state of the link configuration and the Auto-Negotiation process. Bit 7.0.12 is a copy of bit 0.12 in register 0 if present (see 22.2.4.1.4).

The default value of bit 7.0.12 is one, unless the PHY reports via bit 7.1.3 or 1.3 if present (see 22.2.4.2.12) that it lacks the ability to perform Auto-Negotiation, in which case the default value of bit 7.0.12 is zero (see 22.2.4.1.4).

45.2.7.1.4 Restart Auto-Negotiation (7.0.9)

If the PMA/PMD reports (via bit 7.1.3) that it lacks the ability to perform Auto-Negotiation, or if Auto-Negotiation is disabled, the PMA/PMD shall return a value of zero in bit 7.0.9 and any attempt to write a one to bit 7.0.9 shall be ignored.

Otherwise, the Auto-Negotiation process shall be restarted by setting bit 7.0.9 to one. This bit is self-clearing, and a PMA/PMD shall return a value of one in bit 7.0.9 until the Auto-Negotiation process has been initiated. If Auto-Negotiation was completed prior to this bit being set, the process shall be reinitiated. The Auto-Negotiation process shall not be affected by clearing this bit to zero. Bit 7.0.9 is a copy of 0.9 in register 0, if present (see 22.2.4.1.7).

The default value for 7.0.9 is zero (see 22.2.4.1.7).

45.2.7.2 AN status (Register 7.1)

The assignment of bits in the AN status register is shown in Table 45–202. All the bits in the AN status register are read only; therefore, a write to the AN status register shall have no effect.

Table 45–202—AN status register

Bit(s)	Name	Description	R/W[a]
7.1.15:10	Reserved	Value always 0	RO
7.1.9	Parallel detection fault	1 = A fault has been detected via the parallel detection function. 0 = A fault has not been detected via the parallel detection function.	RO LH
7.1.8	Reserved	Value always 0	RO
7.1.7	Extended Next Page status	1 = Extended Next Page format is used 0 = Extended Next Page is not allowed	RO

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Table 45–202—AN status register *(continued)*

Bit(s)	Name	Description	R/W[a]
7.1.6	Page received	1 = A page has been received 0 = A page has not been received	RO LH
7.1.5	Auto-Negotiation complete	1 = Auto-Negotiation process completed 0 = Auto-Negotiation process not completed	RO
7.1.4	Remote fault	1 = remote fault condition detected 0 = no remote fault condition detected	RO LH
7.1.3	Auto-Negotiation ability	1 = PHY is able to perform Auto-Negotiation 0 = PHY is not able to perform Auto-Negotiation	RO
7.1.2	Link status	1 = Link is up 0 = Link is down	RO LL
7.1.1	Reserved	Value always 0	RO
7.1.0	Link partner Auto-Negotiation ability	1 = LP is able to perform Auto-Negotiation 0 = LP is not able to perform Auto-Negotiation	RO

[a]RO = Read only, LH = Latching high, LL = Latching low

45.2.7.2.1 Parallel detection fault (7.1.9)

The parallel detection Fault bit (7.1.9) shall be set to one to indicate that more than one of 1000BASE-KX or 10GBASE-KX4 PMAs have indicated link_status=OK when the autoneg_wait_timer expires. The parallel detection fault bit shall be reset to zero on a read of the AN status register (Register 7.1).

45.2.7.2.2 Extended Next Page status (7.1.7)

When set to one, bit 7.1.7 indicates that both the local device and the link partner have indicated support for Extended Next Page. When set to zero, bit 7.1.7 indicates that Extended Next Page shall not be used. If bit 7.0.13 or bit 7.16.12 are set to zero then this bit shall not be set to one.

45.2.7.2.3 Page received (7.1.6)

The Page received bit (7.1.6) shall be set to one to indicate that a new link codeword has been received and stored in the AN LP Base Page ability registers 7.19 to 7.21 or AN LP XNP ability registers 7.25 to 7.27. The contents of the AN LP Base Page ability registers 7.19 to 7.21 are valid when bit 7.1.6 is set the first time during the Auto-Negotiation. The Page received bit shall be reset to zero on a read of the AN status register (Register 7.1) or if present, the Auto-Negotiation expansion register 6 (see 28.2.4.1.5). This bit is a copy of bit 6.1 in register 6, if present (see 28.2.4.1.5).

45.2.7.2.4 Auto-Negotiation complete (7.1.5)

When read as a one, bit 7.1.5 indicates that the Auto-Negotiation process has been completed, and that the contents of the Auto-Negotiation register 7.16 and 7.19 are valid. When read as a zero, bit 7.1.5 indicates that the Auto-Negotiation process has not been completed, and that the contents of 7.19, 7.22 through 7.27, and 7.33 registers are as defined by the current state of the Auto-Negotiation protocol, or as written for manual configuration. A PMA/PMD shall return a value of zero in bit 7.1.5 if Auto-Negotiation is disabled by clearing bit 7.0.12. A PMA/PMD shall also return a value of zero in bit 7.1.5 if it lacks the ability to perform Auto-Negotiation. Bit 7.1.5 is a copy of bit 1.5 in register 1, if present (see 22.2.4).

45.2.7.2.5 Remote fault (7.1.4)

When read as one, bit 7.1.4 indicates that a remote fault condition has been detected. The type of fault as well as the criteria and method of fault detection is AN specific. The remote fault bit shall be implemented

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with a latching function, such that the occurrence of a remote fault causes the bit 7.1.4 to become set and remain set until it is cleared. Bit 7.1.4 shall be cleared each time register 7.1 is read via the management interface, and shall also be cleared by a AN reset. Bit 7.1.4 is a copy of bit 1.4 in register 1, if present (see 22.2.4).

45.2.7.2.6 Auto-Negotiation ability (7.1.3)

When read as a one, bit 7.1.3 indicates that the PMA/PMD has the ability to perform Auto-Negotiation. When read as a zero, bit 7.1.3 indicates that the PMA/PMD lacks the ability to perform Auto-Negotiation. Bit 7.1.3 is a copy of bit 1.3 in register 1, if present (see 22.2.4).

45.2.7.2.7 Link status (7.1.2)

When read as a one, bit 7.1.2 indicates that the PMA/PMD has determined that a valid link has been established. When read as a zero, bit 7.1.2 indicates that the link has been invalid after this bit was last read. Bit 7.1.2 is set to one when the variable link_status equals OK and is cleared to zero when the variable link_status equals FAIL. The link status bit shall be implemented with a latching function, such that the occurrence of a link_status equals FAIL condition causes the link status bit to become cleared and remain cleared until it is read via the management interface. Bit 7.1.2 shall be cleared upon AN reset. This status indication is intended to support the management attribute defined in 30.5.1.1.4, aMediaAvailable.

45.2.7.2.8 Link partner Auto-Negotiation ability (7.1.0)

The link partner Auto-Negotiation ability bit shall be set to one to indicate that the link partner is able to participate in the Auto-Negotiation function. This bit shall be reset to zero if the link partner is not Auto-Negotiation able.

45.2.7.3 Auto-Negotiation device identifier (Registers 7.2 and 7.3)

Registers 7.2 and 7.3 provide a 32-bit value, which may constitute a unique identifier for an Auto-Negotiation. The identifier shall be composed of the 3rd through 24th bits of the Organizationally Unique Identifier (OUI) assigned to the device manufacturer by the IEEE, plus a six-bit model number, plus a 4-bit revision number. An Auto-Negotiation may return a value of zero in each of the 32 bits of the Auto-Negotiation device identifier.

The format of the Auto-Negotiation device identifier is specified in 22.2.4.3.1.

45.2.7.4 AN devices in package (Registers 7.5 and 7.6)

The AN devices in package registers are defined in Table 45–2.

45.2.7.5 AN package identifier (Registers 7.14 and 7.15)

Registers 7.14 and 7.15 provide a 32-bit value, which may constitute a unique identifier for a particular type of package that the Auto-Negotiation is instantiated within. The identifier shall be composed of the 3rd through 24th bits of the OUI assigned to the package manufacturer by the IEEE, plus a six-bit model number, plus a four-bit revision number. An Auto-Negotiation MMD may return a value of zero in each of the 32 bits of the Auto-Negotiation package identifier.

A non-zero package identifier may be returned by one or more MMDs in the same package. The package identifier may be the same as the device identifier.

The format of the Auto-Negotiation package identifier is specified in 22.2.4.3.1.

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45.2.7.6 AN advertisement register (7.16, 7.17, and 7.18)

If the BP AN ability bit (7.48.0) in the BP Ethernet status register is set to zero then only sixteen bits of the AN advertisement register are used and they are defined in 28.2.1.2.

If the BP AN ability bit (7.48.0) in the BP Ethernet status register is set to one then all forty eight bits are used and they are defined in 73.6.

The Selector field (7.16.4:0) is set to the IEEE 802.3 code as specified in Annex 28A. The Acknowledge bit (7.16.14) is set to zero.

The technology ability field, as defined in 28.2.1.2 and 73.6, represents the technologies supported by the local device. Only bits representing supported technologies may be set. Management may clear bits in the technology ability field and restart Auto-Negotiation to negotiate an alternate common mode.

The management entity initiates renegotiation with the link partner using alternate abilities by setting the Restart Auto-Negotiation bit (7.0.9) in the AN control register to one.

Any writes to this register prior to completion of Auto-Negotiation, as indicated by bit 7.1.5, should be followed by a renegotiation for the new values to take effect. Once Auto-Negotiation has completed, software may examine this register along with the LP Base Page ability register to determine the highest common denominator technology.

If the Auto-Negotiation advertisement register (Register 4) is present, (see 28.2.4.1.3), then this register is a copy of the Auto-Negotiation advertisement register (Register 4). In this case, reads to the AN advertisement register (7.16) report the value of the Auto-Negotiation advertisement register (Register 4); writes to the AN advertisement register (7.16) cause a write to occur to the Auto-Negotiation advertisement register.

The Base Page value is transferred to mr_adv_ability when register 7.16 is written. Therefore, if used, registers 7.17 and 7.18 should be written before 7.16.

Table 45–203—AN advertisement register bit definitions

Bit(s)	Name	Description	R/W[a]
7.16.15	Next Page	See 28.2.1.2 and 73.6.9	R/W
7.16.14	Acknowledge	Value always 0, writes ignored	RO
7.16.13	Remote fault	See 28.2.1.2 and 73.6.7	R/W
7.16.12:5	D12:D5	See 28.2.1.2 and 73.6	R/W
7.16.4:0	Selector field	See Annex 28A	R/W
7.17.15:0	D31:D16	See 73.6	R/W
7.18.15:0	D47:D32	See 73.6	R/W

[a]R/W = Read/Write, RO = Read only

NOTE 1—Auto-Negotiation that supports a 48-bit Base Page uses registers 7.16, 7.17, and 7.18 for storing Base Page information; Auto-Negotiation that supports a 16-bit Base Page only uses register 7.16 for storing Base Page information.

NOTE 2—Clause 37 1000BASE-X Auto-Negotiation is controlled through Clause 22 registers.

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45.2.7.7 AN LP Base Page ability register (7.19, 7.20, and 7.21)

All of the bits in the AN LP Base Page ability register are read only. A write to the AN LP Base Page ability register shall have no effect.

Register 7.19 is a copy of register 5, if present (see 28.2.4.1).

When registers 7.20 and 7.21 are used, the value of the registers 7.20 and 7.21 is latched when register 7.19 is read and reads of registers 7.20 and 7.21 return the latched value rather than the current value.

Bit 7.19.12 is reserved for Backplane Ethernet port types as they do not use Extended Next Pages.

Table 45–204—AN LP Base Page ability register bit definitions

Bit(s)	Name	Description	R/W[a]
7.19.15:0	D15:D0	See 28.2.1.2 and 73.6	RO
7.20.15:0	D31:D16	See 73.6	RO
7.21.15:0	D47:D32	See 73.6	RO

[a]RO = Read only

NOTE—Auto-Negotiation that supports a 48-bit Base Page uses registers 7.19, 7.20, and 7.21 for storing LP Base Page information; Auto-Negotiation that supports a 16-bit Base Page only use register 7.19 for storing LP Base Page information.

45.2.7.8 AN XNP transmit register (7.22, 7.23, and 7.24)

If the BP AN ability bit (7.48.0) in the BP Ethernet status register is set to zero then Extended Next Pages are enabled by setting bit 7.0.13 to one and the AN XNP transmit register contains the Next Page link codeword to be transmitted as defined in 28.2.3.4.

If the BP AN ability bit (7.48.0) is set to one then Next Page transmission is always enabled and the register contains the AN LD Next Page link codeword of the BP Ethernet PHY as defined in 73.7.7.1. Even though Backplane Ethernet does not use Extended Next Pages XNP is still used in the register name.

On power-up or AN reset, this register shall contain the default value, which represents a Message Page with the message code set to Null Message. This value may be replaced by any valid Extended Next Page message code that the device intends to transmit.

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A write to register 7.23 or 7.24 does not set mr_next_page_loaded. Only a write to register 7.22 sets mr_next_page_loaded true as described in 28.2.4.1.8. Therefore registers 7.23 and 7.24 register should be written before register 7.22.

Table 45–205—AN XNP transmit register bit definitions

Bit(s)	Name	Description	R/W[a]
7.22.15	Next Page	See 28.2.3.4 and 73.7.7.1	R/W
7.22.14	Reserved	Value always 0	RO
7.22.13	Message Page	See 28.2.3.4 and 73.7.7.1	R/W
7.22.12	Acknowledge 2	See 28.2.3.4 and 73.7.7.1	R/W
7.22.11	Toggle	See 28.2.3.4 and 73.7.7.1	RO
7.22.10:0	Message/Unformatted Code Field	See 28.2.3.4 and 73.7.7.1	R/W
7.23.15:0	Unformatted Code Field 1	See 28.2.3.4 and 73.7.7.1	R/W
7.24.15:0	Unformatted Code Field 2	See 28.2.3.4 and 73.7.7.1	R/W

[a]R/W = Read/Write, RO = Read only

45.2.7.9 AN LP XNP ability register (7.25, 7.26, and 7.27)

AN LP XNP ability register (registers 7.25, 7.26, and 7.27) store link partner Extended Next Pages as shown in Table 45–206. All of the bits in the AN LP XNP ability register are read only. A write to the AN LP XNP ability register shall have no effect.

The value of registers 7.26 and 7.27 is latched when register 7.25 is read and reads of registers 7.26 and 7.27 return the latched value rather than the current value.

NOTE—If this register is used to store multiple link partner Extended Next Pages, the previous value of this register is assumed to be stored by a management entity that needs the information overwritten by subsequent link partner Extended Next Pages.

Table 45–206—AN LP XNP ability register bit definitions

Bit(s)	Name	Description	R/W[a]
7.25.15	Next Page	See 28.2.3.4 and 73.7.7.1	RO
7.25.14	Acknowledge	See 28.2.3.4 and 73.7.7.1	RO
7.25.13	Message Page	See 28.2.3.4 and 73.7.7.1	RO
7.25.12	Acknowledge 2	See 28.2.3.4 and 73.7.7.1	RO
7.25.11	Toggle	See 28.2.3.4 and 73.7.7.1	RO
7.25.10:0	Message/Unformatted Code Field	See 28.2.3.4 and 73.7.7.1	RO
7.26.15:0	Unformatted Code Field 1	See 28.2.3.4 and 73.7.7.1	RO
7.27.15:0	Unformatted Code Field 2	See 28.2.3.4 and 73.7.7.1	RO

[a]RO = Read only

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45.2.7.10 10GBASE-T AN control register (Register 7.32)

The assignment of bits in the 10GBASE-T AN control register is shown in Table 45–207. The default values for each bit of the 10GBASE-T AN control register should be chosen so that the initial state of the device upon power up or reset is a normal operational state without management intervention.

Table 45–207—10GBASE-T AN control register

Bit(s)	Name	Description	R/W[a]
7.32.15	MASTER-SLAVE manual config enable	1=Enable MASTER-SLAVE manual configuration 0=Disable MASTER-SLAVE manual configuration Default value is 0	R/W
7.32.14	MASTER-SLAVE config value	1=Configure PHY as MASTER 0=Configure PHY as SLAVE Default value is 0	R/W
7.32.13	Port type	1=Multiport device 0=single-port device	R/W
7.32.12	10GBASE-T ability	1 = Advertise PHY as 10GBASE-T capable 0 = Do not advertise the PHY as 10GBASE-T capable	R/W
7.32.11:3	Reserved	Value always 0	RO
7.32.2	LD PMA training reset request	1 = Local device requests that link partner reset PMA training PRBS every frame 0 = Local device requests that link partner run PMA training PRBS continuously	R/W
7.32.1	Fast retrain ability	1 = Advertise PHY as 10GBASE-T fast retrain capable 0 = Do not advertise PHY as 10GBASE-T fast retrain capable	R/W
7.32.0	LD loop timing ability	1 = Advertise PHY as capable of loop timing 0 = Do not advertise PHY as capable of loop timing	R/W

[a]R/W = Read/Write, RO = Read only

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45.2.7.10.1 MASTER-SLAVE manual config enable (7.32.15)

If bit 7.32.15 is set to one then MASTER-SLAVE config value bit 7.32.14 is used to determine if the PHY operates as MASTER or SLAVE. If bit 7.32.15 is set to zero the PHY shall use Auto-Negotiation to determine the selection of MASTER or SLAVE. This bit is a copy of 9.12, if present (see 40.5.1.1), and any write to either 7.32.15 or 9.12 is reflected in both. Additional information regarding the resolution and selection of MASTER-SLAVE and bit 7.32.15 is contained in 55.6.2. The default value for bit 7.32.15 is zero.

45.2.7.10.2 MASTER-SLAVE config value (7.32.14)

Bit 7.32.14 is used to select MASTER or SLAVE operation if MASTER-SLAVE manual config bit 7.32.15 is set to one. If bit 7.32.14 is set to one the PHY shall operate as MASTER. If bit 7.32.14 is set to zero the PHY shall operate as SLAVE. This bit is a copy of 9.11 (see 40.5.1.1), if present, and any write to either 7.32.14 or 9.11 is reflected in both. Additional information regarding the resolution and selection of MASTER-SLAVE and bit 7.32.14 is contained in 55.6.2. The default value for bit 7.32.14 is zero.

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45.2.7.10.3 Port type (7.32.13)

Bit 7.32.13 is to be used to indicate the preference during Auto-Negotiation to operate as MASTER (multiport device) or as SLAVE (single-port device) if the MASTER-SLAVE manual configuration enable bit 7.32.15 is zero. If bit 7.32.13 is set to one a preference to operate as MASTER is indicated. If bit 7.32.13 is set to zero a preference to operate as SLAVE is indicated. This bit is a copy of 9.10 (see 40.5.1.1), if present, and any write to either 7.32.13 or 9.10 is reflected in both. Subclause 55.6.2 contains additional information regarding the resolution and selection of MASTER-SLAVE and this bit.

45.2.7.10.4 10GBASE-T capability (7.32.12)

Bit 7.32.12 is to be used to select whether or not Auto-Negotiation advertises the ability to operate as a 10GBASE-T PHY. If bit 7.32.12 is set to one the PHY shall advertise 10GBASE-T PHY capability. If bit 7.32.12 is set to zero the PHY shall not advertise 10GBASE-T PHY capability.

45.2.7.10.5 LD PMA training reset request (7.32.2)

If bit 7.32.2 is set to one then the local device expects the link partner to reset the PMA training PRBS for every PMA training frame. If bit 7.32.2 is zero then the local device expects link partner to run PMA training PRBS continuously through every PMA training frame.

45.2.7.10.6 Fast retrain ability

Bit 7.32.1 is used to select whether or not Auto-Negotiation advertises the ability to support 10GBASE-T fast retrain. If bit 7.32.1 is set to one, the PHY shall advertise fast retrain ability. If bit 7.32.1 is set to zero, the PHY shall not advertise fast retrain ability.

45.2.7.10.7 LD loop timing ability (7.32.0)

Bit 7.32.0 is to be used to select whether or not Auto-Negotiation advertises the ability to perform loop timing. If bit 7.32.0 is set to one the PHY shall advertise loop timing capability. If bit 7.32.0 is set to zero the PHY shall not advertise loop timing capability.

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45.2.7.11 10GBASE-T AN status register (Register 7.33)

The assignment of bits in the 10GBASE-T AN status register is shown in Table 45–208. All the bits in the 10GBASE-T AN status register are read only; a write shall have no effect.

Table 45–208—10GBASE-T AN status register

Bit(s)	Name	Description	R/W[a]
7.33.15	MASTER-SLAVE configuration fault	1 = MASTER-SLAVE configuration fault detected 0 = No MASTER-SLAVE configuration fault detected	RO LH SC
7.33.14	MASTER-SLAVE configuration resolution	1 = Local PHY configuration resolved to MASTER 0 = Local PHY configuration resolved to SLAVE	RO
7.33.13	Local receiver status	1 = Local receiver OK 0 = Local receiver not OK	RO
7.33.12	Remote receiver status	1 = Remote receiver OK 0 = Remote receiver not OK	RO
7.33.11	Link partner 10GBASE-T capability	1 = Link partner is able to operate as 10GBASE-T 0 = Link partner is not able to operate as 10GBASE-T This bit is guaranteed to be valid only when the Page received bit (7.1.6) has been set to 1.	RO
7.33.10	LP loop timing ability	1 = Link partner is capable of loop timing 0 = Link partner is not capable of loop timing	RO
7.33.9	LP PMA training reset request	1 = Link partner requests that local device reset PMA training PRBS every frame 0 = Link partner requests that local device run PMA training PRBS continuously	RO
7.33.8:2	Reserved	Value always 0	RO
7.33.1	Fast retrain ability	1 = Link partner is capable of 10GBASE-T fast retrain 0 = Link partner is not capable of 10GBASE-T fast retrain	RO
7.33.0	Reserved	Value always 0	RO

[a]RO = Read only, SC = Self-clearing, LH = Latching high

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45.2.7.11.1 MASTER-SLAVE configuration fault (7.33.15)

MASTER-SLAVE configuration fault bit 7.33.15 shall be set in the event that determination of the MASTER-SLAVE cannot be successfully concluded. MASTER-SLAVE configuration fault, as well as the criteria and method of fault detection, is PHY specific. Additional information regarding the resolution and selection of MASTER-SLAVE and bit 7.33.15 for 10GBASE-T in contained in 55.6.2. The MASTER-SLAVE configuration fault bit 7.33.15 shall be cleared each time the 10GBASE-T status register 7.33 is read via the management interface and shall be cleared by a 10GBASE-T PMA reset. Bit 7.33.15 shall self clear upon Auto-Negotiation enable.

45.2.7.11.2 MASTER-SLAVE configuration resolution (7.33.14)

Bit 7.33.14 is determined by the MASTER-SLAVE configuration resolution function described in 55.6.2. If the MASTER-SLAVE configuration resolution bit 7.33.14 is set to one and the Auto-Negotiation complete bit 7.1.5 is set and if MASTER-SLAVE configuration fault bit 7.33.15 in the 10GBASE-T status register is

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zero, then MASTER mode of operation has been selected. If the MASTER-SLAVE configuration resolution bit 7.33.14 is set to zero and the Auto-Negotiation complete bit 7.1.5 is set and if MASTER-SLAVE configuration fault bit 7.33.15 in the 10GBASE-T status register is zero, then SLAVE mode of operation has been selected.

45.2.7.11.3 Local receiver status (7.33.13)

Local receiver status bit 7.33.13 shall be set if the local receiver is OK as defined in 55.2.2.7. If the local receiver status bit 7.33.13 is zero, the local receiver is not OK as defined in 55.2.2.7.2.

45.2.7.11.4 Remote receiver status (7.33.12)

Remote receiver status bit 7.33.13 shall be set if the remote receiver status is OK as defined in 55.2.2.8. If the local receiver status bit 7.33.13 is zero, the local receiver is not OK as defined in 55.2.2.8.2.

45.2.7.11.5 Link partner 10GBASE-T capability (7.33.11)

The bit is only valid when page receive bit 7.1.6 in is set to one. When read as a one, bit 7.33.11 indicates that the link partner is able to operate as 10GBASE-T. When read as a zero, bit 7.33.11 indicates that the link partner is not able to operate as 10GBASE-T.

45.2.7.11.6 Link partner loop timing ability (7.33.10)

When read as a one, bit 7.33.10 indicates that the link partner has the ability to support loop timing as specified in 55.1.3. When read as a zero, bit 7.33.10 indicates that the link partner lacks the ability to support loop timing.

45.2.7.11.7 Link partner PMA training reset request (7.33.9)

If bit 7.33.9 is set to one then the link partner is expecting the local device to reset the PMA training PRBS for every PMA training frame. If bit 7.33.9 is zero then the link partner expects the local device to run PMA training PRBS continuously through every PMA training frame.

45.2.7.11.8 Fast retrain ability (7.33.1)

When read as a one, bit 7.33.1 is used to indicate that the link partner has the ability to support the fast retrain capability as specified in 55.4.2.5.15. When read as a zero, bit 7.33.1 indicates that the PHY lacks the ability to support the fast retrain capability.

45.2.7.12 Backplane Ethernet, BASE-R copper status (Register 7.48)

The assignment of bits in the Backplane Ethernet, BASE-R copper status register is shown in Table 45–209.

Table 45–209—Backplane Ethernet, BASE-R copper status register (Register 7.48) bit definitions

Bit(s)	Name	Description	R/W[a]
7.48.15:12	Reserved	Value always 0	RO
7.48.11	100GBASE-CR4	1 = PMA/PMD is negotiated to perform 100GBASE-CR4 0 = PMA/PMD is not negotiated to perform 100GBASE-CR4	RO

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Table 45–209—Backplane Ethernet, BASE-R copper status register (Register 7.48) bit definitions *(continued)*

7.48.10	100GBASE-KR4	1 = PMA/PMD is negotiated to perform 100GBASE-KR4 0 = PMA/PMD is not negotiated to perform 100GBASE-KR4	RO
7.48.9	100GBASE-KP4	1 = PMA/PMD is negotiated to perform 100GBASE-KP4 0 = PMA/PMD is not negotiated to perform 100GBASE-KP4	RO
7.48.8	100GBASE-CR10	1 = PMA/PMD is negotiated to perform 100GBASE-CR10 0 = PMA/PMD is not negotiated to perform 100GBASE-CR10	RO
7.48.7	Reserved	Value always 0	RO
7.48.6	40GBASE-CR4	1 = PMA/PMD is negotiated to perform 40GBASE-CR4 0 = PMA/PMD is not negotiated to perform 40GBASE-CR4	RO
7.48.5	40GBASE-KR4	1 = PMA/PMD is negotiated to perform 40GBASE-KR4 0 = PMA/PMD is not negotiated to perform 40GBASE-KR4	RO
7.48.4	BASE-R FEC negotiated	1 = PMA/PMD is negotiated to perform BASE-R FEC 0 = PMA/PMD is not negotiated to perform BASE-R FEC	RO
7.48.3	10GBASE-KR	1 = PMA/PMD is negotiated to perform 10GBASE-KR 0 = PMA/PMD is not negotiated to perform 10GBASE-KR	RO
7.48.2	10GBASE-KX4	1 = PMA/PMD is negotiated to perform 10GBASE-KX4 or CX4 0 = PMA/PMD is not negotiated to perform 10GBASE-KX4/CX4	RO
7.48.1	1000BASE-KX	1 = PMA/PMD is negotiated to perform 1000BASE-KX 0 = PMA/PMD is not negotiated to perform 1000BASE-KX	RO
7.48.0	BP AN ability	If a Backplane, BASE-R copper PHY type is implemented, this bit is set to 1	RO

[a]RO = Read only

45.2.7.12.1 BASE-R FEC negotiated (7.48.4)

When the Auto-Negotiation process has completed as indicated by the AN complete bit (7.1.5), bit 7.48.4 indicates that BASE-R FEC operation has been negotiated. This bit is set only if a BASE-R PHY supporting FEC operation has also been negotiated.

45.2.7.12.2 Negotiated Port Type (7.48.1, 7.48.2, 7.48.3, 7.48.5, 7.48.6, 7.48.8, 7.48.9, 7.48.10, 7.48.11)

When the AN process has been completed as indicated by the AN complete bit, these bits (1000BASE-KX, 10GBASE-KX4, 10GBASE-KR, 40GBASE-KR4, 40GBASE-CR4, 100GBASE-CR10, 100GBASE-KP4, 100GBASE-KR4, 100GBASE-CR4) indicate the negotiated port type. Only one of these bits is set depending on the priority resolution function. System developers need to distinguish between parallel detection of 10GBASE-KX4 and 10GBASE-CX4 based on the MDI and media type present.

45.2.7.12.3 Backplane Ethernet, BASE-R copper AN ability (7.48.0)

If a Backplane, BASE-R copper PHY type is implemented, this bit shall be set to 1.

When read as a one, bit 7.48.0 indicates that the PMA/PMD has the ability to perform Backplane Ethernet, BASE-R copper AN. When read as a zero, bit 7.48.0 indicates that the PMA/PMD lacks the ability to perform Backplane Ethernet BASE-R copper AN.

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45.2.7.13 EEE advertisement (Register 7.60)

This register defines the EEE advertisement that is sent in the Unformatted Next Page following a EEE technology message code as defined in 28C.12 or sent in the unformatted code field of Message Next Page with EEE technology message code as defined in 73A.4 or sent as part of the 10GBASE-T and 1000BASE-T technology message code as defined in 28C.11. The assignment of bits in the EEE advertisement register and the correspondence with the bits in the Next Page messages are shown in Table 45–210.

Bits 10:0 of register 7.60 map to bits U10 through U0 respectively of the Unformatted Next Page following a EEE technology message code as defined in 28C.12. Bits 15:0 of register 7.60 map to bits U15 through U0 respectively of the unformatted code field of Message Next Page with EEE technology message code as defined in 73A.4. Bits 3:1 of register 7.60 also map to bits U24 through U22 respectively of the 10GBASE-T and 1000BASE-T technology message code as defined in 28C.11. Devices using Clause 28 auto-negotiation may ignore bits defined for Clause 73 auto-negotiation, and devices using Clause 73 auto-negotiation may ignore bits defined for Clause 28 auto-negotiation.

Table 45–210—EEE advertisement register (Register 7.60) bit definitions

Bit(s)	Name	Description	Clause reference; Next Page bit number	R/W[a]
7.60.15:14	Reserved	Value always 0		RO
7.60.13	100GBASE-CR4 EEE	1 = Advertise that the 100GBASE-CR4 has EEE deep sleep capability 0 = Do not advertise that the 100GBASE-CR4 has EEE deep sleep capability	73.7.7.1; U13	R/W
7.60.12	100GBASE-KR4 EEE	1 = Advertise that the 100GBASE-KR4 has EEE deep sleep capability 0 = Do not advertise that the 100GBASE-KR4 has EEE deep sleep capability	73.7.7.1; U12	R/W
7.60.11	100GBASE-KP4 EEE	1 = Advertise that the 100GBASE-KP4 has EEE deep sleep capability 0 = Do not advertise that the 100GBASE-KP4 has EEE deep sleep capability	73.7.7.1; U11	R/W
7.60.10	100GBASE-CR10 EEE	1 = Advertise that the 100GBASE-CR10 has EEE deep sleep capability 0 = Do not advertise that the 100GBASE-CR10 has EEE deep sleep capability	73.7.7.1; U10	R/W
7.60.9	Reserved	Value always 0		RO
7.60.8	40GBASE-CR4 EEE	1 = Advertise that the 40GBASE-CR4 has EEE deep sleep capability 0 = Do not advertise that the 40GBASE-CR4 has EEE deep sleep capability	73.7.7.1; U8	R/W
7.60.7	40GBASE-KR4 EEE	1 = Advertise that the 40GBASE-KR4 has EEE deep sleep capability 0 = Do not advertise that the 40GBASE-KR4 has EEE deep sleep capability	73.7.7.1; U7	R/W
7.60.6	10GBASE-KR EEE	1 = Advertise that the 10GBASE-KR has EEE capability 0 = Do not advertise that the 10GBASE-KR has EEE capability	73.7.7.1; U6	R/W

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Table 45–210—EEE advertisement register (Register 7.60) bit definitions *(continued)*

7.60.5	10GBASE-KX4 EEE	1 = Advertise that the 10GBASE-KX4 has EEE capability 0 = Do not advertise that the 10GBASE-KX4 has EEE capability	73.7.7.1; U5	R/W
7.60.4	1000BASE-KX EEE	1 = Advertise that the 1000BASE-KX has EEE capability 0 = Do not advertise that the 1000BASE-KX has EEE capability	73.7.7.1; U4	R/W
7.60.3	10GBASE-T EEE	1 = Advertise that the 10GBASE-T has EEE capability 0 = Do not advertise that the 10GBASE-T has EEE capability	28.2.3.4.1; U3 / 28.2.3.4.2; U24	R/W
7.60.2	1000BASE-T EEE	1 = Advertise that the 1000BASE-T has EEE capability 0 = Do not advertise that the 1000BASE-T has EEE capability	28.2.3.4.1; U2 / 28.2.3.4.2; U23	R/W
7.60.1	100BASE-TX EEE	1 = Advertise that the 100BASE-TX has EEE capability 0 = Do not advertise that the 100BASE-TX has EEE capability	28.2.3.4.1; U1 / 28.2.3.4.2; U22	R/W
7.60.0	Reserved	Value always 0		RO

[a]R/W = Read/Write, RO = Read only

45.2.7.13.1 100GBASE-CR4 EEE supported (7.60.13)

Support for EEE deep sleep operation for 100GBASE-CR4, as defined in 92.1, shall be advertised if this bit is set to one. Support for EEE deep sleep operation should only be advertised if it is supported on all sublayers of the PHY as well as physical instantiations of the PMA service interface as appropriate.

45.2.7.13.2 100GBASE-KR4 EEE supported (7.60.12)

Support for EEE deep sleep operation for 100GBASE-KR4, as defined in 93.1, shall be advertised if this bit is set to one. Support for EEE deep sleep operation should only be advertised if it is supported on all sublayers of the PHY as well as physical instantiations of the PMA service interface as appropriate.

45.2.7.13.3 100GBASE-KP4 EEE supported (7.60.11)

Support for EEE deep sleep operation for 100GBASE-KP4, as defined in 94.1, shall be advertised if this bit is set to one. Support for EEE deep sleep operation should only be advertised if it is supported on all sublayers of the PHY as well as physical instantiations of the PMA service interface as appropriate.

45.2.7.13.4 100GBASE-CR10 EEE supported (7.60.10)

Support for EEE deep sleep operation for 100GBASE-CR10, as defined in 85.1, shall be advertised if this bit is set to one. Support for EEE deep sleep operation should only be advertised if it is supported on all sublayers of the PHY as well as physical instantiations of the PMA service interface as appropriate.

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45.2.7.13.5 40GBASE-CR4 EEE supported (7.60.8)

Support for EEE deep sleep operation for 40GBASE-CR4, as defined in 85.1, shall be advertised if this bit is set to one. Support for EEE deep sleep operation should only be advertised if it is supported on all sublayers of the PHY as well as physical instantiations of the PMA service interface as appropriate.

45.2.7.13.6 40GBASE-KR4 EEE supported (7.60.7)

Support for EEE deep sleep operation for 40GBASE-KR4, as defined in 84.1, shall be advertised if this bit is set to one. Support for EEE deep sleep operation should only be advertised if it is supported on all sublayers of the PHY as well as physical instantiations of the PMA service interface as appropriate.

45.2.7.13.7 10GBASE-KR EEE supported (7.60.6)

If the device supports EEE operation for 10GBASE-KR as defined in 72.1, and EEE operation is desired, this bit shall be set to one.

45.2.7.13.8 10GBASE-KX4 EEE supported (7.60.5)

If the device supports EEE operation for 10GBASE-KX4 as defined in 71.2, and EEE operation is desired, this bit shall be set to one.

45.2.7.13.9 1000BASE-KX EEE supported (7.60.4)

If the device supports EEE operation for 1000BASE-KX as defined in 70.1, and EEE operation is desired, this bit shall be set to one.

45.2.7.13.10 10GBASE-T EEE supported (7.60.3)

If the device supports EEE operation for 10GBASE-T as defined in 55.1.3.3, and EEE operation is desired, this bit shall be set to one.

45.2.7.13.11 1000BASE-T EEE supported (7.60.2)

If the device supports EEE operation for 1000BASE-T as defined in 40.2.11, and EEE operation is desired, this bit shall be set to one.

45.2.7.13.12 100BASE-TX EEE supported (7.60.1)

If the device supports EEE operation for 100BASE-TX as defined in 25.5, and EEE operation is desired, this bit shall be set to one.

45.2.7.14 EEE link partner ability (Register 7.61)

All of the bits in the EEE LP ability register are read-only. A write to the EEE LP ability register shall have no effect. When the AN process has been completed, this register shall reflect the contents of the link

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partner's EEE advertisement register. The assignment of bits in the EEE link partner ability register and the correspondence with the bits in the Next Page messages are shown in Table 45–211.

Table 45–211—EEE link partner ability (Register 7.61) bit definitions

Bit(s)	Name	Description	Clause reference; Next Page bit number	R/W[a]
7.61.15:14	Reserved	Value always 0		RO
7.61.13	100GBASE-CR4 EEE	1 = Link partner is advertising EEE deep sleep capability for 100GBASE-CR4 0 = Link partner is not advertising EEE deep sleep capability for 100GBASE-CR4	73.7.7.1; U13	RO
7.61.12	100GBASE-KR4 EEE	1 = Link partner is advertising EEE deep sleep capability for 100GBASE-KR4 0 = Link partner is not advertising EEE deep sleep capability for 100GBASE-KR4	73.7.7.1; U12	RO
7.61.11	100GBASE-KP4 EEE	1 = Link partner is advertising EEE deep sleep capability for 100GBASE-KP4 0 = Link partner is not advertising EEE deep sleep capability for 100GBASE-KP4	73.7.7.1; U11	RO
7.61.10	100GBASE-CR10 EEE	1 = Link partner is advertising EEE deep sleep capability for 100GBASE-CR10 0 = Link partner is not advertising EEE deep sleep capability for 100GBASE-CR10	73.7.7.1; U10	RO
7.61.9	Reserved	Value always 0		RO
7.61.8	40GBASE-CR4 EEE	1 = Link partner is advertising EEE deep sleep capability for 40GBASE-CR4 0 = Link partner is not advertising EEE deep sleep capability for 40GBASE-CR4	73.7.7.1; U8	RO
7.61.7	40GBASE-KR4 EEE	1 = Link partner is advertising EEE deep sleep capability for 40GBASE-KR4 0 = Link partner is not advertising EEE deep sleep capability for 40GBASE-KR4	73.7.7.1; U7	RO
7.61.6	10GBASE-KR EEE	1 = Link partner is advertising EEE capability for 10GBASE-KR 0 = Link partner is not advertising EEE capability for 10GBASE-KR	73.7.7.1; U6	RO
7.61.5	10GBASE-KX4 EEE	1 = Link partner is advertising EEE capability for 10GBASE-KX4 0 = Link partner is not advertising EEE capability for 10GBASE-KX4	73.7.7.1; U5	RO

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Table 45–211—EEE link partner ability (Register 7.61) bit definitions *(continued)*

7.61.4	1000BASE-KX EEE	1 = Link partner is advertising EEE capability for 1000BASE-KX 0 = Link partner is not advertising EEE capability for 1000BASE-KX	73.7.7.1; U4	RO
7.61.3	10GBASE-T EEE	1 = Link partner is advertising EEE capability for 10GBASE-T 0 = Link partner is not advertising EEE capability for 10GBASE-T	28.2.3.4.1; U3 / 55.6.1; U24	RO
7.61.2	1000BASE-T EEE	1 = Link partner is advertising EEE capability for 1000BASE-T 0 = Link partner is not advertising EEE capability for 1000BASE-T	28.2.3.4.1; U2 / 55.6.1; U23	RO
7.61.1	100BASE-TX EEE	1 = Link partner is advertising EEE capability for 100BASE-TX 0 = Link partner is not advertising EEE capability for 100BASE-TX	28.2.3.4.1; U1 / 55.6.1; U22	RO
7.61.0	Reserved	Value always 0		RO

[a]RO = Read only

The definitions for the contents of the EEE LP ability register are given by the definitions for the contents on the link partner's EEE advertisement register, 7.60 (see 45.2.7.13).

45.2.8 Clause 22 extension registers

As new management features are added to 10, 100, and 1000 Mb/s PHYs, more register space is required beyond that defined in Clause 22. The Clause 22 extension MMD provides this space. This MMD is defined only for 10, 100, and 1000 Mb/s PHYs. Since these PHYs do not segment their management by their sublayers, all management extensions to these PHYs will appear in the Clause 22 extension MMD.

The assignment of registers in the Clause 22 extension MMD is shown in Table 45–212.

Table 45–212—Clause 22 extension registers

Register address	Register name	Subclause
29.0 through 29.4	Reserved	
29.5, 29.6	Clause 22 extension devices in package	45.2.8.1
29.7	FEC capability	45.2.8.2
29.8	FEC control	45.2.8.3
29.9	FEC buffer head coding violation counter	45.2.8.4
29.10	FEC corrected blocks counter	45.2.8.5
29.11	FEC uncorrected blocks counter	45.2.8.6
29.12 through 29.32 767	Reserved	

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45.2.8.1 Clause 22 extension devices in package registers (Registers 29.5, 29.6)

The Clause 22 extension devices in package registers are defined in Table 45–2.

45.2.8.2 FEC capability register (Register 29.7)

The assignment of bits in the FEC capability register is shown in Table 45–213.

Table 45–213—FEC capability register bit definitions

Bit(s)	Name	Description	R/W[a]
29.7.15:1	Reserved	Value always 0	RO
29.7.0	FEC capable	1 = FEC supported 0 = FEC unsupported	RO

[a]RO = Read only

45.2.8.2.1 FEC capable (29.7.0)

When read as a one, this bit indicates that the PHY supports forward error correction. When read as a zero, the PHY does not support forward error correction.

45.2.8.3 FEC control register (Register 29.8)

The assignment of bits in the FEC control register is shown in Table 45–214.

Table 45–214—FEC control register bit definitions

Bit(s)	Name	Description	R/W[a]
29.8.15:1	Reserved	Value always 0	RO
29.8.0	FEC enable	1 = FEC enabled 0 = FEC disabled	R/W

[a]RO = Read only, R/W = Read/Write

45.2.8.3.1 FEC enable (29.8.0)

When written as a one, this bit enables the PHY's forward error correction. When written as a zero, FEC is disabled. This bit shall be set to zero upon execution of a PHY reset.

45.2.8.4 FEC buffer head coding violation counter (Register 29.9)

The assignment of bits in the FEC buffer head coding violation counter register is shown in Table 45–215. See 65.2.3.6.1 for a definition of this register. These bits shall be reset to all zeros when the register is read by the management function or upon PHY reset. These bits shall be held at all ones in the case of overflow.

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Table 45–215—FEC buffer head coding violation counter register bit definitions

Bit(s)	Name	Description	R/W[a]
29.9.15:0	FEC buffer head coding violation counter	Error counter	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.8.5 FEC corrected blocks counter (Register 29.10)

The assignment of bits in the FEC corrected blocks counter register is shown in Table 45–216. See 65.2.3.6.2 for a definition of this register. These bits shall be reset to all zeros when the register is read by the management function or upon PHY reset. These bits shall be held at all ones in the case of overflow.

Table 45–216—FEC corrected blocks counter register bit definitions

Bit(s)	Name	Description	R/W[a]
29.10.15:0	FEC corrected blocks counter	Error counter	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.8.6 FEC uncorrected blocks counter (Register 29.11)

The assignment of bits in the FEC uncorrected blocks counter register is shown in Table 45–217. See 65.2.3.6.3 for a definition of this register. These bits shall be reset to all zeros when the register is read by the management function or upon PHY reset. These bits shall be held at all ones in the case of overflow.

Table 45–217—FEC uncorrected blocks counter register bit definitions

Bit(s)	Name	Description	R/W[a]
29.11.15:0	FEC uncorrected blocks counter	Error counter	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.9 Vendor specific MMD 1 registers

The assignment of registers in the vendor specific MMD 1 is shown in Table 45–218. A vendor specific MMD may have a device address of either 30 or 31. It is recommended that the device address is configurable and that the configuration is performed by some means other than via the MDIO.

Table 45–218—Vendor specific MMD 1 registers

Register address	Register name
30.0, 30.1	Vendor specific
30.2, 30.3	Vendor specific MMD 1 device identifier

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Table 45–218—Vendor specific MMD 1 registers *(continued)*

Register address	Register name
30.4 through 30.7	Vendor specific
30.8	Vendor specific MMD 1 status register
30.9 through 30.13	Vendor specific
30.14, 30.15	Vendor specific MMD 1 package identifier
30.16 through 30.65 535	Vendor specific

45.2.9.1 Vendor specific MMD 1 device identifier (Registers 30.2 and 30.3)

Registers 30.2 and 30.3 provide a 32-bit value, which may constitute a unique identifier for a particular type of vendor-specific device. The identifier shall be composed of the 3rd through 24th bits of the Organizationally Unique Identifier (OUI) assigned to the device manufacturer by the IEEE, plus a six-bit model number, plus a four-bit revision number. A vendor-specific device may return a value of zero in each of the 32 bits of the vendor specific MMD 1 device identifier.

The format of the vendor specific MMD 1 device identifier is specified in 22.2.4.3.1.

45.2.9.2 Vendor specific MMD 1 status register (Register 30.8)

The assignment of bits in the vendor specific MMD 1 status register is shown in Table 45–219. All the bits in the vendor specific MMD 1 status register are read only; a write to the vendor specific MMD 1 status register shall have no effect.

Table 45–219—Vendor specific MMD 1 status register bit definitions

Bit(s)	Name	Description	R/W[a]
30.8.15:14	Device present	15 14 1 0 = Device responding at this address 1 1 = No device responding at this address 0 1 = No device responding at this address 0 0 = No device responding at this address	RO
30.8.13:0	Reserved	Value always 0	RO

[a]RO = Read only

45.2.9.2.1 Device present (30.8.15:14)

When read as <10>, bits 30.8.15:14 indicate that a device is present and responding at this register address. When read as anything other than <10>, bits 30.8.15:14 indicate that no device is present at this register address or that the device is not functioning properly.

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45.2.9.3 Vendor specific MMD 1 package identifier (Registers 30.14 and 30.15)

Registers 30.14 and 30.15 provide a 32-bit value, which may constitute a unique identifier for a particular type of package that the vendor specific MMD 1 is instantiated within. The identifier shall be composed of the 3rd through 24th bits of the Organizationally Unique Identifier (OUI) assigned to the package manufacturer by the IEEE, plus a six-bit model number, plus a four-bit revision number. A vendor specific MMD 1 may return a value of zero in each of the 32 bits of the vendor specific MMD 1 package identifier.

A non-zero package identifier may be returned by one or more MMDs in the same package. The package identifier may be the same as the device identifier.

The format of the vendor specific MMD 1 package identifier is specified in 22.2.4.3.1.

45.2.10 Vendor specific MMD 2 registers

The assignment of registers in the vendor specific MMD 2 is shown in Table 45–220. A vendor specific MMD may have a device address of either 30 or 31. It is recommended that the device address is configurable and that the configuration is performed by some means other than via the MDIO.

Table 45–220—Vendor specific MMD 2 registers

Register address	Register name	Subclause
31.0, 31.1	Vendor specific	
31.2, 31.3	Vendor specific MMD 2 device identifier	45.2.10.1
31.4 through 31.7	Vendor specific	
31.8	Vendor specific MMD 2 status register	45.2.10.2
31.9 through 31.13	Vendor specific	
31.14, 30.15	Vendor specific MMD 2 package identifier	45.2.10.3
31.16 through 31.65 535	Vendor specific	

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45.2.10.1 Vendor specific MMD 2 device identifier (Registers 31.2 and 31.3)

Registers 31.2 and 31.3 provide a 32-bit value, which may constitute a unique identifier for a particular type of vendor-specific device. The identifier shall be composed of the 3rd through 24th bits of the Organizationally Unique Identifier (OUI) assigned to the device manufacturer by the IEEE, plus a six-bit model number, plus a four-bit revision number. A vendor-specific device may return a value of zero in each of the 32 bits of the vendor specific MMD 2 device identifier.

The format of the vendor specific MMD 2 device identifier is specified in 22.2.4.3.1.

45.2.10.2 Vendor specific MMD 2 status register (Register 31.8)

The assignment of bits in the vendor specific MMD 2 status register is shown in Table 45–221. All the bits in the vendor specific MMD 2 status register are read only; a write to the vendor specific MMD status register shall have no effect.

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Table 45–221—Vendor specific MMD 2 status register bit definitions

Bit(s)	Name	Description	R/W[a]
31.8.15:14	Device present	15 14 1 0 = Device responding at this address 1 1 = No device responding at this address 0 1 = No device responding at this address 0 0 = No device responding at this address	RO
31.8.13:0	Reserved	Value always 0	RO

[a]RO = Read only

45.2.10.2.1 Device present (31.8.15:14)

When read as <10>, bits 31.8.15:14 indicate that a device is present and responding at this register address. When read as anything other than <10>, bits 31.8.15:14 indicate that no device is present at this register address or that the device is not functioning properly.

45.2.10.3 Vendor specific MMD 2 package identifier (Registers 31.14 and 31.15)

Registers 31.14 and 31.15 provide a 32-bit value, which may constitute a unique identifier for a particular type of package that the vendor specific MMD is instantiated with. The identifier shall be composed of the 3rd through 24th bits of the Organizationally Unique Identifier (OUI) assigned to the package manufacturer by the IEEE, plus a six-bit model number, plus a four-bit revision number. A vendor specific MMD may return a value of zero in each of the 32 bits of the package identifier.

A non-zero package identifier may be returned by one or more MMDs in the same package. The package identifier may be the same as the device identifier.

The format of the vendor specific MMD 2 package identifier is specified in 22.2.4.3.1.

45.3 Management frame structure

The MDIO interface frame structure is compatible with the one defined in 22.2.4.5 such that the two systems can co-exist on the same MDIO bus. The electrical specification for the MDIO interface is incompatible to that defined in 22.2.4.5; therefore, if the two systems are to co-exist on the same bus, a voltage translation device is required (see Annex 45A). The extensions that are used for MDIO indirect register accesses are specified in Table 45–222.

Table 45–222—Extensions to management frame format for indirect access

	Management frame fields							
Frame	PRE	ST	OP	PRTAD	DEVAD	TA	ADDRESS / DATA	IDLE
Address	1...1	00	00	PPPPP	EEEEE	10	AAAAAAAAAAAAAAAA	Z
Write	1...1	00	01	PPPPP	EEEEE	10	DDDDDDDDDDDDDDDD	Z

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Table 45–222—Extensions to management frame format for indirect access *(continued)*

	Management frame fields							
Frame	**PRE**	**ST**	**OP**	**PRTAD**	**DEVAD**	**TA**	**ADDRESS / DATA**	**IDLE**
Read	1...1	00	11	PPPPP	EEEEE	Z0	DDDDDDDDDDDDDDDD	Z
Post-read-increment-address	1...1	00	10	PPPPP	EEEEE	Z0	DDDDDDDDDDDDDDDD	Z

Each MMD shall implement a sixteen bit address register that stores the address of the register to be accessed by data transaction frames. The address register shall be overwritten by address frames. At power up or device reset, the contents of the address register are undefined.

Write, read, and post-read-increment-address frames shall access the register whose address is stored in the address register. Write and read frames shall not modify the contents of the address register.

Upon receiving a post-read-increment-address frame and having completed the read operation, the MMD shall increment the address register by one. For the case where the MMD's address register contains 65 535, the MMD shall not increment the address register.

Implementations that incorporate several MMDs within a single component shall implement separate address registers so that the MMD's address registers operate independently of one another.

45.3.1 IDLE (idle condition)

The idle condition on MDIO is a high-impedance state. All three state drivers shall be disabled and the MMD's pull-up resistor will pull the MDIO line to a one.

45.3.2 PRE (preamble)

At the beginning of each transaction, the station management entity shall send a sequence of 32 contiguous one bits on MDIO with 32 corresponding cycles on MDC to provide the MMD with a pattern that it can use to establish synchronization. An MMD shall observe a sequence of 32 contiguous one bits on MDIO with 32 corresponding cycles on MDC before it responds to any transaction.

45.3.3 ST (start of frame)

The start of frame for indirect access cycles is indicated by the <00> pattern. This pattern assures a transition from the default one and identifies the frame as an indirect access. Frames that contain the ST=<01> pattern defined in Clause 22 shall be ignored by the devices specified in Clause 45.

45.3.4 OP (operation code)

The operation code field indicates the type of transaction being performed by the frame. A <00> pattern indicates that the frame payload contains the address of the register to access. A <01> pattern indicates that the frame payload contains data to be written to the register whose address was provided in the previous address frame. A <11> pattern indicates that the frame is read operation. A <10> pattern indicates that the frame is a post-read-increment-address operation.

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45.3.5 PRTAD (port address)

The port address is five bits, allowing 32 unique port addresses. The first port address bit to be transmitted and received is the MSB of the address. A station management entity must have a priori knowledge of the appropriate port address for each port to which it is attached, whether connected to a single port or to multiple ports.

45.3.6 DEVAD (device address)

The device address is five bits, allowing 32 unique MMDs per port. The first device address bit transmitted and received is the MSB of the address.

45.3.7 TA (turnaround)

The turnaround time is a 2 bit time spacing between the device address field and the data field of a management frame to avoid contention during a read transaction. For a read or post-read-increment-address transaction, both the STA and the MMD shall remain in a high-impedance state for the first bit time of the turnaround. The MMD shall drive a zero bit during the second bit time of the turnaround of a read or post-read-increment-address transaction. During a write or address transaction, the STA shall drive a one bit for the first bit time of the turnaround and a zero bit for the second bit time of the turnaround. Figure 22–15 shows the behavior of the MDIO signal during the turnaround field of a read or post-read-increment-address transaction.

45.3.8 ADDRESS / DATA

The address/data field is 16 bits. For an address cycle, it contains the address of the register to be accessed on the next cycle. For the data cycle of a write frame, the field contains the data to be written to the register. For a read or post-read-increment-address frame, the field contains the contents of the register. The first bit transmitted and received shall be bit 15.

45.4 Electrical interface

45.4.1 Electrical specification

The electrical characteristics of the MDIO interface are shown in Table 45–223. The MDIO uses signal levels that are compatible with devices operating at a nominal supply voltage of 1.2 V. More information on the electrical interface is given in Annex 45A. Voltage translators between the Clause 22 electrical interface and the Clause 45 electrical interface are described in 45A.3 and 45A.4.

NOTE—It is possible to implement the MDIO electrical interface using open drain buffers and a resistive pull-up to a V_{DD} of 1.2 V (see 45A.1).

Table 45–223—MDIO electrical interface characteristics

Symbol	Parameter	Condition	Min.	Max.
V_{IH}	Input high voltage		0.84 V	1.5 V
V_{IL}	Input low voltage		–0.3 V	0.36 V
V_{OH}	Output high voltage	I_{OH} = –100 uA	1.0 V	1.5 V

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Table 45–223—MDIO electrical interface characteristics *(continued)*

Symbol	Parameter	Condition	Min.	Max.
V_{OL}	Output low voltage	I_{OL} = 100 uA	–0.3 V	0.2 V
I_{OH}[a]	Output high current	V_{OH} = 1.0 V		–4 mA
I_{OL}	Output low current	V_{OL} = 0.2 V	+4 mA	
C_i	Input capacitance			10 pF
C_L	Total capacitive load			470 pF

[a]I_{OH} parameter is not applicable to open drain drivers.

45.4.2 Timing specification

MDIO is a bidirectional signal that can be sourced by the Station Management Entity (STA) or the MMD. When the STA sources the MDIO signal, the STA shall provide a minimum of 10 ns of setup time and a minimum of 10 ns of hold time referenced to the rising edge of MDC, as shown in Figure 45–3, measured at the MMD.

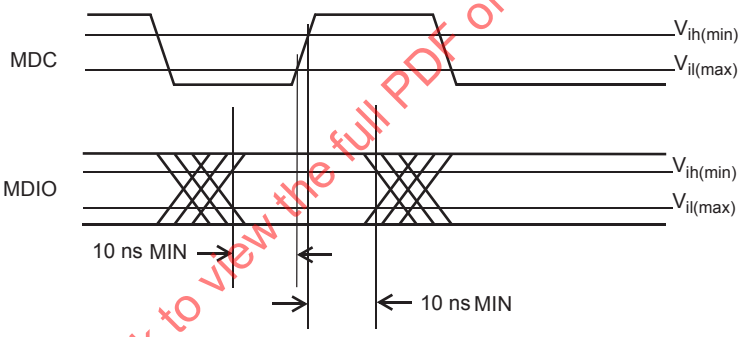

Figure 45–3—MDIO sourced by STA

When the MDIO signal is sourced by the MMD, it is sampled by the STA synchronously with respect to the beginning of the rising edge of MDC. The clock to output delay from the MMD, as measured at the STA, shall be a minimum of 0 ns, and a maximum of 300 ns, as shown in Figure 45–4.

The timing specification for the MDC signal is given in 22.2.2.13.

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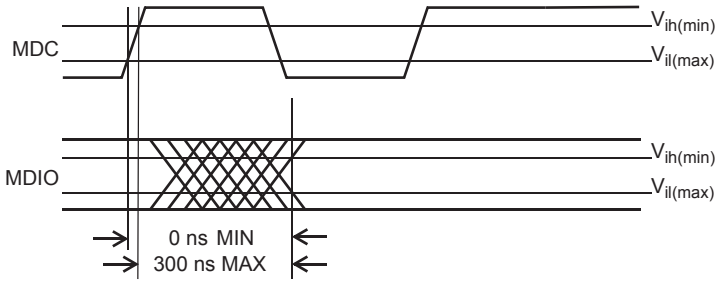

Figure 45–4—MDIO sourced by MMD

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45.5 Protocol implementation conformance statement (PICS) proforma for Clause 45, Management Data Input/Output (MDIO) interface[1]

45.5.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 45, MDIO interface, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

45.5.2 Identification

45.5.2.1 Implementation identification

Supplier[1]	
Contact point for inquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1,3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

45.5.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 45, Management Data Input/Output (MDIO) Interface
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	

Date of Statement	

[1]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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45.5.2.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*PMA	Implementation of PMA/PMD MMD	45.2.1		O	Yes [ ] No [ ]
*WIS	Implementation of WIS MMD	45.2.2		O	Yes [ ] No [ ]
*PCS	Implementation of PCS MMD	45.2.3		O	Yes [ ] No [ ]
*PX	Implementation of PHY XS MMD	45.2.4		O	Yes [ ] No [ ]
*DX	Implementation of DTE XS MMD	45.2.5		O	Yes [ ] No [ ]
*VSA	Implementation of Vendor specific MMD 1	45.2.9		O	Yes [ ] No [ ]
*VSB	Implementation of Vendor specific MMD 2	45.2.10		O	Yes [ ] No [ ]
*TC	Implementation of the TC MMD	45.2.6		10P*2B:M	Yes [ ] No [ ]
*CTT	Implementation of the Clause 22 extension MMD	45.2.8		O	Yes [ ] No [ ]
*ODB	Open drain buffer	45.4.1		O	Yes [ ] No [ ]
*AN	Implementation of Auto-Negotiation MMD	45.2.7		O	Yes [ ] No [ ]

45.5.3 PICS proforma tables for the Management Data Input Output (MDIO) interface

45.5.3.1 MDIO signal functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
SF1	MDIO uses three-state drivers	45.4.1		M	Yes [ ]

45.5.3.2 PMA/PMD MMD options

Item	Feature	Subclause	Value/Comment	Status	Support
*ALB	Implementation of PMA local loopback function	45.2.1.1.5		PMA:O	Yes [ ] No [ ] N/A [ ]
*RLB	Implementation of PMA remote loopback function	45.2.1.1.4		PMA:O	Yes [ ] No [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
*PLF	Implementation of fault detection	45.2.1.7		PMA:O	Yes [ ] No [ ] N/A [ ]
*ALP	Implementation of PMA/PMD low power ability	45.2.1.2.5		PMA:O	Yes [ ] No [ ] N/A [ ]
*PTD	Implementation of transmit disable function	45.2.1.8		PMA:O	Yes [ ] No [ ] N/A [ ]
*10T	Implementation of the 10GBASE-T PMA	45.2.1.6		PMA:O	Yes [ ] No [ ]
*40G	Implementation of 40 Gb/s PMA/PMD	45.2.1.4		PMA:O	Yes [ ] No [ ]
*100G	Implementation of 100 Gb/s PMA/PMD	45.2.1.4		PMA:O	Yes [ ] No [ ]
*10M	Implementation of 10 Mb/s PMA/PMD	45.2.1.4		PMA:O	Yes [ ] No [ ]
*100M	Implementation of 100 Mb/s PMA/PMD	45.2.1.4		PMA:O	Yes [ ] No [ ]
*1G	Implementation of 1000 Mb/s PMA/PMD	45.2.1.4		PMA:O	Yes [ ] No [ ]
*10P	Implementation of the 10PASS-TS PMA/PMD	45.2.1.4		PMA:O	Yes [ ] No [ ]
*2B	Implementation of the 2BASE-TL PMA/PMD	45.2.1.4		PMA:O	Yes [ ] No [ ]
*10G	Implementation of 10 Gb/s PMA/PMD	45.2.1.4		PMA:O	Yes [ ] No [ ]
*KX	Implementation of 1000BASE-KX PMA/PMD	45.2.1.6		PMA:O	Yes [ ] No [ ]
*KX4	Implementation of 10GBASE-KX4 PMA/PMD	45.2.1.6		PMA:O	Yes [ ] No [ ]
*KR	Implementation of 10GBASE-KR PMA/PMD	45.2.1.6		PMA:O	Yes [ ] No [ ]
*PXAR	Implementation of PMA/PMD Extended Ability Register	45.2.1.10	Required for certain abilities	PMA:O	Yes [ ] No [ ]
*40XAR	Implementation of 40G/100G PMA/PMD Extended Ability Register	45.2.1.12	Required for certain abilities	PMA:O	Yes [ ] No [ ]
*MMD8	Implementation of separately addressable instance, address 8	45.2.1	All register definitions as for address 1	PMA:O	Yes [ ] No [ ]
*MMD9	Implementation of separately addressable instance, address 9	45.2.1	All register definitions as for address 1	PMA:O	Yes [ ] No [ ]
*MMD10	Implementation of separately addressable instance, address 10	45.2.1	All register definitions as for address 1	PMA:O	Yes [ ] No [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
*MMD11	Implementation of separately addressable instance, address 11	45.2.1	All register definitions as for address 1	PMA:O	Yes [ ] No [ ]
*FEC-R	Implementation of BASE-R FEC	45.2.1.92		PMA:O	Yes [ ] No [ ]
*RS-FEC	Implementation of RS-FEC	45.2.1.102		PMA:O	Yes [ ] No [ ]

45.5.3.3 PMA/PMD management functions

Item	Feature	Subclause	Value/Comment	Status	Support
MM1	Device responds to all register addresses for that device	45.2		PMA:M	Yes [ ] N/A [ ]
MM2	Writes to undefined and read-only registers have no effect	45.2		PMA:M	Yes [ ] N/A [ ]
MM3	Operation is not affected by writes to reserved and unsupported bits.	45.2		PMA:M	Yes [ ] N/A [ ]
MM4	Reserved and unsupported bits return a value of zero	45.2		PMA:M	Yes [ ] N/A [ ]
MM5	Latching low bits remain low until after they have been read via the management interface	45.2		PMA:M	Yes [ ] N/A [ ]
MM6	Latching low bits assume correct value once read via the management interface	45.2	Correct value is based upon current state	PMA:M	Yes [ ] N/A [ ]
MM7	Latching high bits remain high until after they have been read via the management interface	45.2		PMA:M	Yes [ ] N/A [ ]
MM8	Latching high bits assume correct value once read via the management interface	45.2	Correct value is based upon current state	PMA:M	Yes [ ] N/A [ ]
MM9	Action on reset	45.2.1.1.1	Reset the registers of the entire device to default values and set bit 15 of the Control register to one	PMA:M	Yes [ ] N/A [ ]
MM10	Return 1 until reset completed	45.2.1.1.1		PMA:M	Yes [ ] N/A [ ]
MM11	Control and management interfaces are restored to operation within 0.5 s of reset	45.2.1.1.1		PMA:M	Yes [ ] N/A [ ]
MM12	Responds to reads of bit 15 and 1.8.15:14 during reset	45.2.1.1.1		PMA:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
MM13	Device responds to transactions necessary to exit low-power mode while in low-power state	45.2.1.1.2		PMA:M	Yes [ ] N/A [ ]
MM14	Invalid writes to speed selection bits are ignored	45.2.1.1.3		PMA:M	Yes [ ] N/A [ ]
MM15	PMA is set into local loopback mode when bit 0 is set to a one	45.2.1.1.5		ALB:M	Yes [ ] N/A [ ]
MM16	PMA transmit data is returned on receive path when in local loopback	45.2.1.1.5		ALB:M	Yes [ ] N/A [ ]
MM17	PMA ignores writes to this bit if it does not support local loopback.	45.2.1.1.5		PMA*!ALB:M	Yes [ ] N/A [ ]
MM18	PMA returns a value of zero when read if it does not support local loopback.	45.2.1.1.5		PMA*!ALB:M	Yes [ ] N/A [ ]
MM19	PMA is set into remote loopback mode when bit 1 is set to a one	45.2.1.1.4		RLB:M	Yes [ ] N/A [ ]
MM20	PMA receive data is returned on transmit path when in remote loopback	45.2.1.1.4		RLB:M	Yes [ ] N/A [ ]
MM21	PMA ignores writes to this bit if it does not support remote loopback.	45.2.1.1.4		PMA*!RLB:M	Yes [ ] N/A [ ]
MM22	PMA returns a value of zero when read if it does not support remote loopback.	45.2.1.1.4		PMA*!RLB:M	Yes [ ] N/A [ ]
MM23	Writes to status 1 register have no effect	45.2.1.2		PMA:M	Yes [ ] N/A [ ]
MM24	Receive link status implemented with latching low behavior	45.2.1.2.4		PMA:M	Yes [ ] N/A [ ]
MM25	Unique identifier is composed of 22 bits of OUI, model number and revision	45.2.1.3		PMA:M	Yes [ ] N/A [ ]
MM26	PMA/PMD type is selected using bits 5:0	45.2.1.6.3		PMA:M	Yes [ ] N/A [ ]
MM27	PMA/PMD ignores writes to type selection bits that select types that it has not advertised	45.2.1.6.3		PMA:M	Yes [ ] N/A [ ]
MM28	Writes to the status 2 register have no effect	45.2.1.7		PMA:M	Yes [ ] N/A [ ]
MM29	PMA/PMD returns a value of zero for transmit fault if it is unable to detect a transmit fault	45.2.1.7.4		PMA:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
MM30	Transmit fault is implemented using latching high behavior	45.2.1.7.4		PMA*PLF:M	Yes [ ] N/A [ ]
MM31	PMA/PMD returns a value of zero for receive fault if it is unable to detect a receive fault	45.2.1.7.5		PMA*!PLF:M	Yes [ ] N/A [ ]
MM32	Receive fault is implemented using latching high behavior	45.2.1.7.5		PMA*PLF:M	Yes [ ] N/A [ ]
MM33	Writes to register 9 are ignored by device that does not implement transmit disable	45.2.1.8		PMA*!PTD:M	Yes [ ] N/A [ ]
MM34	Single wavelength device uses bit 1.9.0 for transmit disable	45.2.1.8		PMA*PTD:M	Yes [ ] N/A [ ]
MM35	Single wavelength device ignores writes to bits 10:1 and returns a value of zero for them	45.2.1.8		PTD:M	Yes [ ] N/A [ ]
MM36	Bits 1 to 10, set to 1 disables transmission on corresponding lane	45.2.1.8		PTD:M	Yes [ ] No [ ] N/A [ ]
MM37	Bits 1 to 10, set to 0 enables transmission on corresponding lane	45.2.1.8		PTD:M	Yes [ ] No [ ] N/A [ ]
MM38	Setting bit 0 to a one disables transmission	45.2.1.8.7		PMA*PTD:M	Yes [ ] No [ ] N/A [ ]
MM39	Setting bit 0 to a zero enables transmission	45.2.1.8.7	Only if all lane transmit disables are zero	PMA*PTD:M	Yes [ ] No [ ] N/A [ ]
MM40	Receive signal detect register behaves as described	45.2.1.9		PMA:M	Yes [ ] N/A [ ]
MM41	Writes to the extended ability register have no effect	45.2.1.10		PMA:M	Yes [ ] N/A [ ]
MM42	Unique identifier is composed of 22 bits of OUI, model number and revision	45.2.1.11		PMA:M	Yes [ ] N/A [ ]
MM43	Writes to the 40G/100G PMA/PMD extended ability register have no effect	45.2.1.12		PMA:M	Yes [ ] N/A [ ]
MM44	Bit indicates link down while initializing	45.2.1.2.4		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM45	Bit remains a one and writing a one is ignored when link is up or initializing	45.2.1.11		PMA*10P*2B:M	Yes [ ] N/A [ ]
*MM46	PRBS pattern testing implemented	45.2.1.123	Ability indicated in register 1.1500	PMA:O	Yes [ ] N/A [ ]
MM47	Square wave testing implemented	45.2.1.123	Bit 1.1500.12 is set to one	PMA:O	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
MM48	Counters corresponding to lanes that are not implemented return all zeros	45.2.1.126		MM46:M	Yes [ ] N/A [ ]
MM49	Counters are reset to zero by read or PMA reset	45.2.1.126		MM46:M	Yes [ ] N/A [ ]
MM50	Counters are held at all ones in the case of overflow	45.2.1.126		MM46:M	Yes [ ] N/A [ ]
MM51	Bit set to zero upon reset or upon link down	45.2.1.15.1	-O subtypes only	PMA*10P*2B:M	Yes [ ] N/A [ ]
MM52	Bit set to one upon reset or upon link down	45.2.1.15.1	-R subtypes only	PMA*10P*2B:M	Yes [ ] N/A [ ]
MM53	Handshake tones not sent while bit is set to zero	45.2.1.15.1		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM54	Writes to set unsupported modes or when link is not down are ignored	45.2.1.15.4		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM55	Setting bit to one to one issues a cleardown command	45.2.1.15.5		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM56	MMD clears bit to zero when cleardown command is issued or on reset	45.2.1.15.5		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM57	Writes ignored if link is not in “Link down (ready)” state	45.2.1.15.5	Link state described in 45.2.1.16.4	PMA*10P*2B:M	Yes [ ] N/A [ ]
MM58	PMA/PMD does not respond to handshake tones while bit is set to one	45.2.1.15.6		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM59	PMA/PMD responds to handshake tones properly when bit is set to zero	45.2.1.15.6		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM60	Bit set to zero upon MMD reset	45.2.1.15.6		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM61	Writes to set unsupported modes are ignored	45.2.1.15.7		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM62	Bits zero when link is down or initializing	45.2.1.16.1		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM63	Bits set indicate linked port type or link status	45.2.1.16.4		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM64	Bits indicate 001 while link is initializing	45.2.1.16.4		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM65	Bits indicate 000 when link is down and handshake tones are not detected	45.2.1.16.4		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM66	Bits indicate 100 when link is down and handshake tones are detected	45.2.1.16.4		PMA*10P*2B:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
MM67	Bit held as one during operation, clears to zero after	45.2.1.17.1		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM68	Result = failed after 10 second timeout	45.2.1.17.1		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM69	Writes to one while link is down are marked completed and failed	45.2.1.17.1		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM70	Bit held as one during operation, clears to zero after	45.2.1.17.2		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM71	Result = failed after 10 second timeout	45.2.1.17.2		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM72	Writes to one while link is down are marked completed and failed	45.2.1.17.2		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM73	Bit set to result of the “Get” operation	45.2.1.18.1		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM74	Bit set to zero on read or reset	45.2.1.18.1		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM75	Bit set to result of the “Send” operation	45.2.1.18.2		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM76	Bits are reset to zero when read or on reset	45.2.1.19		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM77	Bits are held to all ones upon counter overflow	45.2.1.19		PMA*10P*2B:M	Yes [ ] N/A [ ]
MM78	Bits are reset to zero when read or reset	45.2.1.26		PMA*10P:M	Yes [ ] N/A [ ]
MM79	Bits are reset to zero when read or reset	45.2.1.27		PMA*10P:M	Yes [ ] N/A [ ]
MM80	Bits are held at all ones when PHY cannot determine value	45.2.1.30.1	ex: While link is down	PMA*10P:M	Yes [ ] N/A [ ]
MM81	Bit remain as one while tones are being refreshed	45.2.1.40.1		PMA*10P:M	Yes [ ] N/A [ ]
MM82	Bit set to zero when operation completes or upon reset	45.2.1.40.1		PMA*10P:M	Yes [ ] N/A [ ]
MM83	Bit remain as one while tones are being activated/deactivated	45.2.1.40.2		PMA*10P:M	Yes [ ] N/A [ ]
MM84	Bit set to zero when operation completes or upon reset	45.2.1.40.2		PMA*10P:M	Yes [ ] N/A [ ]
MM85	Bit remain as one while tone direction is being changed	45.2.1.40.3		PMA*10P:M	Yes [ ] N/A [ ]
MM86	Bit set to zero when operation completes or upon reset	45.2.1.40.3		PMA*10P:M	Yes [ ] N/A [ ]
MM87	Bit remain as one while SNR margins parameters are loaded	45.2.1.40.4		PMA*10P:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
MM88	Bit set to zero when operation completes or upon reset	45.2.1.40.4		PMA*10P:M	Yes [ ] N/A [ ]
MM89	Bit remain as one while PSD level is set	45.2.1.40.5		PMA*10P:M	Yes [ ] N/A [ ]
MM90	Bit set to zero when operation completes or upon reset	45.2.1.40.5		PMA*10P:M	Yes [ ] N/A [ ]
MM91	Bit remain as one while reference PSD level is set	45.2.1.40.6		PMA*10P:M	Yes [ ] N/A [ ]
MM92	Bit set to zero when operation completes or upon reset	45.2.1.40.6		PMA*10P:M	Yes [ ] N/A [ ]
MM93	Bits are reset to zero when read or upon reset	45.2.1.41.1		PMA*10P:M	Yes [ ] N/A [ ]
MM94	Bits read as zero	45.2.1.42.6		PMA*10P:M	Yes [ ] N/A [ ]
MM95	Bits read as zero	45.2.1.42.7		PMA*10P:M	Yes [ ] N/A [ ]
MM96	Writes to an invalid value are ignored	45.2.1.44	Valid values are decimal 10, 20, or 40	PMA*10P:M	Yes [ ] N/A [ ]
MM97	Bits set to default value on MMD reset	45.2.1.44	Default value is decimal 20	PMA*10P:M	Yes [ ] N/A [ ]
MM98	Writes to set an invalid value are ignored	45.2.1.47.1	Valid values are decimal 3 through 89	PMA*10P:M	Yes [ ] N/A [ ]
MM99	Writes to set an invalid value are ignored	45.2.1.47.2	Valid values are decimal 3 through 89	PMA*10P:M	Yes [ ] N/A [ ]
MM100	Writes to set an invalid value are ignored	45.2.1.47.3	Valid values are decimal 1through 86	PMA*10P:M	Yes [ ] N/A [ ]
MM101	Writes to set an invalid value are ignored	45.2.1.47.5	Invalid value is 11	PMA*10P:M	Yes [ ] N/A [ ]
MM102	Bits set to zero when read or reset	45.2.1.48		PMA*2B:M	Yes [ ] N/A [ ]
MM103	Bits set to zero when read or reset	45.2.1.50		PMA*2B:M	Yes [ ] N/A [ ]
MM104	Bits set to zero when read or reset	45.2.1.52		PMA*2B:M	Yes [ ] N/A [ ]
MM105	Bits set to zero when read or reset	45.2.1.54		PMA*2B:M	Yes [ ] N/A [ ]
MM106	Bits set to zero when read or reset	45.2.1.56		PMA*2B:M	Yes [ ] N/A [ ]
MM107	Writes to set an invalid value are ignored	45.2.1.61.1	Valid values are decimal 3 through 89	PMA*10P:M	Yes [ ] N/A [ ]
MM108	Writes to set an invalid value are ignored	45.2.1.61.2	Valid values are decimal 3 through 89	PMA*10P:M	Yes [ ] N/A [ ]
MM109	Writes to set an invalid value are ignored	45.2.1.61.3	Valid values are decimal 1 through 86	PMA*10P:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
MM110	Writes to set an invalid value are ignored	45.2.1.61.5	Invalid value is 11	PMA*10P:M	Yes [ ] N/A [ ]
MM111	Bit set to zero if PMA link_status=FAIL	45.2.1.62.1		PMA*10T:M	Yes [ ] N/A [ ]
MM112	Skew delay register update rate.	45.2.1.78	At least once per second	PMA*10T:M	Yes [ ] N/A [ ]
MM113	A PMA/PMD that is unable to detect a transmit fault returns a value of zero for the transmit fault bit.	45.2.1.89.3		KX:M	Yes [ ] N/A [ ]
MM114	The transmit fault bit is implemented with latching high behavior.	45.2.1.89.3		KX:M	Yes [ ] N/A [ ]
MM115	A PMA/PMD that is unable to detect a receive fault returns a value of zero for the receive fault bit.	45.2.1.89.4		KX:M	Yes [ ] N/A [ ]
MM116	The receive fault bit is implemented with latching high behavior.	45.2.1.89.4		KX:M	Yes [ ] N/A [ ]
MM117	FEC enable is set to zero upon execution of PHY reset	45.2.1.93.1		FEC-R:M	Yes [ ] N/A [ ]
MM118	RS-FEC counters are reset when read or upon PHY reset.	45.2.1.103, 45.2.1.104, 45.2.1.105, 45.2.1.107, 45.2.1.108, 45.2.1.109		RS-FEC:M	Yes [ ] N/A [ ]
MM119	RS-FEC counters are held at all ones in the case of overflow	45.2.1.103, 45.2.1.104, 45.2.1.105, 45.2.1.107, 45.2.1.108, 45.2.1.109		RS-FEC:M	Yes [ ] N/A [ ]
MM120	FEC corrected blocks counters are reset when read or upon PHY reset.	45.2.1.94, 45.2.1.116		FEC-R:M	Yes [ ] N/A [ ]
MM121	FEC corrected blocks counters are held at all ones in the case of overflow	45.2.1.94, 45.2.1.116		FEC-R:M	Yes [ ] N/A [ ]
MM122	FEC uncorrected blocks counters are reset when read or upon PHY reset.	45.2.1.95, 45.2.1.117		FEC-R:M	Yes [ ] N/A [ ]
MM123	FEC uncorrected blocks counters are held at all ones in the case of overflow	45.2.1.95, 45.2.1.117		FEC-R:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
MM124	Backplane Ethernet AN ability bit is set to 1 for 1000BASE-KX, 10GBASE-KX4 and 10GBASE-KR PHYs.	45.2.7.12.3		KX:M KX4:M KR:M	Yes [ ] N/A [ ]
MM125	Writes to this register have no effect	45.2.1.11		PMA:M	Yes [ ] No [ ] N/A [ ]

45.5.3.4 WIS options

Item	Feature	Subclause	Value/Comment	Status	Support
*WPT	Implementation of PRBS31 pattern testing	45.2.2		WIS:O	Yes [ ] No [ ] N/A [ ]

45.5.3.5 WIS management functions

Item	Feature	Subclause	Value/Comment	Status	Support
WM1	Device responds to all register addresses for that device	45.2		WIS:M	Yes [ ] N/A [ ]
WM2	Writes to undefined and read-only registers have no effect	45.2		WIS:M	Yes [ ] N/A [ ]
WM3	Operation is not affected by writes to reserved and unsupported bits.	45.2		WIS:M	Yes [ ] N/A [ ]
WM4	Reserved and unsupported bits return a value of zero	45.2		WIS:M	Yes [ ] N/A [ ]
WM5	Latching low bits remain low until after they have been read via the management interface	45.2		WIS:M	Yes [ ] N/A [ ]
WM6	Latching low bits assume correct value once read via the management interface	45.2	Correct value is based upon current state	WIS:M	Yes [ ] N/A [ ]
WM7	Latching high bits remain high until after they have been read via the management interface	45.2		WIS:M	Yes [ ] N/A [ ]
WM8	Latching high bits assume correct value once read via the management interface	45.2	Correct value is based upon current state	WIS:M	Yes [ ] N/A [ ]
WM9	Action on reset	45.2.2.1.1	Reset the registers of the entire device to default values and set bit 15 of the Control register to one	WIS:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
WM10	Return 1 until reset completed	45.2.2.1.1		WIS:M	Yes [ ] N/A [ ]
WM11	Reset completes within 0.5 s	45.2.2.1.1		WIS:M	Yes [ ] N/A [ ]
WM12	Responds to reads of bits 2.0.15 and 2.8.15:14 during reset	45.2.2.1.1		WIS:M	Yes [ ] N/A [ ]
WM13	Loopback mode	45.2.2.1.2	Whenever bit 2.0.14 is set to a one	WIS:M	Yes [ ] N/A [ ]
WM14	Data received from PMA ignored during loopback	45.2.2.1.2		WIS:M	Yes [ ] N/A [ ]
WM15	Transmit data returned on receive path during loopback	45.2.2.1.2		WIS:M	Yes [ ] N/A [ ]
WM16	Device responds to transactions necessary to exit low-power mode while in low- power state	45.2.2.1.3		WIS:M	Yes [ ] N/A [ ]
WM17	Speed selection bits 13 and 6 are written as one	45.2.2.1.4		WIS:M	Yes [ ] N/A [ ]
WM18	Invalid writes to speed selection bits are ignored	45.2.2.1.4		WIS:M	Yes [ ] N/A [ ]
WM19	Writes to status 1 register have no effect	45.2.2.2		WIS:M	Yes [ ] N/A [ ]
WM20	Fault bit implemented using latching high behavior	45.2.2.2.1		WIS:M	Yes [ ] N/A [ ]
WM21	Link status bit implemented using latching low behavior	45.2.2.2.2		WIS:M	Yes [ ] N/A [ ]
WM22	Unique identifier is composed of 22 bits of OUI, model number and revision	45.2.2.3		WIS:M	Yes [ ] N/A [ ]
WM23	Setting bit 2.7.5 to a one enables PRBS31 receive pattern testing if bit 2.8.1 is a one and bit 2.7.2 is not a one	45.2.2.6.1		WIS* WPT:M	Yes [ ] N/A [ ]
WM24	Setting bit 2.7.5 to a zero disables PRBS31 receive pattern testing	45.2.2.6.1		WIS* WPT:M	Yes [ ] N/A [ ]
WM25	Setting bit 2.7.4 to a one enables PRBS31 transmit pattern testing if bit 2.8.1 is a one and bit 2.7.1 is not a one	45.2.2.6.2		WIS* WPT:M	Yes [ ] N/A [ ]
WM26	Setting bit 2.7.4 to a zero disables PRBS31 transmit pattern testing	45.2.2.6.2		WIS* WPT:M	Yes [ ] N/A [ ]
WM27	Setting bit 3 to one selects the square wave test pattern	45.2.2.6.3		WIS:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
WM28	Setting bit 3 to zero selects the pseudo random test pattern	45.2.2.6.3		WIS:M	Yes [ ] N/A [ ]
WM29	Setting bit 2 to one enables receive pattern testing	45.2.2.6.4		WIS:M	Yes [ ] N/A [ ]
WM30	Setting bit 2 to zero disables receive pattern testing	45.2.2.6.4		WIS:M	Yes [ ] N/A [ ]
WM31	Setting bit 1 to one enables transmit pattern testing	45.2.2.6.5		WIS:M	Yes [ ] N/A [ ]
WM32	Setting bit 1 to zero disables transmit pattern testing	45.2.2.6.5		WIS:M	Yes [ ] N/A [ ]
WM33	Setting bit 0 to a one enables 10GBASE-W logic and sets interface speed	45.2.2.6.6		WIS:M	Yes [ ] N/A [ ]
WM34	Setting bit 0 to a zero disables 10GBASE-W logic, sets interface speed. and bypasses data	45.2.2.6.6		WIS:O	Yes [ ] N/A [ ]
WM35	Writes to bit are ignored by WIS not capable of supporting 10GBASE-R	45.2.2.6.6		WIS:M	Yes [ ] N/A [ ]
WM36	Bit returns one when read if WIS is not capable of supporting 10GBASE-R	45.2.2.6.6		WIS:M	Yes [ ] N/A [ ]
WM37	Writes to status 2 register have no effect	45.2.2.7		WIS:M	Yes [ ] N/A [ ]
WM38	Counter is reset to all zeros when read or reset	45.2.2.8		WIS* WPT:M	Yes [ ] N/A [ ]
WM39	Counter is held at all ones at overflow	45.2.2.8		WIS* WPT:M	Yes [ ] N/A [ ]
WM40	Unique identifier is composed of 22 bits of OUI, model number and revision	45.2.2.9		WIS:M	Yes [ ] N/A [ ]
WM41	Writes to Status 3 register have no effect	45.2.2.10		WIS:M	Yes [ ] N/A [ ]
WM42	SEF bit implemented using latching high behavior	45.2.2.10.1		WIS:M	Yes [ ] N/A [ ]
WM43	Far end PLM-P/LCD-P bit implemented using latching high behavior	45.2.2.10.2		WIS:M	Yes [ ] N/A [ ]
WM44	Far end AIS-P/LOP-P bit implemented using latching high behavior	45.2.2.10.3		WIS:M	Yes [ ] N/A [ ]
WM45	LOF bit implemented using latching high behavior	45.2.2.10.4		WIS:M	Yes [ ] N/A [ ]
WM46	LOS bit implemented using latching high behavior	45.2.2.10.5		WIS:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
WM47	RDI-L bit implemented using latching high behavior	45.2.2.10.6		WIS:M	Yes [ ] N/A [ ]
WM48	AIS-L bit implemented using latching high behavior	45.2.2.10.7		WIS:M	Yes [ ] N/A [ ]
WM49	LCD-P bit implemented using latching high behavior	45.2.2.10.8		WIS:M	Yes [ ] N/A [ ]
WM50	PLM-P bit implemented using latching high behavior	45.2.2.10.9		WIS:M	Yes [ ] N/A [ ]
WM51	AIS-P bit implemented using latching high behavior	45.2.2.10.10		WIS:M	Yes [ ] N/A [ ]
WM52	LOP-P bit implemented using latching high behavior	45.2.2.10.11		WIS:M	Yes [ ] N/A [ ]

45.5.3.6 PCS options

Item	Feature	Subclause	Value/Comment	Status	Support
*100CR	Implementation of 100GBASE-R PCS	45.2.3.7		PCS:O	Yes [ ] No [ ] N/A [ ]
*40CR	Implementation of 40GBASE-R PCS	45.2.3.7		PCS:O	Yes [ ] No [ ] N/A [ ]
*CR	Implementation of 10GBASE-R PCS	45.2.3		PCS:O	Yes [ ] No [ ] N/A [ ]
*XCR	Implementation of 10/40/100GBASE-R PCS	45.2.3.7		100CR:M 40CR:M 10CR:M	Yes [ ] No [ ] N/A [ ]
*CT	Implementation of the 10GBASE-T PCS	45.2.3		PCS:O	Yes [ ] No [ ] N/A [ ]
*CX	Implementation of 10GBASE-X PCS	45.2.3		PCS:O	Yes [ ] No [ ] N/A [ ]
*XP	Implementation of 10GBASE-X pattern testing	45.2.3		CX:O	Yes [ ] No [ ] N/A [ ]
*PPT	Implementation of PRBS31 pattern testing	45.2.3		PCS:O	Yes [ ] No [ ] N/A [ ]
*PTT	Implementation of PRBS9 pattern testing	45.2.3		PCS:O	Yes [ ] No [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
*EPC	Implementation of the 10BASE-TS/2BASE-TL PCS	45.2.3.25		PCS:O	Yes [ ] No [ ] N/A [ ]
*PAF	Implementation of the PME aggregation function	45.2.3.25		EPC:O	Yes [ ] No [ ] N/A [ ]
*CPR	Implementation of 10GBASE-PR or 10/1GBASE-PRX PCS	45.2.3		PCS:O	Yes [ ] No [ ] N/A [ ]
*EEE	Implementation of EEE			O	Yes [ ] N/A [ ]

45.5.3.7 PCS management functions

Item	Feature	Subclause	Value/Comment	Status	Support
RM1	Device responds to all register addresses for that device	45.2		PCS:M	Yes [ ] N/A [ ]
RM2	Writes to undefined and read-only registers have no effect	45.2		PCS:M	Yes [ ] N/A [ ]
RM3	Operation is not affected by writes to reserved and unsupported bits	45.2		PCS:M	Yes [ ] N/A [ ]
RM4	Reserved and unsupported bits return a value of zero	45.2		PCS:M	Yes [ ] N/A [ ]
RM5	Latching low bits remain low until after they have been read via the management interface	45.2		PCS:M	Yes [ ] N/A [ ]
RM6	Latching low bits assume correct value once read via the management interface	45.2	Correct value is based upon current state	PCS:M	Yes [ ] N/A [ ]
RM7	Latching high bits remain high until after they have been read via the management interface	45.2		PCS:M	Yes [ ] N/A [ ]
RM8	Latching high bits assume correct value once read via the management interface	45.2	Correct value is based upon current state	PCS:M	Yes [ ] N/A [ ]
RM9	Action on reset	45.2.3.1.1	Reset the registers of the entire device to default values and set bit 15 of the Control register to one	PCS:M	Yes [ ] N/A [ ]
RM10	Return 1 until reset completed	45.2.3.1.1		PCS:M	Yes [ ] N/A [ ]
RM11	Reset completes within 0.5 s	45.2.3.1.1		PCS:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
RM12	Device responds to reads of register bits 3.0.15 and 3.5.15:14 during reset	45.2.3.1.1		PCS:M	Yes [ ] N/A [ ]
RM13	Loopback mode	45.2.3.1.2	Whenever bit 3.0.14 is set to a one	PCS:M	Yes [ ] N/A [ ]
RM14	Transmit data is returned on the receive path during loopback	45.2.3.1.2		PCS:M	Yes [ ] N/A [ ]
RM15	Writes to loopback bit are ignored when operating at 10 Gb/s with port type selections other than 10GBASE-R or 10GBASE-T	45.2.3.1.2		PCS:M	Yes [ ] N/A [ ]
RM16	Loopback bit returns zero when operating at 10 Gb/s with port type selections other than 10GBASE-R or 10GBASE-T	45.2.3.1.2		PCS:M	Yes [ ] N/A [ ]
RM17	Device responds to transactions necessary to exit low-power mode while in low- power state	45.2.3.1.3		PCS:M	Yes [ ] N/A [ ]
RM18	Speed selection bits 13 and 6 are written as one	45.2.3.1.5		PCS:M	Yes [ ] N/A [ ]
RM19	Invalid writes to speed selection bits are ignored	45.2.3.1.5		PCS:M	Yes [ ] N/A [ ]
RM20	Writes to PCS status 1 register have no effect	45.2.3.2		PCS:M	Yes [ ] N/A [ ]
RM21	Receive link status implemented using latching low behavior	45.2.3.2.2		PCS:M	Yes [ ] N/A [ ]
RM22	Unique identifier is composed of 22 bits of OUI, model number and revision	45.2.3.3		PCS:M	Yes [ ] N/A [ ]
RM23	PCS type is selected using bits 1 through 0	45.2.3.6.1		PCS:M	Yes [ ] N/A [ ]
RM24	Writes to the type selection bits that select types that have not been advertised are ignored	45.2.3.6.1		PCS:M	Yes [ ] N/A [ ]
RM25	Writes to PCS status 2 register have no effect	45.2.3.7		PCS:M	Yes [ ] N/A [ ]
RM26	Transmit fault implemented with latching high behavior	45.2.3.7.2		PCS:M	Yes [ ] N/A [ ]
RM27	Receive fault implemented with latching high behavior	45.2.3.7.3		PCS:M	Yes [ ] N/A [ ]
RM28	Unique identifier is composed of 22 bits of OUI, model number and revision	45.2.3.8		PCS:M	Yes [ ] N/A [ ]
RM29	Writes to 10GBASE-X PCS status register have no effect	45.2.3.11		PCS* CX:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
RM30	Register returns zero if the PCS does not implement the 10GBASE-X port type	45.2.3.11		PCS* !CX:M	Yes [ ] N/A [ ]
RM31	EEE capability indicated for each port type	45.2.3.9		EEE:M	Yes [ ] N/A [ ]
RM32	EEE wake error counter behavior as specified	45.2.3.10		EEE:M	Yes [ ] N/A [ ]
RM33	Writes to bit are ignored and reads return a value of zero	45.2.3.12.1		PCS* PX:M	Yes [ ] N/A [ ]
RM34	Setting the bits to <10> selects the mixed frequency pattern	45.2.3.12.2		PCS* PX:M	Yes [ ] N/A [ ]
RM35	Setting the bits to <01> selects the low-frequency pattern	45.2.3.12.2		PCS* PX:M	Yes [ ] N/A [ ]
RM36	Setting the bits to <00> selects the high-frequency pattern	45.2.3.12.2		PCS* PX:M	Yes [ ] N/A [ ]
RM37	Writes to BASE-R and 10GBASE-T PCS status 1 register have no effect	45.2.3.13		CR:M CT:M	Yes [ ] N/A [ ]
RM38	Reads from BASE-R and 10GBASE-T PCS status 1 register return zero for PCS that does not support 10GBASE-R	45.2.3.13		CR:M CT:M	Yes [ ] N/A [ ]
RM39	Writes to BASE-R and 10GBASE-T PCS status 2 register have no effect	45.2.3.14		XCR:M CT:M	Yes [ ] N/A [ ]
RM40	Reads from BASE-R and 10GBASE-T PCS status 2 register return zero for PCS that does not support 10/40/ 100GBASE-R or 10GBASE-T	45.2.3.14		XCR:M CT:M	Yes [ ] N/A [ ]
RM41	Latched block lock implemented with latching low behavior	45.2.3.14.1		XCR:M CT:M	Yes [ ] N/A [ ]
RM42	Latched high BER implemented with latching high behavior	45.2.3.14.2		XCR:M CT:M	Yes [ ] N/A [ ]
RM43	BER counter resets to all zeros on read or reset	45.2.3.14.3		XCR:M CT:M	Yes [ ] N/A [ ]
RM44	BER counter holds at all ones at overflow	45.2.3.14.3		!RM53:M	Yes [ ] N/A [ ]
RM45	Errored blocks counter implemented as a non roll over counter	45.2.3.14.4		!RM57:M	Yes [ ] N/A [ ]
RM46	Errored blocks counter resets to all zeros on read	45.2.3.14.4		XCR:M CT:M	Yes [ ] N/A [ ]
RM47	Setting bit 3.42.5 to a one enables PRBS31 receive pattern testing if bit 3.32.2 is a one and bit 3.42.2 is not a one	45.2.3.17.3		PCS* PPT:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
RM48	Setting bit 3.42.5 to a zero disables PRBS31 receive pattern testing	45.2.3.17.3		PCS* PPT:M	Yes [ ] N/A [ ]
RM49	Setting bit 3.42.4 to a one enables PRBS31 transmit pattern testing if bit 3.32.2 is a one and bit 3.42.3 is not a one	45.2.3.17.4		PCS* PPT:M	Yes [ ] N/A [ ]
RM50	Setting bit 3.42.4 to a zero disables PRBS31 transmit pattern testing	45.2.3.17.4		PCS* PPT:M	Yes [ ] N/A [ ]
RM51	Test-pattern error counter resets to all zeros on read or reset	45.2.3.18		XCR:M	Yes [ ] N/A [ ]
RM52	Test-pattern error counter holds at all ones at overflow	45.2.3.18		XCR:M	Yes [ ] N/A [ ]
*RM53	BER high order counter implemented	45.2.3.19		CR:O 40CR:M 100CR:M	Yes [ ] N/A [ ]
RM54	High order bits latched on read to 3.33	45.2.3.19		RM53:M	Yes [ ] N/A [ ]
RM55	Counter reset on read to 3.33 or PCS reset	45.2.3.19		RM53:M	Yes [ ] N/A [ ]
RM56	Counter held at all ones in the case of an overflow	45.2.3.19		RM53:M	Yes [ ] N/A [ ]
*RM57	Errored blocks high order counter implemented	45.2.3.20		CR:O 40CR:M 100CR:M	Yes [ ] N/A [ ]
RM58	Register bit 3.45.15 set to 1	45.2.3.20		RM57:M	Yes [ ] N/A [ ]
RM59	High order bits latched on read to 3.33	45.2.3.20		RM57:M	Yes [ ] N/A [ ]
RM60	Counter reset on read to 3.33 or PCS reset	45.2.3.20		RM57:M	Yes [ ] N/A [ ]
RM61	Counter held at all ones in the case of an overflow	45.2.3.20		RM57:M	Yes [ ] N/A [ ]
RM62	Bit indicates fault when any PCS register indicates fault	45.2.3.2.5	If subtype is supported	PCS*EPC:O	Yes [ ] No [ ] N/A [ ]
RM63	Writes to multi-lane BASE-R PCS alignment status 1 register have no effect	45.2.3.21		XCR:M	Yes [ ] N/A [ ]
RM64	Non multi-lane BASE-R device shall return all zeros	45.2.3.21		!XCR:M	Yes [ ] N/A [ ]
RM65	Device shall return a zero for lanes not required	45.2.3.21		XCR:M	Yes [ ] N/A [ ]
RM66	Writes to multi-lane BASE-R PCS alignment status 2 register have no effect	45.2.3.22		XCR:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
RM67	Non multi-PCS lane BASE-R device shall return all zeros	45.2.3.22		!XCR:M	Yes [ ] N/A [ ]
RM68	Device shall return a zero for lanes not required	45.2.3.22		XCR:M	Yes [ ] N/A [ ]
RM69	Writes to multi-lane BASE-R PCS alignment status 3 register have no effect	45.2.3.23		XCR:M	Yes [ ] N/A [ ]
RM70	Non multi-PCS lane BASE-R device shall return all zeros	45.2.3.23		!XCR:M	Yes [ ] N/A [ ]
RM71	Device shall return a zero for lanes not required	45.2.3.23		XCR:M	Yes [ ] N/A [ ]
RM72	Writes to multi-lane BASE-R PCS alignment status 4 register have no effect	45.2.3.24		XCR:M	Yes [ ] N/A [ ]
RM73	Non multi-PCS lane BASE-R device shall return all zeros	45.2.3.24		!XCR:M	Yes [ ] N/A [ ]
RM74	Device shall return a zero for lanes not required	45.2.3.24		XCR:M	Yes [ ] N/A [ ]
RM75	Counters reset on read to 3.200 through 3.219 or PCS reset	45.2.3.44		XCR:M	Yes [ ] N/A [ ]
RM76	Counters held at all ones in the case of an overflow	45.2.3.44		XCR:M	Yes [ ] N/A [ ]
RM77	Writing this bit to a one activates the PAF when link is established	45.2.3.26.3		PCS*PAF:M	Yes [ ] N/A [ ]
RM78	Writes to bit are ignored while link is active or initializing or if PAF is not supported	45.2.3.26.3		PCS*PAF:M	Yes [ ] N/A [ ]
RM79	Bits indicate device capabilities upon reset	45.2.3.27		PCS*PAF:M	Yes [ ] N/A [ ]
RM80	Writes to the register through any PCS MMD in the same package effect the register equally	45.2.3.27		PCS*PAF:M	Yes [ ] N/A [ ]
RM81	Single bit set to one and all others cleared to zero when device does not support aggregation of multiple PMEs	45.2.3.27		PCS:M	Yes [ ] N/A [ ]
RM82	PME aggregation used if one or more bits set	45.2.3.28		PCS*PAF:M	Yes [ ] N/A [ ]
RM83	Registers set to all zeros upon reset	45.2.3.28		PCS*PAF:M	Yes [ ] N/A [ ]
RM84	Writes to the register through any PCS MMD in the same package effect the register equally	45.2.3.28		PCS*PAF:M	Yes [ ] N/A [ ]
RM85	Bits reset to zero when read or upon MMD reset	45.2.3.29		PCS*PAF:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
RM86	Bits held to one upon overflow	45.2.3.29		PCS*PAF:M	Yes [ ] N/A [ ]
RM87	Bits reset to zero when read or upon MMD reset	45.2.3.30		PCS*PAF:M	Yes [ ] N/A [ ]
RM88	Bits held to one upon overflow	45.2.3.30		PCS*PAF:M	Yes [ ] N/A [ ]
RM89	Bits reset to zero when read or upon MMD reset	45.2.3.31		PCS*PAF:M	Yes [ ] N/A [ ]
RM90	Bits held to one upon overflow	45.2.3.31		PCS*PAF:M	Yes [ ] N/A [ ]
RM91	Bits reset to zero when read or upon MMD reset	45.2.3.32		PCS*PAF:M	Yes [ ] N/A [ ]
RM92	Bits held to one upon overflow	45.2.3.32		PCS*PAF:M	Yes [ ] N/A [ ]
RM93	Bits reset to zero when read or upon MMD reset	45.2.3.33		PCS*PAF:M	Yes [ ] N/A [ ]
RM94	Bits held to one upon overflow	45.2.3.33		PCS*PAF:M	Yes [ ] N/A [ ]
RM95	Bits reset to zero when read or upon MMD reset	45.2.3.34		PCS*PAF:M	Yes [ ] N/A [ ]
RM96	Bits held to one upon overflow	45.2.3.34		PCS*PAF:M	Yes [ ] N/A [ ]
RM97	Bits reset to zero when read or upon MMD reset	45.2.3.35		PCS*PAF:M	Yes [ ] N/A [ ]
RM98	Bits held to one upon overflow	45.2.3.35		PCS*PAF:M	Yes [ ] N/A [ ]
RM99	Bits reset to zero when read or upon MMD reset	45.2.3.36		PCS*PAF:M	Yes [ ] N/A [ ]
RM100	Bits held to one upon overflow	45.2.3.36		PCS*PAF:M	Yes [ ] N/A [ ]
RM101	Setting bit 3.42.6 to a one enables PRBS9 transmit pattern testing if bit 3.32.3 is a one and bit 3.42.3 is not a one and bit 3.42.4 is not a one	45.2.3.17.2		PCS* PTT:M	Yes [ ] N/A [ ]
RM102	Setting bit 3.42.6 to a zero disables PRBS9 transmit pattern testing	45.2.3.17.2		PCS* PTT:M	Yes [ ] N/A [ ]
RM103	Corrected FEC codeword counter is reset when read or upon PHY reset	45.2.3.39		CPR:M	Yes [ ] No [ ] N/A [ ]
RM104	Corrected FEC codeword counter is held at all ones in the case of overflow	45.2.3.39		CPR:M	Yes [ ] No [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
RM105	Uncorrected FEC codeword counter is reset when read or upon PHY reset	45.2.3.40		CPR:M	Yes [ ] No [ ] N/A [ ]
RM106	Uncorrected FEC codeword counter is held at all ones in the case of overflow	45.2.3.40		CPR:M	Yes [ ] No [ ] N/A [ ]

45.5.3.8 Auto-Negotiation options

Item	Feature	Subclause	Value/Comment	Status	Support
*AT	Implementation of 10GBASE-T Auto-Negotiation	45.2.7		AN:O	Yes [ ] No [ ] N/A [ ]
*AB	Implementation of Backplane Ethernet Auto-negotiation	45.2.7		AN:M	Yes [ ] No [ ] N/A [ ]
*ABN	Implementation of Next Page support for Backplane Ethernet Auto-negotiation	45.2.7		AB:M	Yes [ ] No [ ] N/A [ ]
*EEE	Implementation of EEE			O	Yes [ ] N/A [ ]

45.5.3.9 Auto-Negotiation management functions

Item	Feature	Subclause	Value/Comment	Status	Support
AM1	Device responds to all register addresses for that device	45.2		AN:M	Yes [ ] N/A [ ]
AM2	Writes to undefined and read-only registers have no effect	45.2		AN:M	Yes [ ] N/A [ ]
AM3	Operation is not affected by writes to reserved and unsupported bits	45.2		AN:M	Yes [ ] N/A [ ]
AM4	Reserved and unsupported bits return a value of zero	45.2		AN:M	Yes [ ] N/A [ ]
AM5	Latching low bits remain low until after they have been read via the management interface	45.2		AN:M	Yes [ ] N/A [ ]
AM6	Latching low bits assume correct value once read via the management interface	45.2	Correct value is based upon current state	AN:M	Yes [ ] N/A [ ]
AM7	Latching high bits remain high until after they have been read via the management interface	45.2		AN:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
AM8	Latching high bits assume correct value once read via the management interface	45.2	Correct value is based upon current state	AN:M	Yes [ ] N/A [ ]
AM9	Action on reset	45.2.7.1.1	Reset the registers of the entire device to default values and set bit 15 of the Control register to one	AN:M	Yes [ ] N/A [ ]
AM10	Return 1 until reset completed	45.2.7.1.1		AN:M	Yes [ ] N/A [ ]
AM11	Reset completes within 0.5 s	45.2.7.1.1		AN:M	Yes [ ] N/A [ ]
AM12	Device responds to reads of register bit 7.0.15	45.2.7.1.1	All other register bits should be ignored	AN:M	Yes [ ] N/A [ ]
AM13	Bit set enables Extended Next Page exchange	45.2.7.1.2		AN:M	Yes [ ] N/A [ ]
AM14	Bit 7.0.13 has no effect unless bit 7.16.12 is set	45.2.7.1.2		AN:M	Yes [ ] N/A [ ]
AM15	Auto-Negotiation enabled by setting bit 7.0.12	45.2.7.1.3		AN:M	Yes [ ] N/A [ ]
AM16	Bits 1.0.13, 1.0.6, 1.0.5:2, and 1.7.3:0 have no effect and Auto-Negotiation determines link configuration	45.2.7.1.3		AN:M	Yes [ ] N/A [ ]
AM17	Writes are ignored and bit is set to zero if Auto-Negotiation is disabled or unsupported	45.2.7.1.4		AN:M	Yes [ ] N/A [ ]
AM18	Setting bit to one restarts Auto-Negotiation if supported and enabled	45.2.7.1.4		AN:M	Yes [ ] N/A [ ]
AM19	Bit set until Auto-Negotiation started then self cleared to zero	45.2.7.1.4		AN:M	Yes [ ] N/A [ ]
AM20	Setting this bit restarts Auto-Negotiation if previously completed	45.2.7.1.4		AN:M	Yes [ ] N/A [ ]
AM21	Setting the bit to zero has no effect on Auto-Negotiation process	45.2.7.1.4		AN:M	Yes [ ] N/A [ ]
AM22	Writing the bit to one is ignored if 7.1.3 = 0 or Auto-Negotiation is disabled	45.2.7.1.4		AN:M	Yes [ ] N/A [ ]
AM23	Writes to register ignored	45.2.7.2		AN:M	Yes [ ] N/A [ ]
AM24	Bit set to zero when bits 7.0.13 or 7.16.12 are set to zero	45.2.7.2.2		AN:M	Yes [ ] N/A [ ]
AM25	Extended Next Page not used when bit set to zero	45.2.7.2.2		AN:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
AM26	Bit set to one with link codeword received and stored	45.2.7.2.3		AN:M	Yes [ ] N/A [ ]
AM27	Bit set to zero upon read of register 7.1	45.2.7.2.3		AN:M	Yes [ ] N/A [ ]
AM28	Bit set to zero when bit 7.0.12 is set to zero	45.2.7.2.4		AN:M	Yes [ ] N/A [ ]
AM29	Bit set to zero if device does not support Auto-Negotiation	45.2.7.2.4		AN:M	Yes [ ] N/A [ ]
AM30	Bit remains set until cleared	45.2.7.2.5		AN:M	Yes [ ] N/A [ ]
AM31	Bit cleared to zero upon reset or read of register	45.2.7.2.5		AN:M	Yes [ ] N/A [ ]
AM32	Bit remains set until cleared by register read	45.2.7.2.7		AN:M	Yes [ ] N/A [ ]
AM33	Bit cleared upon AN reset	45.2.7.2.7		AN:M	Yes [ ] N/A [ ]
AM34	Bit set to one if link partner is able to participate in Auto-Negotiation	45.2.7.2.8		AN:M	Yes [ ] N/A [ ]
AM35	Bit set to zero if link partner is not able to participate in Auto-Negotiation	45.2.7.2.8		AN:M	Yes [ ] N/A [ ]
AM36	Unique Identifier is composed of 22 bits of OUI, model number and revision	45.2.7.5		AN:M	Yes [ ] N/A [ ]
AM37	Prior to Auto-Negotiation bits 7.16.12:5 accurately reflect device capability	45.2.7.6		AN:M	Yes [ ] N/A [ ]
AM38	Write has no effect	45.2.7.7		AN:M	Yes [ ] N/A [ ]
AM39	At power up or AN reset message code set to null message	45.2.7.8		AN:M	Yes [ ] N/A [ ]
AM40	Write has no effect	45.2.7.9		AN:M	Yes [ ] N/A [ ]
AM41	Auto-Negotiation used to determine MASTER or SLAVE when bit set to zero	45.2.7.10.1		AN:M	Yes [ ] N/A [ ]
AM42	Operates as MASTER when bit set to one	45.2.7.10.2		AN:M	Yes [ ] N/A [ ]
AM43	Operates as SLAVE when bit set to zero	45.2.7.10.2		AN:M	Yes [ ] N/A [ ]
AM44	Advertise 10GBASE-T PHY capability when bit is set to one	45.2.7.10.4		AN:M	Yes [ ] N/A [ ]
AM45	10GBASE-T PHY capability not advertised when bit is set to zero	45.2.7.10.4		AN:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
AM46	Advertise loop timing capability when bit is set to one	45.2.7.10.7		AN:M	Yes [ ] N/A [ ]
AM47	Loop timing capability not advertised when bit is set to zero	45.2.7.10.7		AN:M	Yes [ ] N/A [ ]
AM48	Write has no effect	45.2.7.11		AN:M	Yes [ ] N/A [ ]
AM49	Bit set if MASTER-SLAVE cannot be successfully concluded	45.2.7.11.1		AN:M	Yes [ ] N/A [ ]
AM50	Bit set to zero on read of register 7.33	45.2.7.11.1		AN:M	Yes [ ] N/A [ ]
AM51	Bit set to zero by 10GBASE-T PMA reset	45.2.7.11.1		AN:M	Yes [ ] N/A [ ]
AM52	Bit set to zero when Auto-Negotiation is enabled	45.2.7.11.1		AN:M	Yes [ ] N/A [ ]
AM53	Bit set to one if local receiver is OK as defined in 55.2.2.7	45.2.7.11.3		AN:M	Yes [ ] N/A [ ]
AM54	Bit is set to one if the remote receiver status is OK as defined in 55.2.2.8	45.2.7.11.4		AN:M	Yes [ ] N/A [ ]
AM55	Parallel detection fault (7.1.9)	45.2.7.2.1	ONE to indicate more than one Backplane Ethernet PMA indicates link_status of OK when autoneg_wait_timer expires	AB:M	Yes [ ] N/A [ ]
AM56	Parallel detection fault clearing	45.2.7.2.1	ZERO on read of the AN status register.	AN:M	Yes [ ] N/A [ ]
AM57	Bit 7.48.0 set to 1	45.2.7.12.3	Set to 1 if KX, KX4, or KR PHY is implemented	AB:M	Yes [ ] N/A [ ]
AM58	EEE capability in advertisement register for each port type	45.2.7.13		AN:EEE:M	Yes [ ] N/A [ ]
AM59	EEE LP advertisement register reflects link partner's capabilities	45.2.7.14		AN:EEE:M	Yes [ ] N/A [ ]
AM60	Writes to EEE LP advertisement register have no effect	45.2.7.14		AN:EEE:M	Yes [ ] N/A [ ]

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45.5.3.10 PHY XS options

Item	Feature	Subclause	Value/Comment	Status	Support
*PL	Implementation of loopback	45.2.4		PX:O	Yes [ ] No [ ] N/A [ ]
*PT	Implementation of pattern testing	45.2.4		PX:O	Yes [ ] No [ ] N/A [ ]

45.5.3.11 PHY XS management functions

Item	Feature	Subclause	Value/Comment	Status	Support
PM1	Device responds to all register addresses for that device	45.2		PX:M	Yes [ ] N/A [ ]
PM2	Writes to undefined and read-only registers have no effect	45.2		PX:M	Yes [ ] N/A [ ]
PM3	Operation is not affected by writes to reserved and unsupported bits	45.2		PX:M	Yes [ ] N/A [ ]
PM4	Reserved and unsupported bits return a value of zero	45.2		PX:M	Yes [ ] N/A [ ]
PM5	Latching low bits remain low until after they have been read via the management interface	45.2		PX:M	Yes [ ] N/A [ ]
PM6	Latching low bits assume correct value once read via the management interface	45.2	Correct value is based upon current state	PX:M	Yes [ ] N/A [ ]
PM7	Latching high bits remain high until after they have been read via the management interface	45.2		PX:M	Yes [ ] N/A [ ]
PM8	Latching high bits assume correct value once read via the management interface	45.2	Correct value is based upon current state	PX:M	Yes [ ] N/A [ ]
PM9	Action on reset	45.2.4.1.1	Reset the registers of the entire device to default values and set bit 15 of the Control register to one	PX:M	Yes [ ] N/A [ ]
PM10	Return 1 until reset completed	45.2.4.1.1		PX:M	Yes [ ] N/A [ ]
PM11	Reset completes within 0.5 s	45.2.4.1.1		PX:M	Yes [ ] N/A [ ]
PM12	Device responds to reads of bits 4.0.15 and 4.8.15:14 during reset	45.2.4.1.1		PX:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
PM13	Loopback mode	45.2.4.1.2	Whenever bit 4.0.14 is set to a one	PX*PL:M	Yes [ ] N/A [ ]
PM14	Receive data is returned on transmit path during loopback	45.2.4.1.2		PX*PL:M	Yes [ ] N/A [ ]
PM15	Writes to loopback bit are ignored and reads return zero	45.2.4.1.2		PX*!PL:M	Yes [ ] N/A [ ]
PM16	Device responds to transactions necessary to exit low-power mode while in low-power state	45.2.4.1.3		PX:M	Yes [ ] N/A [ ]
PM17	Speed selection bits 13 and 6 are written as one	45.2.4.1.6		PX:M	Yes [ ] N/A [ ]
PM18	Invalid writes to speed selection bits are ignored	45.2.4.1.6		PX:M	Yes [ ] N/A [ ]
PM19	Writes to status 1 register have no effect	45.2.4.2		PX:M	Yes [ ] N/A [ ]
PM20	Transmit link status implemented using latching low behavior	45.2.4.2.7		PX:M	Yes [ ] N/A [ ]
PM21	Unique identifier is composed of 22 bits of OUI, model number and revision	45.2.4.3		PX:M	Yes [ ] N/A [ ]
PM22	Writes to status 2 register have no effect	45.2.4.6		PX:M	Yes [ ] N/A [ ]
PM23	Transmit fault implemented with latching high behavior	45.2.4.6.2		PX:M	Yes [ ] N/A [ ]
PM24	Receive fault implemented with latching high behavior	45.2.4.6.3		PX:M	Yes [ ] N/A [ ]
PM25	Unique identifier is composed of 22 bits of OUI, model number and revision	45.2.4.7		PX:M	Yes [ ] N/A [ ]
PM26	Writes to 10G PHY XGXS Lane status register have no effect	45.2.4.10		PX:M	Yes [ ] N/A [ ]
PM27	Writes to bit are ignored and reads return a value of zero	45.2.4.11.1		PX*!PT:M	Yes [ ] N/A [ ]
PM28	Setting the bits to <10> selects the mixed frequency pattern	45.2.4.11.2		PX*PT:M	Yes [ ] N/A [ ]
PM29	Setting the bits to <01> selects the low-frequency pattern	45.2.4.11.2		PX*PT:M	Yes [ ] N/A [ ]
PM30	Setting the bits to <00> selects the high-frequency pattern	45.2.4.11.2		PX*PT:M	Yes [ ] N/A [ ]

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45.5.3.12 DTE XS options

Item	Feature	Subclause	Value/Comment	Status	Support
*DT	Implementation of pattern testing	45.2.5		DX:O	Yes [ ] No [ ] N/A [ ]

45.5.3.13 DTE XS management functions

Item	Feature	Subclause	Value/Comment	Status	Support
DM1	Device responds to all register addresses for that device	45.2		DX:M	Yes [ ] N/A [ ]
DM2	Writes to undefined and read-only registers have no effect	45.2		DX:M	Yes [ ] N/A [ ]
DM3	Operation is not affected by writes to reserved and unsupported bits	45.2		DX:M	Yes [ ] N/A [ ]
DM4	Reserved and unsupported bits return a value of zero	45.2		DX:M	Yes [ ] N/A [ ]
DM5	Latching low bits remain low until after they have been read via the management interface	45.2		DX:M	Yes [ ] N/A [ ]
DM6	Latching low bits assume correct value once read via the management interface	45.2	Correct value is based upon current state	DX:M	Yes [ ] N/A [ ]
DM7	Latching high bits remain high until after they have been read via the management interface	45.2		DX:M	Yes [ ] N/A [ ]
DM8	Latching high bits assume correct value once read via the management interface	45.2	Correct value is based upon current state	DX:M	Yes [ ] N/A [ ]
DM9	Action on reset	45.2.5.1.1	Reset the registers of the entire device to default values and set bit 15 of the Control register to one	DX:M	Yes [ ] N/A [ ]
DM10	Return 1 until reset completed	45.2.5.1.1		DX:M	Yes [ ] N/A [ ]
DM11	Reset completes within 0.5 s	45.2.5.1.1		DX:M	Yes [ ] N/A [ ]
DM12	Device responds to reads of bits 5.0.15 and 5.8.15:14 during reset	45.2.5.1.1		DX:M	Yes [ ] N/A [ ]
DM13	Loopback mode	45.2.5.1.2	Whenever bit 5.0.14 is set to a one	DX:M	Yes [ ] N/A [ ]
DM14	Transmit data is returned on receive path during loopback	45.2.5.1.2		DX:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
DM15	Device responds to transactions necessary to exit low-power mode while in low-power state	45.2.5.1.3		DX:M	Yes [ ] N/A [ ]
DM16	Speed selection bits 13 and 6 are written as one	45.2.5.1.6		DX:M	Yes [ ] N/A [ ]
DM17	Invalid writes to speed selection bits are ignored	45.2.5.1.6		DX:M	Yes [ ] N/A [ ]
DM18	Writes to status 1 register have no effect	45.2.5.2		DX:M	Yes [ ] N/A [ ]
DM19	Receive link status implemented using latching low behavior	45.2.5.2.7		DX:M	Yes [ ] N/A [ ]
DM20	Unique identifier is composed of 22 bits of OUI, model number and revision	45.2.5.3		DX:M	Yes [ ] N/A [ ]
DM21	Writes to status 2 register have no effect	45.2.5.6		DX:M	Yes [ ] N/A [ ]
DM22	Transmit fault implemented with latching high behavior	45.2.5.6.2		DX:M	Yes [ ] N/A [ ]
DM23	Receive fault implemented with latching high behavior	45.2.5.6.3		DX:M	Yes [ ] N/A [ ]
DM24	Unique identifier is composed of 22 bits of OUI, model number and revision	45.2.5.7		DX:M	Yes [ ] N/A [ ]
DM25	Writes to 10G DTE XGXS Lane status register have no effect	45.2.5.10		DX:M	Yes [ ] N/A [ ]
DM26	Writes to bit are ignored and reads return a value of zero	45.2.5.11.1		DX*!DT:M	Yes [ ] N/A [ ]
DM27	Setting the bits to <10> selects the mixed frequency pattern	45.2.5.11.2		DX*DT:M	Yes [ ] N/A [ ]
DM28	Setting the bits to <01> selects the low-frequency pattern	45.2.5.11.2		DX*DT:M	Yes [ ] N/A [ ]
DM29	Setting the bits to <00> selects the high-frequency pattern	45.2.5.11.2		DX*DT:M	Yes [ ] N/A [ ]

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45.5.3.14 Vendor specific MMD 1 management functions

Item	Feature	Subclause	Value/Comment	Status	Support
VSA1	Device responds to all register addresses for that device	45.2		VSA:M	Yes [ ] N/A [ ]
VSA2	Writes to undefined and read-only registers have no effect	45.2		VSA:M	Yes [ ] N/A [ ]
VSA3	Operation is not affected by writes to reserved and unsupported bits	45.2		VSA:M	Yes [ ] N/A [ ]
VSA4	Reserved and unsupported bits return a value of zero	45.2		VSA:M	Yes [ ] N/A [ ]
VSA5	Unique identifier is composed of 22 bits of OUI, model number and revision	45.2.9.1		VSA:M	Yes [ ] N/A [ ]
VSA6	Writes to status register have no effect	45.2.9.2		VSA:M	Yes [ ] N/A [ ]
VSA7	Unique identifier is composed of 22 bits of OUI, model number and revision	45.2.9.3		VSA:M	Yes [ ] N/A [ ]

45.5.3.15 Vendor specific MMD 2 management functions

Item	Feature	Subclause	Value/Comment	Status	Support
VSB1	Device responds to all register addresses for that device	45.2		VSB:M	Yes [ ] N/A [ ]
VSB2	Writes to undefined and read-only registers have no effect	45.2		VSB:M	Yes [ ] N/A [ ]
VSB3	Operation is not affected by writes to reserved and unsupported bits	45.2		VSB:M	Yes [ ] N/A [ ]
VSB4	Reserved and unsupported bits return a value of zero	45.2		VSB:M	Yes [ ] N/A [ ]
VSB5	Unique identifier is composed of 22 bits of OUI, model number and revision	45.2.10.1		VSB:M	Yes [ ] N/A [ ]
VSB6	Writes to status register have no effect	45.2.10.2		VSB:M	Yes [ ] N/A [ ]
VSB7	Unique identifier is composed of 22 bits of OUI, model number and revision	45.2.10.3		VSB:M	Yes [ ] N/A [ ]

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45.5.3.16 Management frame structure

Item	Feature	Subclause	Value/Comment	Status	Support
MF1	Device has implemented sixteen bit address register	45.3		M	Yes [ ]
MF2	Address register is overwritten by address frames	45.3		M	Yes [ ]
MF3	Write, read, and post-read-increment-address frames access the register whose address is held in the address register	45.3		M	Yes [ ]
MF4	Write and read frames do not modify the address register	45.3		M	Yes [ ]
MF5	Post-read-increment-address frames increment the address register by one unless the address register contains 65 535	45.3		M	Yes [ ]
MF6	Components containing several MMDs implement separate address registers	45.3		M	Yes [ ]
MF7	Tri state drivers are disabled during idle	45.3.1		M	Yes [ ]
MF8	STA sources 32 contiguous ones at the beginning of each transaction	45.3.2		M	Yes [ ]
MF9	MMD observes 32 contiguous ones at the beginning of each transaction	45.3.2		M	Yes [ ]
MF10	Frames containing ST=<01> sequence are ignored	45.3.3		M	Yes [ ]
MF11	STA tri state driver is high impedence during first bit of TA during read or post-read-increment-address frames	45.3.7		M	Yes [ ]
MF12	MMD tri state driver is high impedence during first bit of TA during read or post-read-increment-address frames	45.3.7		M	Yes [ ]
MF13	MMD tri state driver drives a zero bit during second bit of TA during read or post-read-increment-address frames	45.3.7		M	Yes [ ]
MF14	STA tri state driver drives a one bit followed by a zero bit for the TA during write or address frames	45.3.7		M	Yes [ ]
MF15	First bit transmitted and received is bit 15	45.3.8		M	Yes [ ]

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45.5.3.17 TC management functions

Item	Feature	Subclause	Value/Comment	Status	Support
TC1	Device responds to all register addresses for that device	45.2		TC:M	Yes [ ] N/A [ ]
TC2	Writes to undefined and read only register have no effect	45.2		TC:M	Yes [ ] N/A [ ]
TC3	Operation is not affected by writes to reserved and unsupported bits	45.2		TC:M	Yes [ ] N/A [ ]
TC4	Reserved and unsupported bits return a value of zero	45.2		TC:M	Yes [ ] N/A [ ]
TC5	Setting bit to a one sets all TC registers to their default states	45.2.6.1.1		TC:M	Yes [ ] N/A [ ]
TC6	Bit reads one while reset is in progress otherwise reads zero	45.2.6.1.1		TC:M	Yes [ ] N/A [ ]
TC7	Control and management interface is restored within 0.5s from setting bit to a one	45.2.6.1.1		TC:M	Yes [ ] N/A [ ]
TC8	During reset, TC responds to reads from bit	45.2.6.1.1		TC:M	Yes [ ] N/A [ ]
TC9	Writes that would select an unsupported speed are ignored	45.2.6.1.2		TC:M	Yes [ ] N/A [ ]
TC10	Identifier composed properly	45.2.6.2		TC:M	Yes [ ] N/A [ ]
TC11	Identifier composed properly	45.2.6.5		TC:M	Yes [ ] N/A [ ]
TC12	Register is unique across all PCS MMDs in a package	45.2.6.6		TC:M	Yes [ ] N/A [ ]
TC13	Operation ignored when link is up or initializing	45.2.6.6.1		TC:M	Yes [ ] N/A [ ]
TC14	Bits indicate “Ready” when PAF is capable	45.2.6.6.1		TC:M	Yes [ ] N/A [ ]
TC15	Writes ignored and “Ready” indicated if PAF is unsupported	45.2.6.6.1		TC:M	Yes [ ] N/A [ ]
TC16	Bits indicate “Ready” when operation is complete or upon reset	45.2.6.6.1		TC:M	Yes [ ] N/A [ ]
TC17	Bits read as zero if PAF is unsupported	45.2.6.7.1		TC:M	Yes [ ] N/A [ ]
TC18	Bits read as zero if PAF is unsupported	45.2.6.7.2		TC:M	Yes [ ] N/A [ ]
TC19	Register is unique across all PCS MMDs in a package	45.2.6.8		TC:M	Yes [ ] N/A [ ]
TC20	Register is unique across all PCS MMDs in a package	45.2.6.9		TC:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
TC21	Operation ignored when link is up or initializing	45.2.6.9.1		TC:M	Yes [ ] N/A [ ]
TC22	Bits indicate “Ready” when PAF is capable	45.2.6.9.1		TC:M	Yes [ ] N/A [ ]
TC23	Writes ignored and “Ready” indicated if PAF is unsupported	45.2.6.9.1		TC:M	Yes [ ] N/A [ ]
TC24	Bits indicate “Ready” when operation is complete or on reset	45.2.6.9.1		TC:M	Yes [ ] N/A [ ]
TC25	Register is unique across all PCS MMDs in a package	45.2.6.10		TC:M	Yes [ ] N/A [ ]
TC26	Bits reset to zero when read or reset	45.2.6.11		TC:M	Yes [ ] N/A [ ]
TC27	Bits held to one upon overflow	45.2.6.11		TC:M	Yes [ ] N/A [ ]
TC28	Bits reset to zero when read or reset	45.2.6.12		TC:M	Yes [ ] N/A [ ]
TC29	Bits held to one upon overflow	45.2.6.12		TC:M	Yes [ ] N/A [ ]

45.5.3.18 Clause 22 extension options

Item	Feature	Subclause	Value/Comment	Status	Support
*FEC	Implementation of PHY FEC	65.4.4.6		CTT:O	Yes [ ] No [ ] N/A [ ]

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45.5.3.19 Clause 22 extension management functions

Item	Feature	Subclause	Value/Comment	Status	Support
CT1	Device responds to all register addresses for that device	45.2		CTT:M	Yes [ ] N/A [ ]
CT2	Writes to undefined and read only register have no effect	45.2		CTT:M	Yes [ ] N/A [ ]
CT3	Operation is not affected by writes to reserved and unsupported bits	45.2		CTT:M	Yes [ ] N/A [ ]
CT4	Reserved and unsupported bits return a value of zero	45.2		CTT:M	Yes [ ] N/A [ ]
CT5	Bits set to zero upon PHY reset	45.2.8.3.1		CTT*FEC:M	Yes [ ] N/A [ ]
CT6	Bits reset to all zeros when the register is read by the management function or upon PHY reset.	45.2.8.4		CTT*FEC:M	Yes [ ] N/A [ ]
CT7	Bits held at all ones in the case of overflow	45.2.8.4		CTT*FEC:M	Yes [ ] N/A [ ]
CT8	Bits reset to all zeros when the register is read by the management function or upon PHY reset.	45.2.8.5		CTT*FEC:M	Yes [ ] N/A [ ]
CT9	Bits held at all ones in the case of overflow	45.2.8.5		CTT*FEC:M	Yes [ ] N/A [ ]
CT10	Bits reset to all zeros when the register is read by the management function or upon PHY reset.	45.2.8.6		CTT*FEC:M	Yes [ ] N/A [ ]
CT11	Bits held at all ones in the case of overflow	45.2.8.6		CTT*FEC:M	Yes [ ] N/A [ ]

45.5.3.20 Signal timing characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
ST1	MDIO setup and hold time	45.4.2	Setup min = 10 ns; Hold min = 10 ns per Figure 45–3	M	Yes [ ]
ST2	MDIO clock to output delay	45.4.2	Min = 0 ns; Max = 300 ns per Figure 45–4	M	Yes [ ]
ST3	MDC min high/low time	45.4.2	160 ns	M	Yes [ ]
ST4	MDC min period	45.4.2	400 ns	M	Yes [ ]

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45.5.3.21 Electrical characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
EC1	V_{OH}	45.4.1	≥ 1.0 V (I_{OH} = –100 uA) ≤ 1.5 V (I_{OH} = –100 uA)	M	Yes [ ]
EC2	V_{OL}	45.4.1	≥ –0.3 V (I_{OL} = 100 uA) ≤ 0.2 V (I_{OL} = 100 uA)	M	Yes [ ]
EC3	V_{IH}	45.4.1	0.84 V ≤ V_{IH} ≤ 1.5 V	M	Yes [ ]
EC4	V_{IL}	45.4.1	–0.3 ≤ V_{IL} ≤ 0.36 V	M	Yes [ ]
EC5	Input capacitance for MDIO	45.4.1	≤ 10 pF	M	Yes [ ]
EC6	Total capacitive load	45.4.1	≤ 470 pF	M	Yes [ ]
EC7	I_{OH}	45.4.1	≤ –4 mA at V_{OH} = 1.0 V	!ODB:M	Yes [ ] N/A[ ]
EC8	I_{OL}	45.4.1	≥ +4 mA at V_{OL} = 0.2 V	M	Yes [ ]

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46. Reconciliation Sublayer (RS) and 10 Gigabit Media Independent Interface (XGMII)

46.1 Overview

This clause defines the logical and electrical characteristics for the Reconciliation Sublayer (RS) and 10 Gigabit Media Independent Interface (XGMII) between Ethernet media access controllers and various PHYs. Figure 46–1 shows the relationship of the RS and XGMII to the ISO/IEC (IEEE) OSI reference model.

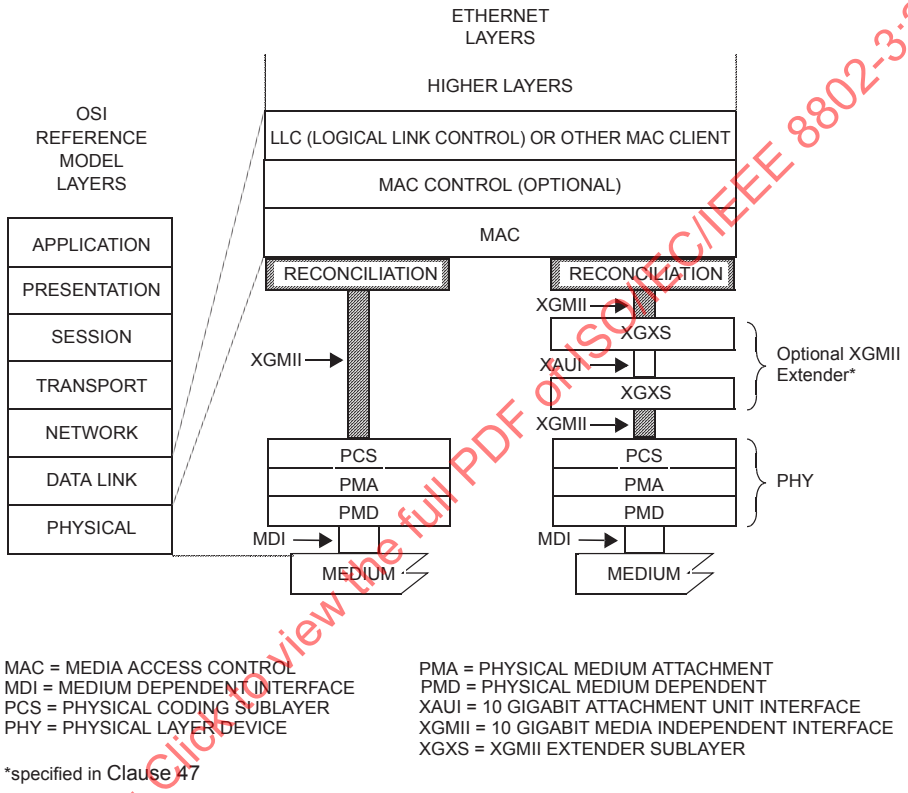

Figure 46–1—XGMII relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

The purpose of the XGMII is to provide a simple, inexpensive, and easy-to-implement interconnection between the Media Access Control (MAC) sublayer and the Physical Layer (PHY). The 10 Gigabit Attachment Unit Interface (XAUI) may optionally be used to extend the operational distance of the XGMII with reduced pin count (see Clause 47).

The RS adapts the bit serial protocols of the MAC to the parallel encodings of 10 Gb/s PHYs. Though the XGMII is an optional interface, it is used extensively in this standard as a basis for specification. The 10 Gb/s Physical Coding Sublayer (PCS) is specified to the XGMII, so if not implemented, a conforming implementation shall behave functionally as if the RS and XGMII were implemented.

The XGMII has the following characteristics:

a) It is capable of supporting 10 Gb/s operation.
b) Data and delimiters are synchronous to clock reference.

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c) It provides independent 32-bit-wide transmit and receive data paths.
d) It uses signal levels compatible with common digital ASIC processes.
e) It provides for full duplex operation only.

46.1.1 Summary of major concepts

The following are the major concepts of XGMII:

a) The XGMII is functionally similar to the MII defined in Clause 22 and GMII defined in Clause 35 as they all define an interface allowing independent development of MAC and PHY logic.
b) The RS converts between the MAC serial data stream and the parallel data paths of the XGMII.
c) The RS maps the signal set provided at the XGMII to the PLS service primitives provided at the MAC.
d) Each direction of data transfer is independent and serviced by data, control, and clock signals.
e) The RS generates continuous data or control characters on the transmit path and expects continuous data or control characters on the receive path.
f) The RS participates in link fault detection and reporting by monitoring the receive path for status reports that indicate an unreliable link, and generating status reports on the transmit path to report detected link faults to the DTE on the remote end of the connecting link.
g) When the XGMII is optionally extended with XAUI, two XGMII interfaces logically exist (see Figure 46–1). The transmit path signals are from the RS to the DTE (top) XGXS of the XAUI via one XGMII and from the PHY (bottom) XGXS to the PCS via the other XGMII. The receive path signals are from the PCS to the PHY XGXS of the XAUI via one XGMII and from the DTE XGXS to the RS via the other XGMII. The descriptions of the XGMII as between the RS and the PCS are, therefore, equally applicable between the RS and the DTE XGXS or the PHY XGXS and the PCS.
h) The XGMII may also support Low Power Idle (LPI) signaling for PHY types supporting Energy-Efficient Ethernet (EEE) (see Clause 78).

46.1.2 Application

This clause applies to the interface between the MAC and PHY. The physical implementation of the interface is primarily intended as a chip-to-chip (integrated circuit to integrated circuit) interface implemented with traces on a printed circuit board. The XGMII may also be used in other ways, for example, as a logical interface between ASIC logic modules within an integrated circuit.

This interface is used to provide media independence so that an identical media access controller may be used with all 10GBASE-P PHY types.

46.1.3 Rate of operation

The XGMII supports only the 10 Gb/s MAC data rate as defined within this clause. Operation at 10 Mb/s and 100 Mb/s is supported by the MII defined in Clause 22 and operation at 1000 Mb/s by the GMII defined in Clause 35.

PHYs that provide an XGMII shall support the 10 Gb/s MAC data rate. 10GBASE-X and 10GBASE-R PHYs operate at a 10 Gb/s data rate. 10GBASE-W PHYs operate at the STS-192/VC-4-64c line rate of 9.95328 Gb/s, mapping the encoded data stream at a 9.58464 Gb/s payload rate. On transmit, this mapping is performed by discarding Idle control characters corresponding to the stretched interpacket gap created by the MAC in this mode of operation, and on receive, by adding interpacket gap Idle control characters as required to adapt to the XGMII RX_CLK rate.

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46.1.4 Delay constraints

Predictable operation of the MAC Control PAUSE operation (Clause 31, Annex 31B) demands that there be an upper bound on the propagation delays through the network. This implies that MAC, MAC Control sublayer, and PHY implementers must conform to certain delay maxima, and that network planners and administrators conform to constraints regarding the cable topology and concatenation of devices. The maximum cumulative MAC Control, MAC and RS round-trip (sum of transmit and receive) delay shall meet the values specified in Table 46–1. Bit time is specified in 1.4, and pause_quanta is specified in 31B.2.

Table 46–1—Round-trip delay constraints

Sublayer	Maximum (bit time)	Maximum (pause_quanta)
MAC, RS, and MAC Control	8192	16

46.1.5 Allocation of functions

The allocation of functions at the XGMII balances the need for media independence with the need for a simple and cost-effective interface. The bus width and signaling rate are applicable to short distance chip-to-chip interconnect with printed circuit board trace lengths electrically limited to approximately 7 cm. The XGMII (like the MII and GMII) maximizes media independence by cleanly separating the Data Link and Physical Layers of the ISO (IEEE) seven-layer reference model. This allocation also recognizes that implementations can benefit from a close coupling between the PLS sublayer or PCS and the PMA sublayer.

46.1.6 XGMII structure

The XGMII is composed of independent transmit and receive paths. Each direction uses 32 data signals (TXD<31:0> and RXD<31:0>), four control signals (TXC<3:0> and RXC<3:0>), and a clock (TX_CLK and RX_CLK). Figure 46–2 depicts a schematic view of the RS inputs and outputs.

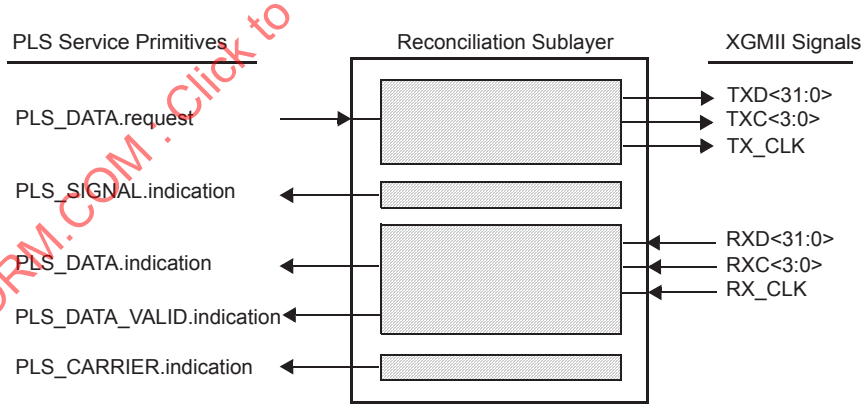

Figure 46–2—Reconciliation Sublayer (RS) inputs and outputs

The 32 TXD and four TXC signals shall be organized into four data lanes, as shall the 32 RXD and four RXC signals (see Table 46–2). The four lanes in each direction share a common clock—TX_CLK for transmit and RX_CLK for receive. The four lanes are used in round-robin sequence to carry an octet stream. On transmit, each eight PLS_DATA.request transactions represent an octet transmitted by the MAC. The

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first octet is aligned to lane 0, the second to lane 1, the third to lane 2 the fourth to lane 3, then repeating with the fifth to lane 0, etc. Delimiters and interframe idle characters are encoded on the TXD and RXD signals with the control code indicated by assertion of TXC and RXC, respectively.

Table 46–2—Transmit and receive lane associations

TXD RXD	TXC RXC	Lane
<7:0>	<0>	0
<15:8>	<1>	1
<23:16>	<2>	2
<31:24>	<3>	3

46.1.7 Mapping of XGMII signals to PLS service primitives

The Reconciliation Sublayer (RS) shall map the signals provided at the XGMII to the PLS service primitives defined in Clause 6. The PLS service primitives provided by the RS and described here behave in exactly the same manner as defined in Clause 6. Full duplex operation only is implemented at 10 Gb/s; therefore, PLS service primitives supporting CSMA/CD operation are not mapped through the RS to the XGMII. The mapping is changed if EEE capability is supported (see 78.3). This behavior and restrictions are the same as described in 22.7, with the details of the signaling described in 46.3. LPI_REQUEST shall not be set to ASSERT unless the attached link has been operational for at least one second (i.e., link_status = OK, according to the underlying PCS/PMA).

EEE capability requires the use of the MAC defined in Annex 4A for simplified full duplex operation (with carrier sense deferral). This provides full duplex operation but uses the carrier sense signal to defer transmission when the PHY is in its low power state.

Mappings for the following primitives are defined for 10 Gb/s operation:

PLS_DATA.request
PLS_DATA.indication
PLS_CARRIER.indication
PLS_SIGNAL.indication
PLS_DATA_VALID.indication

46.1.7.1 Mapping of PLS_DATA.request

46.1.7.1.1 Function

Map the primitive PLS_DATA.request to the XGMII signals TXD<31:0>, TXC<3:0>, and TX_CLK.

46.1.7.1.2 Semantics of the service primitive

PLS_DATA.request (OUTPUT_UNIT)

The OUTPUT_UNIT parameter can take one of three values: ONE, ZERO, or DATA_COMPLETE. It represents a single data bit. The DATA_COMPLETE value signifies that the Media Access Control sublayer has no more data to output.

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46.1.7.1.3 When generated

This primitive is generated by the MAC sublayer to request the transmission of a single data bit on the physical medium or to stop transmission.

46.1.7.1.4 Effect of receipt

The OUTPUT_UNIT values are conveyed to the PHY by the signals TXD<31:0> and TXC<3:0> on each TX_CLK edge. Each PLS_DATA.request transaction shall be mapped to a TXD signal in sequence (TXD<0>, TXD<1>,... TXD<31>, TXD<0>) as described in 46.2. After 32 PLS_DATA.request transactions from the MAC sublayer (four octets of eight PLS_DATA.request transactions each), the RS requests transmission of 32 data bits by the PHY. The first octet of preamble shall be converted to a Start control character and aligned to lane 0. The TXD<31:0> and TXC<3:0> shall be generated by the RS for each 32 bit-times of the MAC sublayer.

The DATA_COMPLETE value shall be mapped to a Terminate control character encoded on the next eight TXD signals in sequence after the last data octet; and is transferred to the PHY at the next TX_CLK edge. This may be on the same TX_CLK edge as the last data octet or the subsequent TX_CLK edge. When the Terminate control character is in lane 0, 1, or 2, the lanes following in sequence are encoded with an Idle control character.

46.1.7.2 Mapping of PLS_DATA.indication

46.1.7.2.1 Function

Map the primitive PLS_DATA.indication to the XGMII signals RXD<31:0>, RXC<3:0> and RX_CLK.

46.1.7.2.2 Semantics of the service primitive

PLS_DATA.indication (INPUT_UNIT)

The INPUT_UNIT parameter can take one of two values: ONE or ZERO. It represents a single data bit.

46.1.7.2.3 When generated

The INPUT_UNIT values are derived from the signals RXC<3:0> and RXD<31:0> received from the PHY on each edge of RX_CLK. Each primitive generated to the MAC sublayer entity corresponds to a PLS_DATA.request issued by the MAC at the remote end of the link connecting two DTEs. For each RXD<31:0> during frame reception, the RS shall generate 32 PLS_DATA.indication transactions until the end of frame (Terminate control character), where 0, 8, 16, or 24 PLS_DATA.indication transactions will be generated from the RXD<31:0> containing the Terminate. During frame reception, each RXD signal shall be mapped in sequence into a PLS_DATA.indication transaction (RXD<0>, RXD<1>,... RXD<31>, RXD<0>) as described in 46.2.

The RS shall convert a valid Start control character to a preamble octet prior to generation of the associated PLS_DATA.indication transactions. The RS shall not generate any PLS_DATA.indication primitives for a Terminate control character. To assure robust operation, the value of the data transferred to the MAC may be changed by the RS as required by XGMII error indications (see 46.3.3). Sequence ordered sets are not indicated to the MAC (see 46.3.4).

46.1.7.2.4 Effect of receipt

The effect of receipt of this primitive by the MAC sublayer is unspecified.

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46.1.7.3 Mapping of PLS_CARRIER.indication

10 Gb/s operation supports full duplex operation only. The RS never generates this primitive for PHYs that do not support EEE or Link Interruption.

For PHYs that support EEE capability, CARRIER_STATUS is set in response to LPI_REQUEST as shown in Figure 46–13. For PHYs that support Link Interruption, CARRIER_STATUS may be set in response to link_fault. CARRIER_STATUS is set to CARRIER_ON if LPI_CARRIER_STATUS is TRUE or if link_fault is Link Interruption. CARRIER_STATUS is otherwise set to CARRIER_OFF. The deferral mechanism based upon the Link Interruption signal may be enabled or disabled by management.

46.1.7.4 Mapping of PLS_SIGNAL.indication

10 Gb/s operation supports full duplex operation only. The RS never generates this primitive.

46.1.7.5 Mapping of PLS_DATA_VALID.indication

46.1.7.5.1 Function

Map the primitive PLS_DATA_VALID.indication to the XGMII signals RXC<3:0> and RXD<31:0>.

46.1.7.5.2 Semantics of the service primitive

PLS_DATA_VALID.indication (DATA_VALID_STATUS)

The DATA_VALID_STATUS parameter can take one of two values: DATA_VALID or DATA_NOT_VALID. The DATA_VALID value indicates that the INPUT_UNIT parameter of the PLS_DATA.indication primitive contains a valid data of an incoming frame. The DATA_NOT_VALID value indicates that the INPUT_UNIT parameter of the PLS_DATA.indication primitive does not contain valid data of an incoming frame.

46.1.7.5.3 When generated

The PLS_DATA_VALID.indication service primitive shall be generated by the RS whenever the DATA_VALID_STATUS parameter changes from DATA_VALID to DATA_NOT_VALID or vice versa.

DATA_VALID_STATUS shall assume the value DATA_VALID when a PLS_DATA.indication transaction is generated in response to reception of a Start control character on lane 0 if the prior RXC<3:0> and RXD<31:0> contained four Idle characters or a Sequence ordered set. DATA_VALID_STATUS shall assume the value DATA_NOT_VALID when RXC of the current lane in sequence is asserted for anything except an Error control character. In the absence of errors, DATA_NOT_VALID is caused by a Terminate control character. When DATA_VALID_STATUS changes from DATA_VALID to DATA_NOT_VALID because of a control character other than Terminate, the RS shall ensure that the MAC will detect a FrameCheckError prior to indicating DATA_NOT_VALID to the MAC (see 46.3.3.1).

46.1.7.5.4 Effect of receipt

The effect of receipt of this primitive by the MAC sublayer is unspecified.

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46.2 XGMII data stream

Packets transmitted through the XGMII shall be transferred within the XGMII data stream. The data stream is a sequence of bytes, where each byte conveys either a data octet or control character. The parts of the data stream are shown in Figure 46–3.

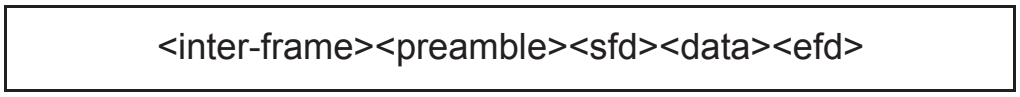

Figure 46–3—XGMII data stream

For the XGMII, transmission and reception of each bit and mapping of data octets to lanes shall be as shown in Figure 46–4.

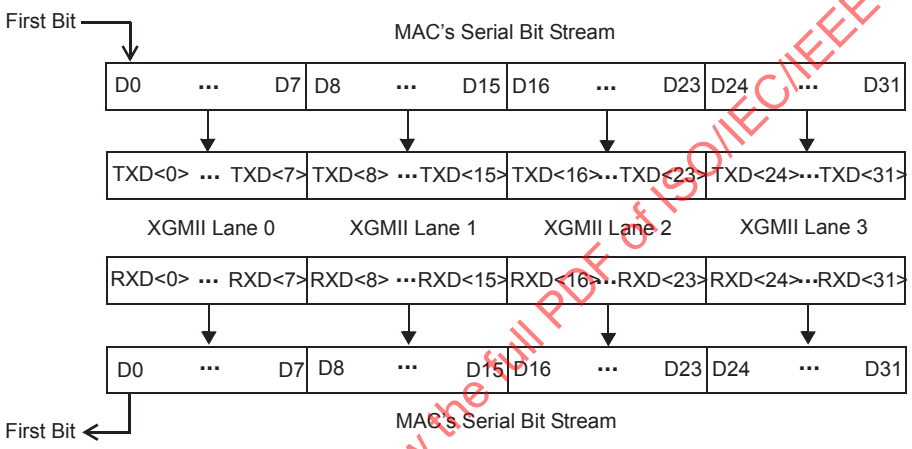

Figure 46–4—Relationship of data lanes to MAC serial bit stream

46.2.1 Inter-frame <inter-frame>

The inter-frame <inter-frame> period on an XGMII transmit or receive path is an interval during which no frame data activity occurs. The <inter-frame> corresponding to the MAC interpacket gap begins with the Terminate control character, continues with Idle control characters and ends with the Idle control character prior to a Start control character. The length of the interpacket gap may be changed between the transmitting MAC and receiving MAC by one or more functions (e.g., RS lane alignment, PHY clock rate compensation, or 10GBASE-W data rate adaptation functions). The minimum IPG at the XGMII of the receiving RS is five octets.

The signaling of link status information logically occurs in the <inter-frame> period (see 46.3.4). Subclause 46.3.3 describes frame processing when signaling of link status information is initiated or terminated.

46.2.2 Preamble <preamble> and start of frame delimiter <sfd>

The preamble <preamble> begins a frame transmission by a MAC as specified in 4.2.5 and when generated by a MAC consists of 7 octets with the following bit values:

10101010 10101010 10101010 10101010 10101010 10101010 10101010

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The Start control character indicates the beginning of MAC data on the XGMII. On transmit, the RS converts the first data octet of preamble transferred from the MAC into a Start control character. On receive, the RS will convert the Start control character into a preamble data octet. The start control character is aligned to lane 0 of the XGMII by the RS on transmit and by the PHY on receive.

The start of frame delimiter <sfd> indicates the start of a frame and immediately follows the preamble. The bit value of <sfd> at the XGMII is unchanged from the Start Frame Delimiter (SFD) specified in 4.2.6 and is the bit sequence:

10101011

The preamble and SFD are shown previously with their bits ordered for serial transmission from left to right. As shown, the left-most bit of each octet is the LSB of the octet and the right-most bit of each octet is the MSB of the octet.

The preamble and SFD are transmitted through the XGMII as octets sequentially ordered on the lanes of the XGMII. The first preamble octet is replaced with a Start control character and it is aligned to lane 0, the second octet on lane 1, the third on lane 2 and the fourth on lane 3, and the four octets are transferred on the next edge of TX_CLK. The fifth octet is assigned to lane 0 with subsequent octets sequentially assigned to the lanes with the SFD assigned to lane 3. The XGMII <preamble> and <sfd> are as follows:

Lane 0	**Lane 1**	**Lane 2**	**Lane 3**
Start	10101010	10101010	10101010
10101010	10101010	10101010	10101011

46.2.3 Data <data>

The data <data> in a well-formed frame shall consist of a set of data octets.

46.2.4 End of frame delimiter <efd>

Assertion of TXC with the appropriate Terminate control character encoding of TXD on a lane constitutes an end of frame delimiter <efd> for the transmit data stream. Similarly, assertion of RXC with the appropriate Terminate control character encoding of RXD constitutes an end of frame delimiter for the receive data stream. The XGMII shall recognize the end of frame delimiter on any of the four lanes of the XGMII.

46.2.5 Definition of Start of Packet and End of Packet Delimiters

For the purposes of Clause 30, the Start of Packet delimiter is defined as the Start control character, and the End of Packet delimiter is defined as the end of the last sequential data octet preceding the Terminate control character or other control character causing a change from DATA_VALID to DATA_NOT_VALID. (See 46.1.7.5.2 and 30.3.2.1.5.)

46.3 XGMII functional specifications

The XGMII is designed to make the differences among the various media and transceiver combinations transparent to the MAC sublayer. The selection of logical control signals and the functional procedures are all designed to this end.

NOTE—No XGMII loopback is defined, but XGMII signals are specified such that transmit signals may be connected to receive signals to create a loopback path. To do this, TXD<0> is connected to RXD<0> ... TXD<31> to RXD<31>, TXC<0> to RXC<0> ... TXC<3> to RXC<3>, and TXCLK to RXCLK. Such a loopback does not test the Link Fault Signaling state diagram, nor any of the error handling functions of the receive RS.

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46.3.1 Transmit

46.3.1.1 TX_CLK (10 Gb/s transmit clock)

TX_CLK is a continuous clock used for operation at 10 Gb/s. TX_CLK provides the timing reference for the transfer of the TXC<3:0> and TXD<31:0> signals from the RS to the PHY. The values of TXC<3:0> and TXD<31:0> shall be sampled by the PHY on both the rising edge and falling edge of TX_CLK. TX_CLK is sourced by the RS.

The TX_CLK frequency shall be 156.25 MHz ±0.01%, one-sixty-fourth of the MAC transmit data rate.

NOTE—For EEE capability, TX_CLK may be halted according to 46.3.1.5.

46.3.1.2 TXC<3:0> (transmit control)

TXC<3:0> indicate that the RS is presenting either data or control characters on the XGMII for transmission. The TXC signal for a lane shall be de-asserted when a data octet is being sent on the corresponding lane and asserted when a control character is being sent. In the absence of errors, the TXC signals are de-asserted by the RS for each octet of the preamble (except the first octet that is replaced with a Start control character) and remain de-asserted while all octets to be transmitted are presented on the lanes of the XGMII. TXC<3:0> are driven by the RS and shall transition synchronously with respect to both the rising and falling edges of TX_CLK. Table 46–3 specifies the permissible encodings of TXD and TXC for a XGMII transmit lane. Additional requirements apply for proper code sequences and in which lanes particular codes are valid (e.g., Start control character is to be aligned to lane 0).

A PHY with EEE capability shall interpret the combination of TXC and TXD as shown in Table 46–3 as an assertion of LPI. Transition into and out of the LPI state is shown in Figure 46–7.

46.3.1.3 TXD<31:0> (transmit data)

TXD is a bundle of 32 data signals organized into four lanes of eight signals each (TXD<7:0>, TXD<15:8>, TXD<23:16>, and TXD<31:24>) that are driven by the RS. Each lane is associated with a TXC signal as shown in Table 46–2 and shall be encoded as shown in Table 46–3. TXD<31:0> shall transition synchronously with respect to both the rising and falling edges of TX_CLK. For each high or low TX_CLK transition, data and/or control are presented on TXD<31:0> to the PHY for transmission. TXD<0> is the least significant bit of lane 0, TXD<8> the least significant bit of lane 1, TXD<16> the least significant bit of lane 2, and TXD<24> the least significant bit of lane 3.

Assertion on a lane of appropriate TXD values when TXC is asserted will cause the PHY to generate code-groups associated with either Idle, Start, Terminate, Sequence, or Error control characters. While the TXC of a lane is de-asserted, TXD of the lane is used to request the PHY to generate code-groups corresponding to the data octet value of TXD. An example of normal frame transmission is illustrated in Figure 46–5.

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Table 46–3—Permissible encodings of TXC and TXD

TXC	TXD	Description	PLS_DATA.request parameter
0	00 through FF	Normal data transmission	ZERO, ONE (eight bits)
1	00 through 05	Reserved	—
1	06	Only valid on all four lanes simultaneously to request LPI	No applicable parameter (normal interframe)
1	07	Idle	No applicable parameter (Normal inter-frame)
1	08 through 9B	Reserved	—
1	9C	Sequence (only valid in lane 0)	No applicable parameter (Inter-frame status signal)
1	9D through FA	Reserved	—
1	FB	Start (only valid in lane 0)	No applicable parameter, replaces first eight ZERO, ONE of a frame (preamble octet)
1	FC	Reserved	—
1	FD	Terminate	DATA_COMPLETE
1	FE	Transmit error propagation	No applicable parameter
1	FF	Reserved	—
NOTE—Values in TXD column are in hexadecimal, most significant bit to least significant bit (i.e., <7:0>).			

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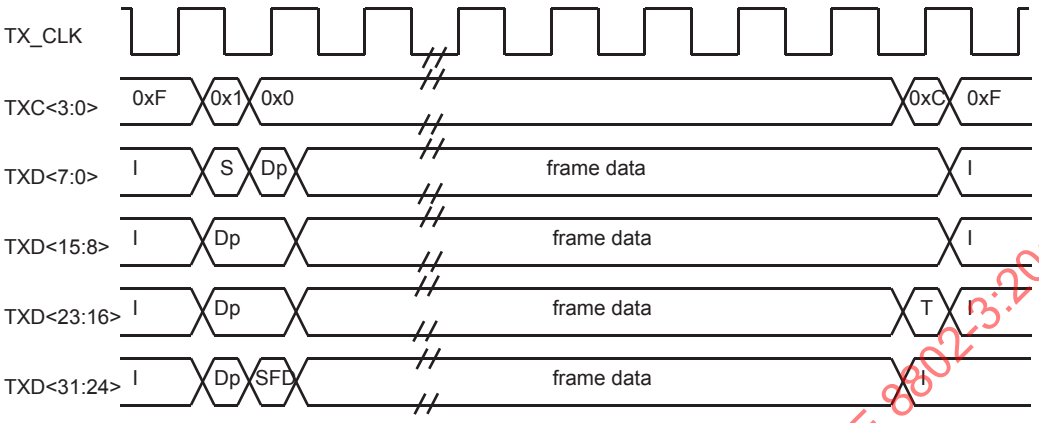
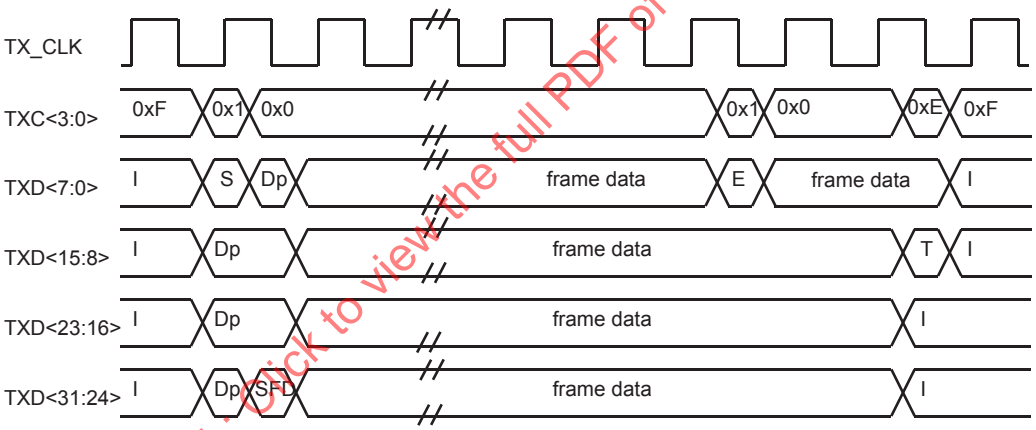
Figure 46–6 shows the behavior of TXD and TXC during an example transmission of a frame propagating an error.



I: Idle control character, S: Start control character, Dp: preamble Data octet, T: Terminate control character

Figure 46–5—Normal frame transmission



I: Idle control character, S: Start control character, Dp: preamble Data octet, T: Terminate control character,
E: Error control character

Figure 46–6—Transmit Error Propagation

46.3.1.4 Start control character alignment

On transmit, it may be necessary for the RS to modify the length of the <inter-frame> in order to align the Start control character (first octet of preamble) on lane 0. This shall be accomplished in one of the following two ways:

1) A MAC implementation may incorporate this RS function into its design and always insert additional idle characters to align the start of preamble on a four byte boundary. Note that this will reduce the effective data rate for certain packet sizes separated with minimum inter-frame spacing.

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2) Alternatively, the RS may maintain the effective data rate by sometimes inserting and sometimes deleting idle characters to align the Start control character. When using this method the RS must maintain a Deficit Idle Count (DIC) that represents the cumulative count of idle characters deleted or inserted. The DIC is incremented for each idle character deleted, decremented for each idle character inserted, and the decision of whether to insert or delete idle characters is constrained by bounding the DIC to a minimum value of zero and maximum value of three. Note that this may result in inter-frame spacing observed on the transmit XGMII that is up to three octets shorter than the minimum transmitted inter-frame spacing specified in Clause 4; however, the frequency of shortened inter-frame spacing is constrained by the DIC rules. The DIC is only reset at initialization and is applied regardless of the size of the IPG transmitted by the MAC sublayer. An equivalent technique may be employed to control RS alignment of the Start control character provided that the result is the same as if the RS implemented DIC as described.

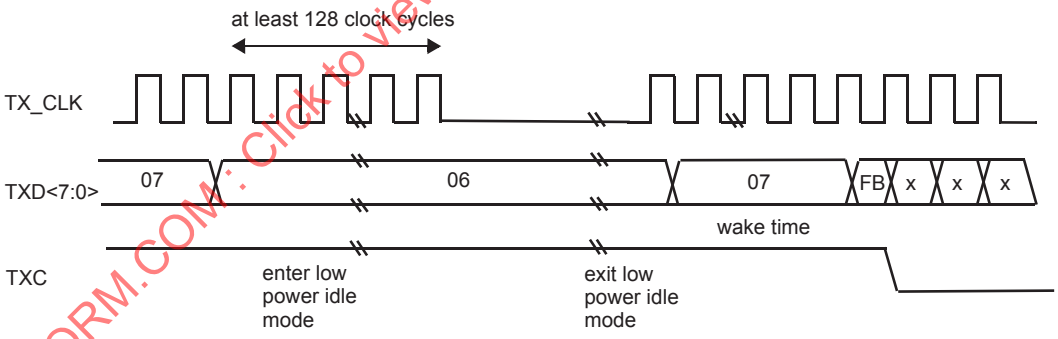
46.3.1.5 Transmit direction LPI transition

LPI operation and the LPI client are described in 78.1. The RS requests the PHY to transition to the LPI state by asserting TXC and setting TXD to 0x06 (in all lanes). The RS maintains the same state for these signals for the entire time that the PHY is to remain in the LPI state.

The RS may halt TX_CLK at any time more than 128 clock cycles after the start of the LPI state as shown in Figure 46–7 if the clock stop capable bit of the attached sublayer is asserted (see 45.2.3.2.1 and 45.2.5.2.1). It is the responsibility of the management entity to ensure that the RS does not halt the TX_CLK if the attached device does not have its stop clock capable bit set. The RS shall restart TX_CLK so that at least one positive transition occurs before it deasserts LPI.

The RS asserts TXC and asserts IDLE on lanes 0–3 in order to make the PHY transition out of the LPI state. The RS should not present a start code for valid transmit data until after the wake-up time specified for the PHY.

Figure 46–7 shows the behavior of TXC and TXD<7:0> during the transition into and out of the LPI state.



NOTE—TXC and TXD are shown for one lane, all four lanes behave identically during LPI.

Figure 46–7—LPI transition

Table 46–3 summarizes the permissible encodings of TXD<31:0>, TXC<3:0>.

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46.3.2 Receive

46.3.2.1 RX_CLK (receive clock)

RX_CLK is a continuous clock that provides the timing reference for the transfer of the RXC<3:0> and RXD<31:0> signals from the PHY to the RS. RXC<3:0> and RXD<31:0> shall be sampled by the RS on both the rising and falling edge of RX_CLK. RX_CLK is sourced by the PHY.

The frequency of RX_CLK may be derived from the received data or it may be that of a nominal clock (e.g., TX_CLK). When the received data rate at the PHY is within tolerance, the RX_CLK frequency shall be 156.25 MHz ±0.01%, one-sixty-fourth of the MAC receive data rate.

There is no need to transition between the recovered clock reference and a nominal clock reference on a frame-by-frame basis. If loss of received signal from the medium causes a PHY to lose the recovered RX_CLK reference, the PHY shall source the RX_CLK from a nominal clock reference. Transitions from nominal clock to recovered clock or from recovered clock to nominal clock shall not decrease the time between adjacent edges of RX_CLK.

NOTE—This standard neither requires nor assumes a guaranteed phase relationship between the RX_CLK and TX_CLK signals. For EEE capability, RX_CLK may be halted according to 46.3.2.4.

46.3.2.2 RXC<3:0> (receive control)

RXC<3:0> indicate that the PHY is presenting either recovered and decoded data or control characters on the XGMII. The RXC signal for a lane shall be de-asserted when a data octet is being received on the corresponding lane and asserted when a control character is being received. In the absence of errors, the RXC signals are de-asserted by the PHY for each octet of the preamble (except the first octet that is replaced with a Start control character) and remain de-asserted while all octets to be received are presented on the lanes of the XGMII. RXC<3:0> are driven by the PHY and shall transition synchronously with respect to both the rising and falling edges of RX_CLK. Table 46–4 specifies the permissible encodings of RXD and RXC for a XGMII receive lane. Additional requirements apply for proper code sequences and in which lanes particular codes are valid (e.g., Start control character is to be aligned to lane 0).

Figure 46–8 shows the behavior of RXC<3:0> during an example frame reception with no errors.

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Table 46–4—Permissible lane encodings of RXD and RXC

RXC	RXD	Description	PLS_DATA.indication parameter
0	00 through FF	Normal data reception	ZERO, ONE (eight bits)
1	00 through 05	Reserved	—
1	06	Only valid on all four lanes simultaneously to indicate LP_IDLE is asserted	No applicable parameter (Normal interframe)
1	07	Idle	No applicable parameter (Normal inter-frame)
1	08 through 9B	Reserved	—
1	9C	Sequence (only valid in lane 0)	No applicable parameter (Inter-frame status signal)
1	9D through FA	Reserved	—
1	FB	Start (only valid in lane 0)	No applicable parameter, first eight ZERO, ONE of a frame (a preamble octet)
1	FC	Reserved	—
1	FD	Terminate	No applicable parameter (Start of inter-frame)
1	FE	Receive error	No applicable parameter
1	FF	Reserved	—
NOTE—Values in RXD column are in hexadecimal, most significant bit to least significant bit (i.e., <7:0>).			

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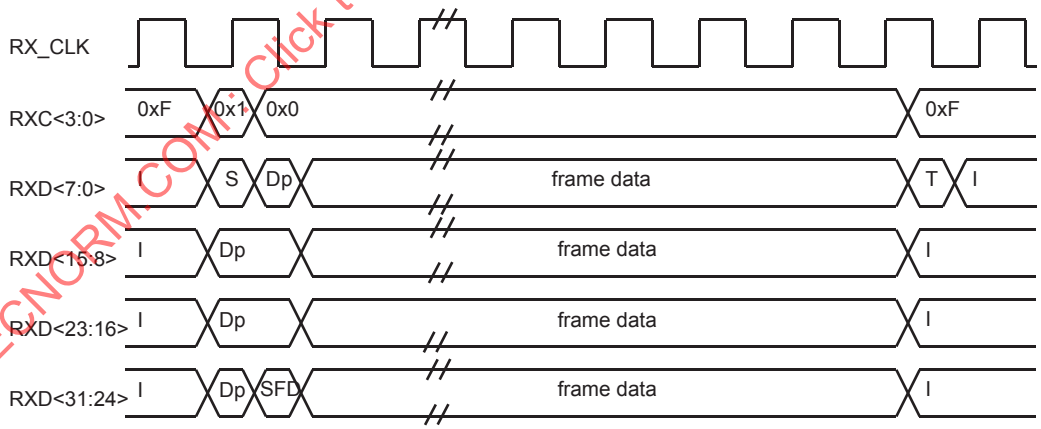

I: Idle control character, S: Start control character, Dp: preamble Data octet, T: Terminate control character

Figure 46–8—Basic frame reception

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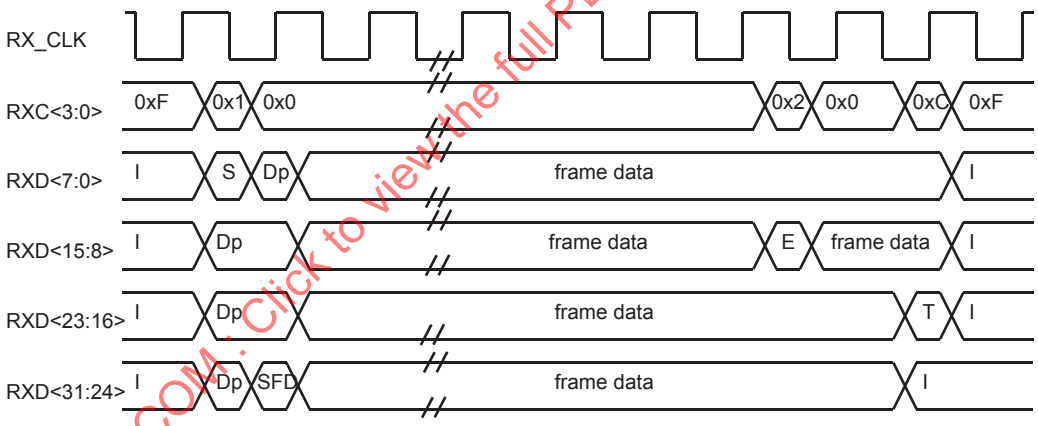
46.3.2.3 RXD (receive data)

RXD is a bundle of 32 data signals (RXD<31:0>) organized into four lanes of eight signals each (RXD<7:0>, RXD<15:8>, RXD<23:16>, and RXD<31:24>) that are driven by the PHY. Each lane is associated with a RXC signal as shown in Table 46–2 and shall be decoded by the RS as shown in Table 46–4. RXD<31:0> shall transition synchronously with respect to both the rising and falling edges of RX_CLK. For each high or low RX_CLK transition, received data and/or control are presented on RXD<31:0> for mapping by the RS. RXD<0> is the least significant bit of lane 0, RXD<8> the least significant bit of lane 1, RXD<16> the least significant bit of lane 2, and RXD<24> the least significant bit of lane 3. Figure 46–8 shows the behavior of RXD<31:0> during frame reception.

While the RXC of a lane is de-asserted, RXD of the lane is used by the RS to generate PLS_DATA.indication transactions. Assertion on a lane of appropriate RXD values when RXC is asserted indicates to the RS the Start control character, Terminate control character, Sequence control character, or Error control character that drive its mapping functions.

RXC of a lane is asserted with the appropriate Error control character encoding on RXD of the lane to indicate an error was detected somewhere in the frame presently being transferred from the PHY to the RS (e.g., a coding error, or any error that the PHY is capable of detecting, and that may otherwise be undetectable at the MAC sublayer).

The effect of an Error control character on the RS is defined in 46.3.3.1. Figure 46–9 shows the behavior of RXC and RXD during the reception of an example frame with an error.



I: Idle control character, S: Start control character, Dp: preamble Data octet, T: Terminate control character, E: Error control character

Figure 46–9—Reception with error

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46.3.2.4 Receive direction LPI transition

LPI operation and the LPI client are described in 78.1. When the PHY receives signals from the link partner to indicate transition into the low power state, it indicates this to the RS by asserting RXC and setting RXD to 0x06 (in all lanes). The PHY maintains these signals in this state while it remains in the LPI state. When the PHY receives signals from the link partner to indicate transition out of the LPI state, it indicates this to the RS by asserting RXC and asserting idle on lanes 0–3 to return to a normal interframe state. The RS shall interpret the LPI coding as shown in Table 46–4.

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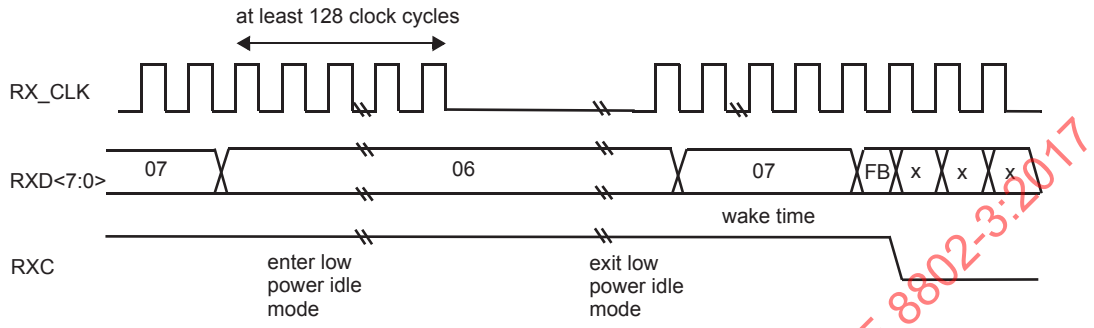
The PHY or DTE XS may halt RX_CLK at any time more than 128 clock cycles after the start of the LPI state as shown in Figure 46–10 if the clock stop enable bit is asserted (see 45.2.3.1.4 and 45.2.5.1.4). The PHY shall restart RX_CLK so that at least one positive transition occurs before it deasserts LPI.

Figure 46–10 shows the behavior of RXC and RXD<7:0> during LPI transitions.



NOTE 1—RXC and RXD are shown for one lane, all 4 lanes behave identically during LPI.
NOTE 2—In some instances, LPI may be followed by characters other than IDLE during wake time.

Figure 46–10—LPI transition

46.3.3 Error and fault handling

46.3.3.1 Response to error indications by the XGMII

If, during frame reception (i.e., when DATA_VALID_STATUS = DATA_VALID), a control character other than a Terminate control character is signaled on a received lane, the RS shall ensure that the MAC will detect a FrameCheckError in that frame. This requirement may be met by incorporating a function in the RS that produces a received frame data sequence delivered to the MAC sublayer that is guaranteed to not yield a valid CRC result, as specified by the frame check sequence algorithm (see 3.2.8). This data sequence may be produced by substituting data delivered to the MAC. The RS generates eight PLS_DATA.indication primitives for each Error control character received within a frame, and may generate eight PLS_DATA.indication primitives to ensure FrameCheckError when a control character other than Terminate causes the end of the frame.

Other techniques may be employed to respond to a received Error control character provided that the result is that the MAC sublayer behaves as though a FrameCheckError occurred in the received frame.

46.3.3.2 Conditions for generation of transmit Error control characters

If, during the process of transmitting a frame, it is necessary to request that the PHY deliberately corrupt the contents of the frame in such a manner that a receiver will detect the corruption with the highest degree of probability, then an Error control character may be asserted on a transmit lane by the appropriate encoding of the lane's TXD and TXC signals.

46.3.3.3 Response to received invalid frame sequences

The 10 Gb/s PCS is required to either preserve the column alignment of the transmitting RS, or align the Start control character to lane 0. The RS shall not indicate DATA_VALID to the MAC for a Start control character received on any other lane. Error free 10 Gb/s operation will not change the SFD alignment in lane

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3. A 10 Gb/s MAC/RS implementation is not required to process a packet that has an SFD in a position other than lane 3 of the column following the column containing the Start control character.

46.3.4 Link fault signaling

Link fault signaling operates between the remote RS and the local RS. Faults detected between the remote RS and the local RS are received by the local RS as Local Fault. Only an RS originates Remote Fault signals.

Sublayers within the PHY are capable of detecting faults that render a link unreliable for communication. Upon recognition of a fault condition a PHY sublayer indicates Local Fault status on the data path. When this Local Fault status reaches an RS, the RS stops sending MAC data or LPI, and continuously generates a Remote Fault status on the transmit data path (possibly truncating a MAC frame being transmitted). When Remote Fault or Link Interruption status is received by an RS, the RS stops sending MAC data or LPI, and continuously generates Idle control characters. When the RS no longer receives fault status messages, it returns to normal operation, sending MAC data or LPI.

Status is signaled in a four byte Sequence ordered set as shown in Table 46–5. The PHY indicates Local Fault with a Sequence control character in lane 0 and data characters of 0x00 in lanes 1 and 2 plus a data character of 0x01 in lane 3. The RS indicates a Remote Fault with a Sequence control character in lane 0 and data characters of 0x00 in lanes 1 and 2 plus a data character of 0x02 in lane 3. Though most fault detection is on the receive data path of a PHY, in some specific sublayers, faults can be detected on the transmit side of the PHY. This is also indicated by the PHY with a Local Fault status.

For operation with links that may be temporarily interrupted, optional detection of a third fault condition, Link Interruption, is provided. Link Interruption is indicated by the PHY receive function by continuously sending the Link Interruption ordered set as defined in Table 46–5.

Table 46–5—Sequence ordered sets

Lane 0	Lane 1	Lane 2	Lane 3	Description
Sequence	0x00	0x00	0x00	Reserved
Sequence	0x00	0x00	0x01	Local Fault
Sequence	0x00	0x00	0x02	Remote Fault
Sequence	0x00	0x00	0x03	Link Interruption
Sequence	≥ 0x00	≥ 0x00	≥ 0x04	Reserved
NOTE—Values in Lane 1, Lane 2, and Lane 3 columns are in hexadecimal, most significant bit to least significant bit (i.e., <7:0>). The link fault signaling state diagram allows future standardization of reserved Sequence ordered sets for functions other than link fault indications				

The RS reports the fault status of the link. Local Fault indicates a fault detected on the receive data path between the remote RS and the local RS. Remote Fault indicates a fault on the transmit path between the local RS and the remote RS. The RS shall implement the link fault signaling state diagram (see Figure 46–11).

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46.3.4.1 Conventions

The notation used in the state diagram follows the conventions of 21.5. The notation ++ after a counter indicates it is to be incremented.

46.3.4.2 Variables and counters

The link fault signaling state diagram uses the following variables and counters:

col_cnt
: A count of the number of columns received not containing a fault_sequence. This counter increments at RX_CLK rate (on both the rising and falling clock transitions) unless reset.

fault_sequence
: A new column received on RXC<3:0> and RXD<31:0> comprising a Sequence ordered set of four bytes and consisting of a Sequence control character in lane 0 and a seq_type in lanes 1, 2, and 3 indicating either Local Faut, Remote Fault, or Link Interruption.

last_seq_type
: The seq_type of the previous Sequence ordered set received
Values:Local Fault; 0x00 in lane 1, 0x00 in lane 2, 0x01 in lane 3.
Remote Fault; 0x00 in lane 1, 0x00 in lane 2, 0x02 in lane 3.
Link Interruption; 0x00 in lane 1, 0x00 in lane 2, 0x03 in lane 3.

link_fault
: An indicator of the fault status.
Values:OK; No fault.
Local Fault; fault detected by the PHY.
Remote Fault; fault detection signaled by the remote RS.
Link Interruption; link temporarily unavailable, signaled by the PHY.

reset
: Condition that is true until such time as the power supply for the device that contains the RS has reached the operating region.
Values:FALSE: The device is completely powered and has not been reset (default).
TRUE: The device has not been completely powered or has been reset.

seq_cnt
: A count of the number of received Sequence ordered sets of the same type.

seq_type
: The value received in the current Sequence ordered set
Values:Local Fault; 0x00 in lane 1, 0x00 in lane 2, 0x01 in lane 3.
Remote Fault; 0x00 in lane 1, 0x00 in lane 2, 0x02 in lane 3.
Link Interruption; 0x00 in lane 1, 0x00 in lane 2, 0x03 in lane 3.

46.3.4.3 State diagram

The link fault signaling state diagram specifies the RS monitoring of RXC<3:0> and RXD<31:0> for Sequence ordered sets. The variable link_fault is set to indicate the value of a received Sequence ordered set when four fault_sequences containing the same fault value have been received with each pair of fault sequences separated by less than 128 columns and no intervening fault_sequences of a different fault value.

The variable link_fault is set to OK following any interval of 128 columns not containing a Remote Fault, Local Fault, or Link Interruption Sequence ordered set.

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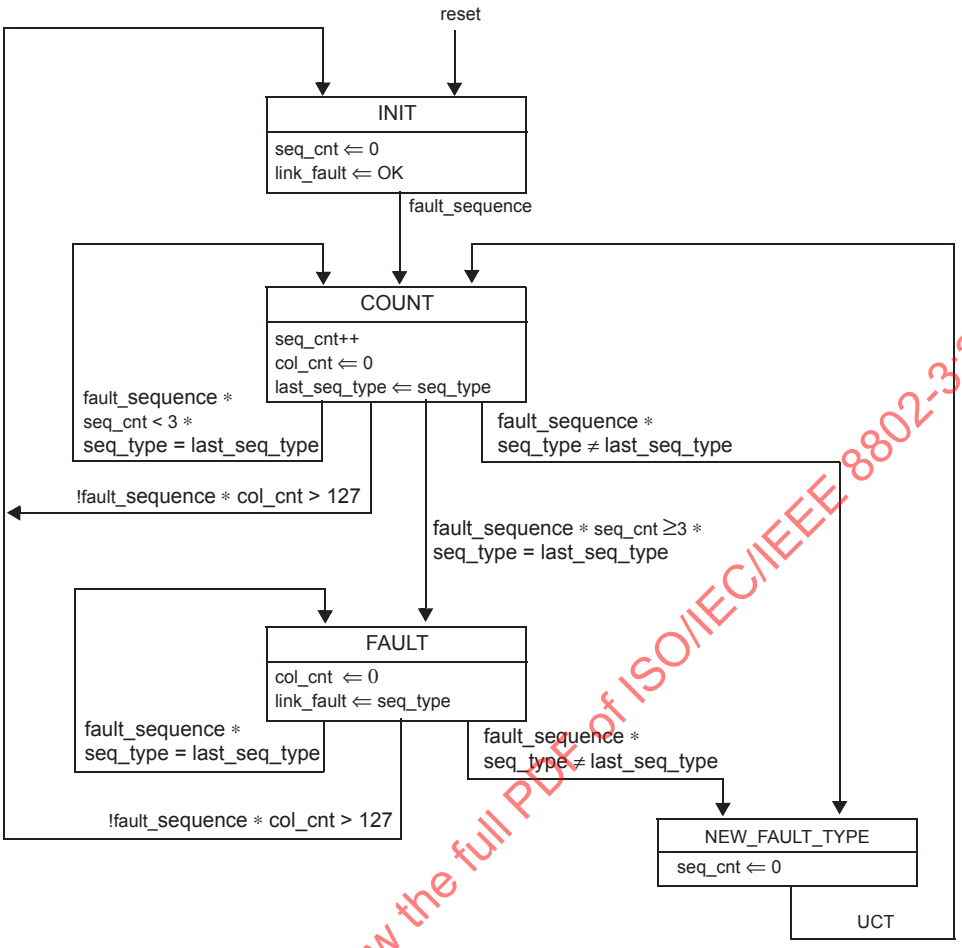

Figure 46–11—Link fault signaling state diagram

The RS output onto TXC<3:0> and TXD<31:0> is controlled by the variable link_fault.

a) link_fault = OK
The RS shall send MAC frames as requested through the PLS service interface. In the absence of MAC frames, the RS shall generate Idle control characters.
b) link_fault = Local Fault
The RS shall continuously generate Remote Fault Sequence ordered sets.
c) link_fault = Remote Fault or link_fault = Link Interruption
The RS shall continuously generate Idle control characters.

46.4 LPI assertion and detection

Certain PHYs support Energy-Efficient Ethernet (see Clause 78). PHYs with EEE capability support LPI assertion and detection. LPI operation and the LPI client are described in 78.1. LPI signaling allows the RS to signal to the PHY and to the link partner that a break in the data stream is expected and components may use this information to enter power-saving modes that require additional time to resume normal operation. Similarly, it allows the LPI client to understand that the link partner has sent such an indication.

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The LPI assertion and detection mechanism fits conceptually between the PLS Service Primitives and the XGMII signals as shown in Figure 46–12.

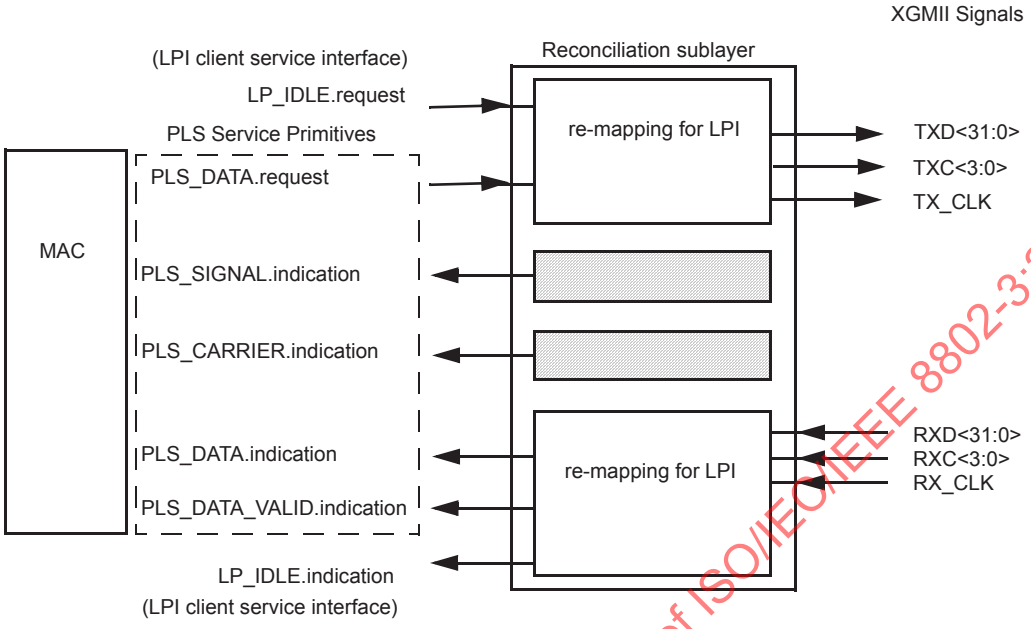

Figure 46–12—LPI assertion and detection mechanism

The definition of TXC<3:0> and TXD<31:0> is derived from the state of PLS_DATA.request (46.1.7), except when it is overridden by an assertion of LP_IDLE.request.

Similarly, RXC<3:0> and RXD<31:0> are mapped to PLS_DATA.indication except when LP_IDLE is detected

PLS_CARRIER.indication(CARRIER_STATUS) will be set to CARRIER_ON when the link is in LPI mode. See 46.1.7.3.

The timing of PLS_CARRIER.indication when used for the LPI function is controlled by the LPI transmit state diagram.

46.4.1 LPI messages

LP_IDLE.indication(LPI_INDICATION)

A primitive that indicates to the LPI client that the PHY has detected the assertion or de-assertion of LPI from the link partner.

Values:DEASSERT: The link partner is operating with normal interframe behavior (default).
ASSERT: The link partner has asserted LPI.

LP_IDLE.request(LPI_REQUEST)

The LPI_REQUEST parameter can take one of two values: ASSERT or DE-ASSERT. ASSERT initiates the signaling of LPI to the link partner. DE-ASSERT stops the signaling of LPI to the link partner. The effect of receipt of this primitive is undefined if link_status is not OK (see 28.2.6.1.1) or within 1 s of the change of link_status to OK.

46.4.2 Transmit LPI state diagram

The operation of LPI in the PHY requires that the MAC does not send valid data for a time after LPI has been de-asserted as governed by resolved Transmit T_{w_sys} defined in 78.4.2.3.

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This wake-up time is enforced by the transmit LPI state diagram using CARRIER_SENSE.indication. The implementation shall conform to the behavior described by the transmit LPI state diagram shown in Figure 46–13.

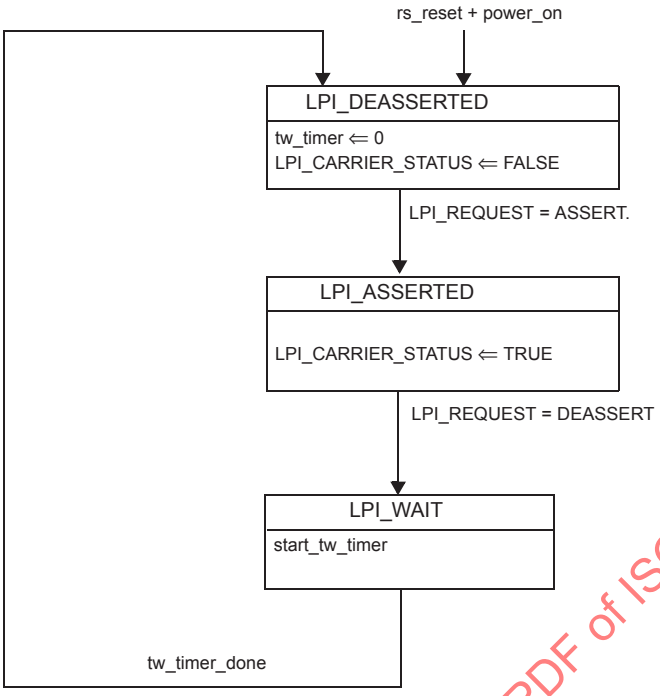

Figure 46–13—Transmit LPI state diagram

46.4.2.1 Variables and counters

The transmit LPI state diagram uses the following variables and counters:

LPI_CARRIER_STATUS
: The LPI_CARRIER_STATUS variable indicates how the CARRIER_STATUS parameter is controlled by the LPI_REQUEST parameter. The LPI_CARRIER_STATUS is either TRUE or FALSE as determined by the Transmit LPI state diagram in Figure 46–13.

power_on
: Condition that is true until such time as the power supply for the device that contains the RS has reached the operating region.
Values:FALSE: The device is completely powered (default).
TRUE: The device has not been completely powered.

rs_reset
: Used by management to control the resetting of the RS.
Values:FALSE: Do not reset the RS (default).
TRUE: Reset the RS.

tw_timer
: A timer that counts, in microseconds, the time since the de-assertion of LPI. The terminal count of the timer is the value of the resolved $T_{w_sys_tx}$ as defined in 78.2. If DTE XS XAUI stop enable bit is asserted (5.0.9), the terminal count of the timer is the value of the resolved $T_{w_sys_tx}$ as defined in 78.2 plus additional time equal to $T_{w_sys_tx} - T_{w_sys_rx}$ for the XGXS as shown in Table 78–4.

The signal tw_timer_done is asserted when tw_timer reaches its terminal count.

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46.4.3 Considerations for transmit system behavior

The transmit system should expect that egress data flow will be halted for at least resolved $T_{w_sys_tx}$ (see 78.2) time, in microseconds, after it requests the de-assertion of LPI. Buffering and queue management should be designed to accommodate this.

46.4.4 Considerations for receive system behavior

The mapping function of the Reconciliation Sublayer shall continue to signal IDLE on PLS_DATA.indicate while it is detecting LP_IDLE on the XGMII. The receive system should be aware that data frames may arrive at the XGMII following the de-assertion of LPI_INDICATION with a delay corresponding to the link partner's resolved $T_{w_sys_rx}$ (as specified in 78.5) time, in microseconds.

If the PHY XS XAUI stop enable bit (4.0.9) is asserted, the PHY XS may stop signaling on the XAUI in the receive direction to conserve energy. The receiver should negotiate an additional 9.5 µs for the remote T_{w_sys} (equal to $T_{w_sys_tx} - T_{w_sys_rx}$ for the XGXS as shown in Table 78–4) before setting the PHY XS XAUI stop enable bit.

46.5 XGMII electrical characteristics

The electrical characteristics of the XGMII are specified such that the XGMII can be applied within a variety of 10 Gb/s equipment types. The electrical specifications are selected for an integrated circuit to integrated circuit application. The electrical characteristics specified in this clause apply to all XGMII signals.

When implemented as a chip-to-chip interface, the XGMII uses High Speed Transceiver Logic (HSTL), specified for a 1.5 volt output buffer supply voltage. XGMII chip-to-chip signals shall comply with EIA/JEDEC Standard EIA/JESD8-6 using Class I, output buffers. Output impedance shall be greater than 38Ω to assure acceptable overshoot and undershoot performance in an unterminated interconnection.

The thresholds and parametric values for HSTL XGMII signals are shown in the informative Figure 46–14 and informative Table 46–6.

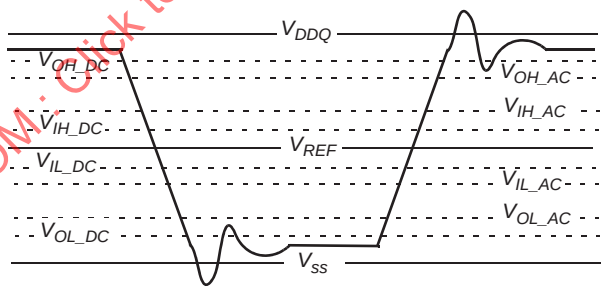

Figure 46–14—Electrical characteristics (informative)

The HSTL specification shows a number of termination options for different applications. Informative Figure 46–15 illustrates a possible XGMII circuit topology. Unterminated interconnection is recommended.

The XGMII chip-to-chip signals shall meet the timing requirements shown in Figure 46–16. All XGMII timing measurements shall be made at the XGMII driver output with the optional termination shown in Figure 46–15 and with a capacitive load from all sources of 10pF and are specified relative to the $V_{IL_AC(max)}$ and $V_{IH_AC(min)}$ thresholds.

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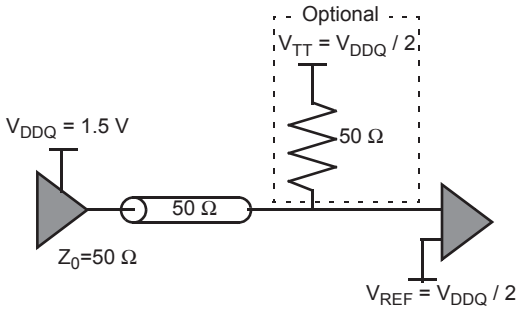
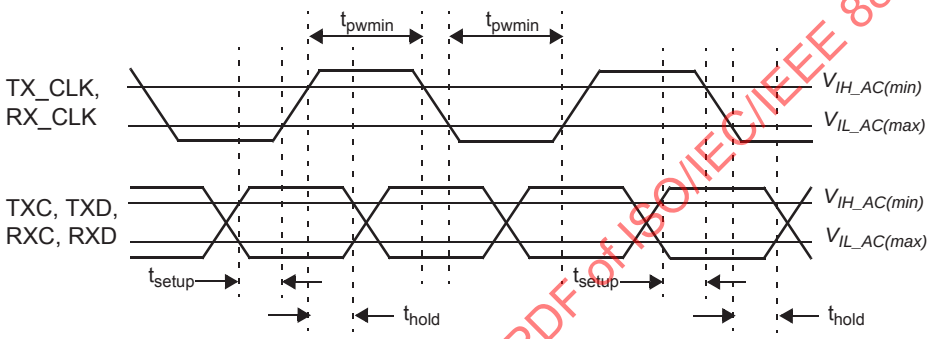


Figure 46–15—Circuit topology example (informative)



Symbol	Driver	Receiver	Units
t_{setup}	960	480	ps
t_{hold}	960	480	ps
t_{pwmin}	2.5	—	ns

Figure 46–16—TX_CLK and RX_CLK timing parameters

Table 46–6—DC and AC specifications (informative)

Symbol	Parameter	Min	Nom	Max	Units
V_{DDQ}	Output supply voltage	1.4	1.5	1.6	V
V_{REF}	Input reference voltage	0.68	0.75	0.90	V
V_{IH_DC}	DC input logic high	V_{REF}+0.10	—	V_{DDQ}+0.3	V
V_{IL_DC}	DC input logic low	–0.30	—	V_{REF}–0.1	V
V_{IH_AC}	AC input logic high	V_{REF}+0.20	—	—	V
V_{IL_AC}	AC input logic low	—	—	V_{REF}–0.20	V

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46.6 Protocol implementation conformance statement (PICS) proforma for Clause 46, Reconciliation Sublayer (RS) and 10 Gigabit Media Independent Interface (XGMII)[2]

46.6.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 46, Reconciliation Sublayer (RS) and 10 Gigabit Media Independent Interface (XGMII), shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

46.6.2 Identification

46.6.2.1 Implementation identification

Supplier[1]	
Contact point for inquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1,3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

46.6.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 46, Reconciliation Sublayer (RS) and 10 Gigabit Media Independent Interface (XGMII)
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	

Date of Statement	

[2]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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46.6.2.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*PHY	PHY support of XGMII	46.2, 46.3		O	Yes [ ] No [ ]
*RS	Reconciliation Sublayer support of XGMII	46.2, 46.3		O	Yes [ ] No [ ]
*XGE	XGMII electrical interface	46.4		O	Yes [ ] No [ ]
*LPI	Implementation of LPI	46.1.7		O	Yes [ ] No [ ]

46.6.3 PICS proforma Tables for Reconciliation Sublayer and 10 Gigabit Media Independent Interface

46.6.3.1 General

Item	Feature	Subclause	Value/Comment	Status	Support
G1	PHY support of MAC data rate	46.1.3	Support MAC data rate of 10 Gb/s	PHY:M	Yes [ ] N/A [ ]
G2	Cumulative MAC Control, MAC and RS round-trip delay	46.1.4	Per Table 46–1	RS:M	Yes [ ] N/A [ ]
G3	Lane structure	46.1.6	Per Table 46–2	M	Yes [ ]

46.6.3.2 Mapping of PLS service primitives

Item	Feature	Subclause	Value/Comment	Status	Support
PL1	Mapping to Clause 6	46.1.7	RS implements mapping to Clause 6 PLS service primitives	RS:M	Yes [ ] N/A [ ]
PL2	Mapping of PLS_DATA.requests	46.1.7.1.4	In sequence TXD<0> to TXD<31>	RS:M	Yes [ ] N/A [ ]
PL3	Start control character creation	46.1.7.1.4	First octet of preamble converted to Start control character	RS:M	Yes [ ] N/A [ ]
PL4	TXD and TXC generation	46.1.7.1.4	For each 32 PLS_DATA.requests	RS:M	Yes [ ] N/A [ ]
PL5	Terminate control character creation	46.1.7.1.4	DATA_COMPLETE causes creation of Terminate control character in next lane in sequence	RS:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
PL6	Mapping RXD to PLS_DATA.incicates	46.1.7.2.3	Create PLS_DATA.increments in sequence from RXD<0> to RXD<31>	RS:M	Yes [ ] N/A [ ]
PL7	PLS_DATA.indication generation	46.1.7.2.3	Generate 32 PLS_DATA.indications for each RXD<0:31> until Terminate then generating 0, 8, 16, or 24	RS:M	Yes [ ] N/A [ ]
PL8	Start control character conversion	46.1.7.2.3	Convert valid Start control character to preamble before generating PLS_DATA.indications	RS:M	Yes [ ] N/A [ ]
PL9	Terminate control character	46.1.7.2.3	No PLS_DATA.indications generated	RS:M	Yes [ ] N/A [ ]
PL10	PLS_DATA_VALID.indication generation	46.1.7.5.3	On change of value of DATA_VALID_STATUS	RS:M	Yes [ ] N/A [ ]
PL11	DATA_VALID_STATUS	46.1.7.5.3	Value of DATA_VALID on a lane 0 Start control character preceded by four idles or a Sequence ordered set	RS:M	Yes [ ] N/A [ ]
PL12	DATA_VALID_STATUS	46.1.7.5.3	Value of DATA_NOT_VALID on any control character but Error	RS:M	Yes [ ] N/A [ ]
PL13	Frame not ending with Terminate control character	46.1.7.5.3	Ensure MAC detects CRC error	RS:M	Yes [ ] N/A [ ]

46.6.3.3 Data stream structure

Item	Feature	Subclause	Value/Comment	Status	Support
DS1	Frame transfer	46.2	Within XGMII data stream	RS:M	Yes [ ] N/A [ ]
DS2	Bit mapping	46.2	Per Figure 46–4	RS:M	Yes [ ] N/A [ ]
DS3	Content of <data>	46.2.3	Consist of data octets	RS:M	Yes [ ] N/A [ ]
DS4	Recognition of <efd>	46.2.4	Terminate recognized in any lane	RS:M	Yes [ ] N/A [ ]

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46.6.3.4 LPI functions

Item	Feature	Subclause	Value/Comment	Status	Support
L1	Assertion of LPI in Tx direction	46.3.1.2	As defined in Table 46–3	LPI:M	Yes [ ] N/A [ ]
L2	Assertion of LPI in Rx direction	46.3.2.2	As defined in Table 46–4	LPI:M	Yes [ ] N/A [ ]
*L3	TX_CLK stoppable during LPI	46.3.1.5	At least 128 cycles after LPI assertion	LPI:O	Yes [ ] No [ ]
L4	TX_CLK restart before LPI deassert	46.3.1.5	At least 1 positive edge before LPI deassertion	L3:M	Yes [ ] N/A [ ]
L5	RX_CLK stoppable during LPI	46.3.2.4		LPI:O	Yes [ ] No [ ]

46.6.3.5 Link Interruption

Item	Feature	Subclause	Value/Comment	Status	Support
LINT	Detection of Link Interruption	46.3.4		O	Yes [ ] No [ ]
LINT1	CARRIER_STATUS response to Link Interruption	46.1.7.3	Set to CARRIER_ON if link_fault is Link Interruption	LINT:O	Yes [ ] No [ ]

46.6.3.6 XGMII signal functional specifications

NOTE—An XGXS adjacent to an RS exhibits the characteristics of a PHY for the items in this subclause, and an XGXS adjacent to a PCS exhibits the characteristics of an RS for the items in this subclause.

Item	Feature	Subclause	Value/Comment	Status	Support
FS1	TX_CLK active edges	46.3.1.1	TXD and TXC sampled on both edges of TX_CLK	XGE:M	Yes [ ] N/A [ ]
FS2	TX_CLK frequency	46.3.1.1	156.25 MHz ± 0.01%	XGE:M	Yes [ ] N/A [ ]
FS3	TXC assertion and de-assertion	46.3.1.2	De-asserted for data, asserted for control character	RS:M	Yes [ ] N/A [ ]
FS4	TXC clock	46.3.1.2	Synchronous to TX_CLK	XGE:M	Yes [ ] N/A [ ]
FS5	TXD encoding	46.3.1.3	Per Table 46–3	RS:M	Yes [ ] N/A [ ]
FS6	TXD clock	46.3.1.3	Synchronous to TX_CLK	XGE:M	Yes [ ] N/A [ ]
FS7	Start alignment	46.3.1.4	Start control character aligned to lane 0	RS:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
FS8	RX_CLK active edges	46.3.2.1	RXD and RXC sampled on both edges of RX_CLK	XGE:M	Yes [ ] N/A [ ]
FS9	RX_CLK frequency	46.3.2.1	156.25 MHz ± 0.01% when received data rate is within tolerance	XGE:M	Yes [ ] N/A [ ]
FS10	Loss of receive signal	46.3.2.1	Source RX_CLK from nominal clock	PHY:M	Yes [ ] N/A [ ]
FS11	Transition between clock sources	46.3.2.1	No decrease of RX_CLK period when switching sources	PHY:M	Yes [ ] N/A [ ]
FS12	RXC assertion and de-assertion	46.3.2.2	De-asserted for data, asserted for control character	PHY:M	Yes [ ] N/A [ ]
FS13	RXC clock	46.3.2.2	Synchronous to RX_CLK	XGE:M	Yes [ ] N/A [ ]
FS14	RXD decoding	46.3.2.3	Per Table 46–4	RS:M	Yes [ ] N/A [ ]
FS15	RXD clock	46.3.2.3	Synchronous to RX_CLK	XGE:M	Yes [ ] N/A [ ]
FS16	Received Error control character	46.3.3.1	RS cause MAC_FrameCheckError	RS:M	Yes [ ] N/A [ ]
FS17	DATA_VALID assertion	46.3.3.3	RS not assert DATA_VALID unless Start control character in lane 0	RS:M	Yes [ ] N/A [ ]

46.6.3.7 Link fault signaling state diagram

Item	Feature	Subclause	Value/Comment	Status	Support
LF1	Link fault signaling state diagram	46.3.4	Implement per Figure 46–11	RS:M	Yes [ ] N/A [ ]
LF2	link_fault = OK and MAC frames	46.3.4.3	RS services MAC frame transmission requests	RS:M	Yes [ ] N/A [ ]
LF3	link_fault = OK and no MAC frames	46.3.4.3	In absence of MAC frames, RS transmits Idle control characters	RS:M	Yes [ ] N/A [ ]
LF4	link_fault = Local Fault	46.3.4.3	RS transmits continuous Remote Fault Sequence ordered sets	RS:M	Yes [ ] N/A [ ]
LF5	link_fault = Remote Fault	46.3.4.3	RS transmits continuous Idle control characters	RS:M	Yes [ ] N/A [ ]

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46.6.3.8 Electrical characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
EC1	Referenced standard for signals	46.5	Signals to be compliant with EIA/JESD8-6 using Class I, output buffers	XGE:M	Yes [ ] N/A [ ]
EC2	Output impedance	46.5	Signal output impedance of at least 38 Ω	XGE:M	Yes [ ] N/A [ ]
EC3	Signal timing	46.5	Per Figure 46–16	XGE:M	Yes [ ] N/A [ ]
EC4	Signal measurement	46.5	At driver output with optional termination per Figure 46–15 and with a capacitive load from all sources of 10 pF	XGE:M	Yes [ ] N/A [ ]

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47. XGMII Extender Sublayer (XGXS) and 10 Gigabit Attachment Unit Interface (XAUI)

47.1 Overview

This clause defines the functional and electrical characteristics for the optional XGMII Extender Sublayer (XGXS) and 10 Gigabit Attachment Unit Interface (XAUI). Figure 47–1 shows the relationships of the XGMII, XGMII Extender, XGXS, and XAUI.

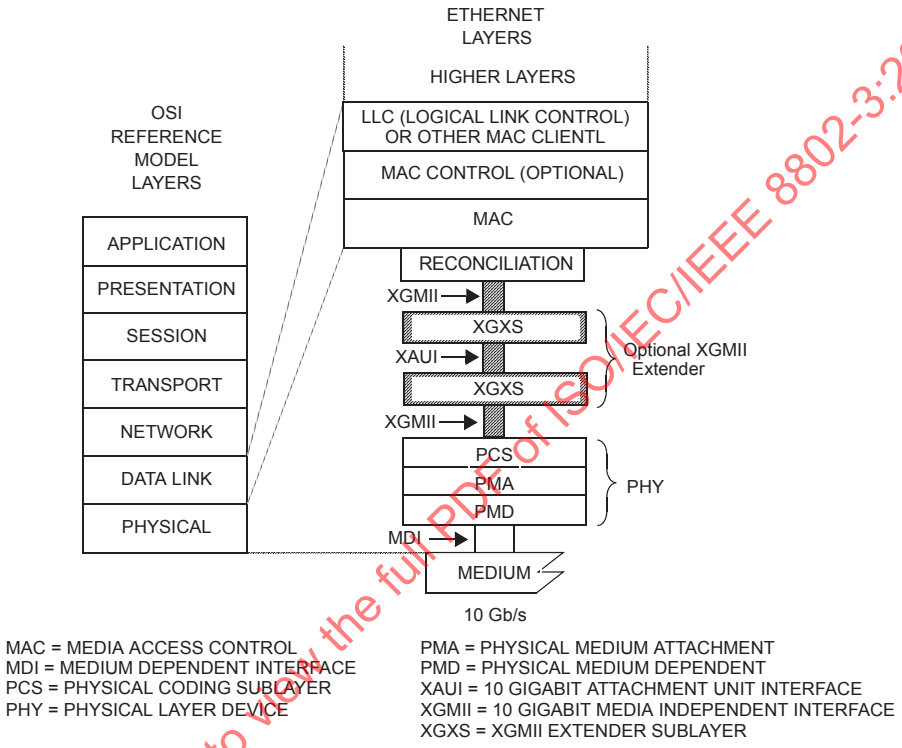

Figure 47–1—XAUI and XGXS relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

The purpose of the XGMII Extender, which is comprised of an XGXS at the RS end (DTE XGXS), an XGXS at the PHY end (PHY XGXS) and a XAUI between them, is to extend the operational distance of the XGMII and to reduce the number of interface signals. Applications include extending the physical separation possible between MAC and PHY components in a 10 Gigabit Ethernet system distributed across a circuit board.

An XGMII Extender with the optional Energy-Efficient Ethernet (EEE) capability (see 78.3) may enter a low power state to conserve energy during periods of low link utilization. The ability to support transition to a low power state is indicated by register 4.20.0 (for a PHY XS) or 5.20.0 (for a DTE XS). Transition to the low power state is enabled by register 4.0.9 (for a PHY XS) or 5.0.9 (for a DTE XS). The assertion of Low Power Idle (LPI) at the XGMII is encoded in the transmitted symbols. Detection of LPI encoding in the received symbols is indicated as LPI at the XGMII. When LPI is received on the transmit XGMII, an energy-efficient XGMII Extender sends sleep symbols, then, if enabled, ceases transmission and deactivates XAUI transmit signals to conserve energy. When the receiver sees the sleep symbols it transitions to a quiet state. The XGMII Extender periodically transmits during the quiet period to allow the attached XGMII Extender to refresh its receiver state (e.g., timing recovery, adaptive filter coefficients) and thereby track

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long-term variation in the timing of the link or the underlying channel characteristics. If, during the quiet or refresh periods, normal interframe idle is asserted at the transmit XGMII, the XGMII Extender reactivates transmit functions and initiates transmission. This transmission will be detected by the attached XGMII Extender, causing it to also exit the low power state.

The optional XGMII Extender has the following characteristics:

a) Simple signal mapping to the XGMII
b) Independent transmit and receive data paths
c) Four lanes conveying the XGMII 32-bit data and control
d) Differential signaling with low voltage swing
e) Self-timed interface allows jitter control to the PCS
f) Shared technology with other 10 Gb/s interfaces
g) Shared functionality with other 10 Gb/s Ethernet blocks
h) Utilization of 8B/10B coding
i) Optionally extend LPI signaling to PHY for EEE
j) Optionally conserve energy during periods of low utilization

47.1.1 Summary of major concepts

The following is a list of the major concepts of XGXS and XAUI:

a) The optional XGMII Extender can be inserted between the Reconciliation Sublayer and the PHY to transparently extend the physical reach of the XGMII and reduce the interface pin count.
b) The XGMII is organized into four lanes with each lane conveying a data octet or control character on each edge of the associated clock. The source XGXS converts bytes on an XGMII lane into a self clocked, serial, 8B/10B encoded data stream. Each of the four XGMII lanes is transmitted across one of the four XAUI lanes.
c) The source XGXS converts XGMII Idle control characters (interframe) into an 8B/10B code sequence. The destination XGXS recovers clock and data from each XAUI lane and deskews the four XAUI lanes into the single-clock XGMII.
d) The destination XGXS adds to or deletes from the interframe as needed for clock rate disparity compensation prior to converting the interframe code sequence back into XGMII Idle control characters.
e) The XGXS uses the same code and coding rules as the 10GBASE-X PCS and PMA specified in Clause 48.

47.1.2 Application

This clause applies to the XGMII between the MAC and PHY. The implementation of the optional XGMII Extender is primarily intended as a chip-to-chip (integrated circuit to integrated circuit) interface implemented with traces on a printed circuit board. Where the XGMII is electrically limited to distances of approximately 7 cm, the XGMII Extender allows distances up to approximately 50 cm.

47.1.3 Rate of operation

The XGMII Extender supports the 10 Gb/s data rate of the XGMII. The 10 Gb/s MAC data stream is converted into four lanes at the XGMII (by the Reconciliation Sublayer for transmit or the PHY for receive). The byte stream of each lane is 8B/10B encoded by the XGXS for transmission across the XAUI at a nominal rate of 3.125 GBd. The XGXS at the PHY end of the XGMII Extender (PHY XGXS) and the XGXS at the RS end (DTE XGXS) may operate on independent clocks.

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47.1.4 Allocation of functions

The XGMII Extender is transparent to the Reconciliation Sublayer and PHY device, and operates symmetrically with similar functions on the DTE transmit and receive data paths. The XGMII Extender is logically composed of two XGXSs interconnected with a XAUI data path in each direction. One XGXS acts as the source to the XAUI data path in the DTE transmit path and as the destination in the receive path. The other XGXS is the destination in the transmit path and source in the receive path. Each XAUI data path is composed of four serial lanes. All specifications for the XGMII Extender are written assuming conversion from XGMII to XAUI and back to XGMII, but other techniques may be employed provided that the result is that the XGMII Extender operates as if all specified conversions had been made. One example of this is the use of the optional XAUI with the 10GBASE-LX4 8B/10B PHY, where the XGXS interfacing to the Reconciliation Sublayer provides the PCS and PMA functionality required by the PHY. An XGXS layer is not required at the PHY end of the XAUI in this case. However, means may still be required to remove jitter introduced on the XAUI in order to meet PHY jitter requirements.

47.1.5 Global signal detect function

Global signal detect is mandatory for EEE capability, otherwise it is optional and its definition is beyond the scope of this standard. When global signal detect is not implemented, the value of SIGNAL_DETECT shall be set to OK for purposes of management and signaling of the primitive.

For EEE capability, the global signal detect function shall control the PMA SIGNAL_DETECT parameter. The SIGNAL_DETECT parameter can take on one of two values, OK or FAIL, indicating whether the XGXS is detecting electrical energy at the XAUI receiver (OK) or not (FAIL). When SIGNAL_DETECT = FAIL, PMA parameter rx_lane<3:0> is undefined.

47.1.6 Global transmit disable function

Global transmit disable is mandatory for EEE capability. The transmit disable function shall turn off all transmitter lanes after tx_mode changes to QUIET within a time and voltage level specified in 47.3.3.2. The transmit disable function shall turn on all transmitter lanes after tx_mode changes to DATA within a time and voltage level specified in 47.3.3.2.

47.2 Functional specifications

At the source side of a XAUI, the XGXS takes XGMII data streams striped over four lanes as its input, maps XGMII data and control characters into XAUI code-groups, and encodes them for transmission. At the destination end of the XAUI, the XGXS decodes the code-groups, deskews the four lanes, compensates for clock rate disparity, and maps the XAUI code-groups back into XGMII data and control characters. Each XGXS is bidirectional, having both source and destination functionality. Figure 47–2 depicts a schematic representation of the XGXS inputs and outputs.

47.2.1 PCS and PMA functionality

The XGXS shall meet all mandatory portions of 48.2 and 48.3, and may meet any optional portions of 48.2 and 48.3. Since the PHY XGXS operates with the XGMII below the XAUI, the transmit requirements of 48.2 and 48.3 apply to the PHY XGXS receive requirements and the receive requirements apply to the PHY XGXS transmit functionality.

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47.2.2 Delay constraints

The XGMII Extender shall meet the delay constraints in 48.5. The contribution of the XAUI interconnect is included in these delay constraints.

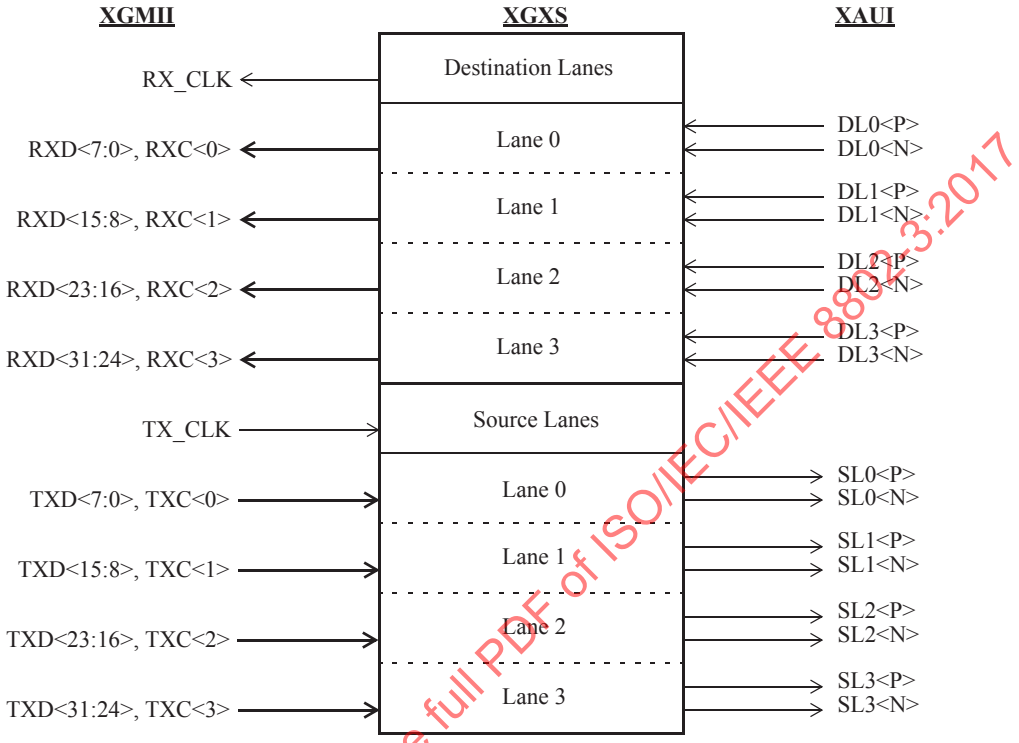

Figure 47–2—XGXS inputs and outputs

47.3 XAUI Electrical characteristics

The electrical characteristics of the XGMII Extender are specified such that it can be applied within a variety of 10 Gb/s Ethernet equipment types. There are two interface types associated with the XGMII Extender: the XGMII and XAUI. The electrical characteristics of both are selected for an integrated circuit to integrated circuit application. The electrical characteristics for the XGMII are specified in 46.5. The electrical characteristics for XAUI are specified in this subclause. Unless specified otherwise, the electrical characteristics defined in this subclause are applicable to all valid sequences of code-groups.

47.3.1 Signal levels

The XAUI is a low swing AC-coupled differential interface. AC-coupling allows for interoperability between components operating from different supply voltages. Low swing differential signaling provides noise immunity and improved electromagnetic interference (EMI). Differential signal swings defined in 47.3 depend on several factors, such as transmitter pre-equalization and transmission line losses.

47.3.2 Signal paths

The XAUI signal paths are point-to-point connections. Each path corresponds to a XAUI lane and is comprised of two complementary signals making a balanced differential pair. There are four differential

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paths in each direction for a total of eight pairs, or sixteen connections. The signal paths are intended to operate up to approximately 50 cm over controlled impedance traces on standard FR4 printed circuit boards (PCBs).

47.3.3 Driver characteristics

The XAUI driver characteristics are summarized in Table 47–1. The XAUI Baud shall be 3.125 GBd ±100 ppm. The corresponding Baud period is nominally 320 ps.

Table 47–1—Driver characteristics

Parameter	Value	Units
Baud rate tolerance	3.125 GBd ± 100 ppm	GBd, ppm
Unit interval nominal	320	ps
Differential amplitude maximum	1600	mV_{p-p}
Absolute output voltage limits maximum minimum	 2.3 –0.4	 V V
Differential output return loss minimum	[See Equation (47–1)]	dB
Output jitter Near-end maximums Total jitter Deterministic jitter Far-end maximums Total jitter Deterministic jitter	 ± 0.175 peak from the mean ± 0.085 peak from the mean ± 0.275 peak from the mean ± 0.185 peak from the mean	 UI UI UI UI

47.3.3.1 Load

The load is 100 Ω ± 5% differential to 2.5 GHz for these measurements, unless otherwise noted.

47.3.3.2 Amplitude and swing

Driver differential output amplitude shall be less than 1600 mV_{p-p} including any transmit equalization. DC-referenced logic levels are not defined since the receiver is AC-coupled. Absolute driver output voltage shall be between –0.4 V and 2.3 V with respect to ground. See Figure 47–3 for an illustration of absolute driver output voltage limits and definition of differential peak-to-peak amplitude.

For EEE capability, the transmitter lane's differential peak-to-peak output voltage shall be less than 30 mV within 500 ns of tx_quiet being asserted. Furthermore, the transmitter lane's differential peak-to-peak output voltage shall be greater than 800 mV within 500 ns of tx_quiet being de-asserted.

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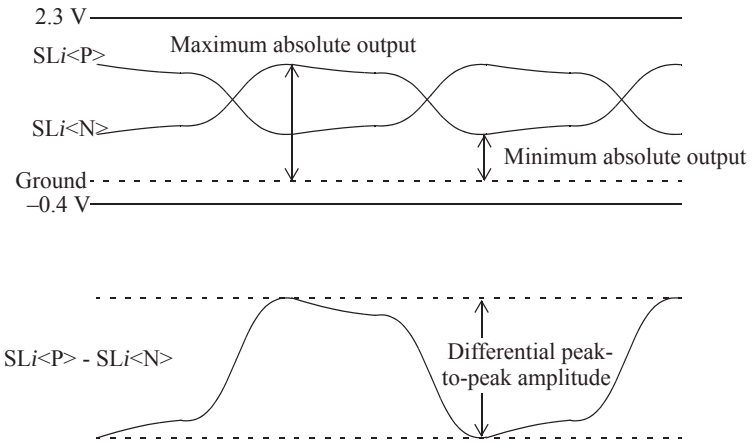

Figure 47–3—Driver output voltage limits and definitions
[L*i*<P> and L*i*<N> are the positive and negative sides of the differential signal pair for lane *i* (*i* = 0, 1, 2, 3)]

47.3.3.3 Transition time

Differential transition times between 60 and 130 ps are recommended, as measured between the 20% and 80% levels. Shorter transitions may result in excessive high-frequency components and increase EMI and crosstalk. The upper recommended limit of 130 ps corresponds to a sine wave at the half Baud.

47.3.3.4 Output impedance

For frequencies from 312.5 MHz to 3.125 GHz, the differential return loss of the driver shall exceed Equation (47–1). Differential return loss includes contributions from on-chip circuitry, chip packaging, and any off-chip components related to the driver. This output impedance requirement applies to all valid output levels. The reference impedance for differential return loss measurements is 100 Ω.

$$s_{11} = -10 \text{ dB for } 312.5 \text{ MHz} < \text{Freq } (f) < 625 \text{ MHz, and} \qquad (47\text{–}1)$$
$$-10 + 10\log(f/625) \text{ dB for } 625 \text{ MHz} \le \text{Freq } (f) \le 3.125 \text{ GHz}$$

where f is frequency in MHz.

47.3.3.5 Driver template and jitter

The driver shall satisfy either the near-end eye template and jitter requirements, or the far-end eye template and jitter requirements. The eye templates are given in Figure 47–4 and Table 47–2. The template measurement requirements are specified in 47.4.2. The jitter requirements at the near end are for a maximum total jitter of ± 0.175 UI peak from the mean and a maximum deterministic component of ± 0.085 UI peak from the mean. The far-end requirements are for a maximum total jitter of ± 0.275 UI peak from the mean and a maximum deterministic component of ± 0.185 UI peak from the mean. Note that these values assume symmetrical jitter distributions about the mean. If a distribution is not symmetrical, its peak-to-peak total jitter value must be less than these total jitter values to claim compliance to the template requirements per the methods of 47.4.2. Jitter specifications include all but 10^{-12} of the jitter population. The maximum random jitter is equal to the maximum total jitter minus the actual deterministic jitter. Jitter measurement requirements are described in 47.4.3.

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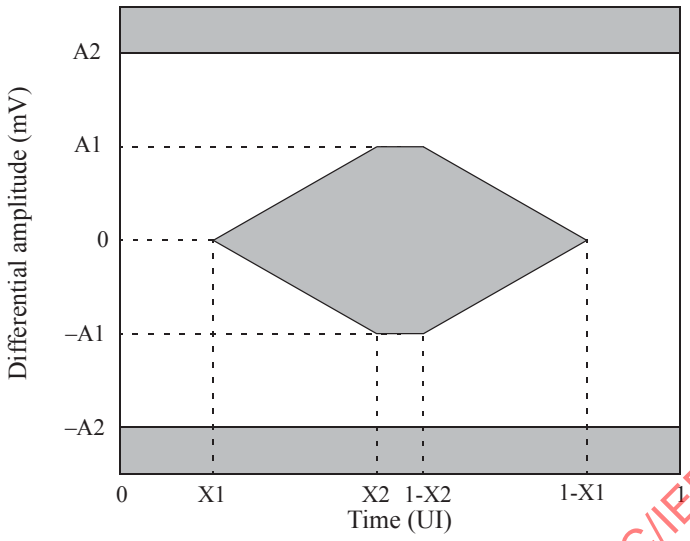

Figure 47–4—Driver template

Table 47–2—Driver template intervals

Symbol	Near-end value	Far-end value	Units
X1	0.175	0.275	UI
X2	0.390	0.400	UI
A1	400	100	mV
A2	800	800	mV

47.3.4 Receiver characteristics

Receiver characteristics are summarized in Table 47–3 and detailed in the following subclauses.

47.3.4.1 Bit error ratio

The receiver shall operate with a BER of better than 10^{-12} in the presence of a reference input signal as defined in 47.3.4.2.

47.3.4.2 Reference input signals

Reference input signals to a XAUI receiver have the characteristics determined by compliant XGXSs and XAUI drivers. Reference input signals satisfy the far-end template given in Figure 47–4 and Table 47–2 when the signal source impedance is 100 Ω ±5%. The template measurement requirements are specified in 47.4.2. Note that the input signal might not meet this template when this load is replaced by the actual receiver. Signal jitter does not exceed the jitter tolerance requirements specified in 47.3.4.6.

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Table 47–3—Receiver characteristics

Parameter	Value	Units
Baud rate tolerance	3.125 ±100	GBd ppm
Unit interval (UI) nominal	320	ps
Receiver coupling	AC	
EEE Signal Detect deactivation time (T_{SD}) from active to LPI quiet	750	ns
EEE Signal Detect activation time (T_{SA}) from LPI quiet to active	750	ns
Return loss[a] differential common-mode	 10 6	 dB dB
Jitter amplitude tolerance[b]	0.65	UI_{p-p}

[a]Relative to 100 Ω differential and 25 Ω common-mode. See 47.3.4.5 for input impedance details.
[b]See 47.3.4.6 for jitter tolerance details.

47.3.4.3 Input signal amplitude

XAUI receivers shall accept differential input signal amplitudes produced by compliant transmitters connected without attenuation to the receiver. Note that this may be larger than the 1600 mV_{p-p} maximum of 47.3.3.2 due to actual driver and receiver input impedances. The minimum input amplitude is defined by the far-end driver template and the actual receiver input impedance. Note that the far-end driver template is defined using a well controlled load impedance. The minimum signal amplitude into an actual receiver may vary from the minimum template height due to the actual receiver input impedance. Since the XAUI receiver is AC-coupled to the XAUI, the absolute voltage levels with respect to the receiver ground are dependent on the receiver implementation.

47.3.4.4 AC-coupling

The XAUI receiver shall be AC-coupled to the XAUI to allow for maximum interoperability between various 10 Gb/s components. AC-coupling is considered to be part of the receiver for the purposes of this specification unless explicitly stated otherwise. It should be noted that there may be various methods for AC-coupling in actual implementations.

47.3.4.5 Input impedance

Receiver input impedance shall result in a differential return loss better than 10 dB and a common-mode return loss better than 6 dB from 100 MHz to 2.5 GHz. This includes contributions from on-chip circuitry, the chip package and any off-chip components related to the receiver. AC-coupling components are included in this requirement. The reference impedance for return loss measurements is 100 Ω for differential return loss and 25 Ω for common-mode.

47.3.4.6 Jitter tolerance

The XAUI receiver shall have a peak-to-peak total jitter amplitude tolerance of at least 0.65 UI. This total jitter is composed of three components: deterministic jitter, random jitter, and an additional sinusoidal jitter. Deterministic jitter tolerance shall be at least 0.37 UI_{p-p}. Tolerance to the sum of deterministic and random jitter shall be at least 0.55 UI_{p-p}. The XAUI receiver shall tolerate an additional sinusoidal jitter with any

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frequency and amplitude defined by the mask of Figure 47–5. This additional component is intended to ensure margin for low-frequency jitter, wander, noise, crosstalk and other variable system effects. Jitter specifications include all but 10^{-12} of the jitter population. Jitter tolerance test requirements are specified in 47.4.3.

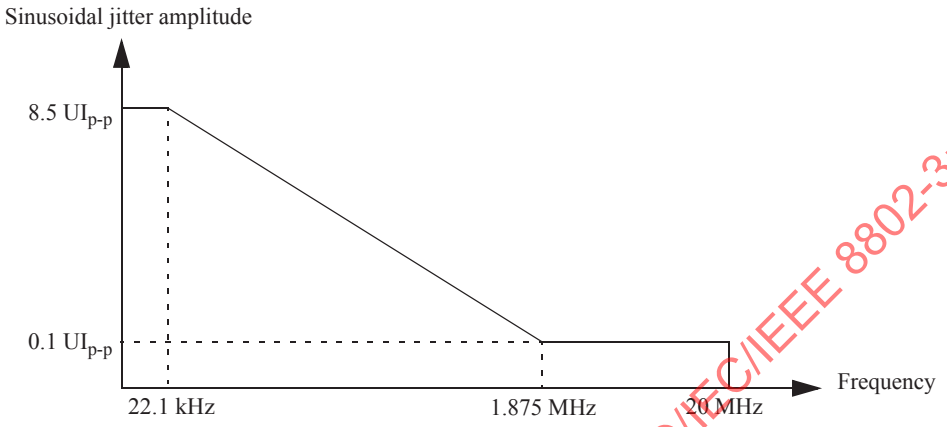

Figure 47–5—Single-tone sinusoidal jitter mask

47.3.4.7 EEE receiver timing

For EEE capability, the receiver shall meet the timing requirements shown in Table 47–3 for Signal_Detect activation and deactivation.

47.3.5 Interconnect characteristics

The XAUI is primarily intended as a point-to-point interface of up to approximately 50 cm between integrated circuits using controlled impedance traces on low-cost printed circuit boards (PCBs). Informative loss and jitter budgets are presented in Table 47–4 to demonstrate the feasibility of standard FR4 epoxy PCBs. The performance of an actual XAUI interconnect is highly dependent on the implementation. The compliance interconnect limit of 47.4.1 represents the median performance of a range of interconnect designs. The range included designs from 46 to 56 cm in total length, having trace widths of 0.125 to 0.300 mm, and using different grades and thicknesses of FR4. Interconnect configurations ranged from single-board designs to systems of two daughter cards mating to a backplane through high-speed electrical connectors.

47.3.5.1 Characteristic impedance

The recommended differential characteristic impedance of circuit board trace pairs is 100 Ω ± 10% from 100 MHz to 2.5 GHz.

47.3.5.2 Connector impedance

The recommended impedance of any connectors, such as used between circuit board subsystems, is 100 Ω ± 30%.

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Table 47–4—Informative XAUI loss, skew and jitter budget

	Loss (dB)[a]	Differential skew (ps_{p-p})	Total jitter (UI_{p-p})[c]	Deterministic jitter (UI_{p-p})[c]
Driver	0	15	0.35	0.17
Interconnect	7.5	60	0.20	0.20
Other[b]	4.5		0.10	0.10
Total	12.0	75	0.65	0.47

[a]Budgetary loss in height of eye opening.
[b]Includes such effects as crosstalk, noise, and interaction between jitter and eye height.
[c]Jitter specifications include all but 10^{-12} of the jitter population.

47.4 Electrical measurement requirements

47.4.1 Compliance interconnect definition

The compliance interconnect is a 100 Ω differential system specified with respect to transmission magnitude response and intersymbol interference (ISI) loss. The compliance interconnect limits have been chosen to allow a realistic differential interconnect of about 50 cm length on FR4 epoxy PCB. See 47.3.5 for a more detailed description of the target XAUI interconnect. The transmission magnitude response, $|s_{21}|$, of the compliance interconnect in dB satisfies Equation (47–2).

$$|s_{21}| \le |s_{21}|_{limit} = -20\log(e) \times [a_1\sqrt{f} + a_2 f + a_3 f^2] \quad (47\text{–}2)$$

where f is frequency in Hz, $a_1 = 6.5 \times 10^{-6}$, $a_2 = 2.0 \times 10^{-10}$, and $a_3 = 3.3 \times 10^{-20}$. This limit applies from DC to 3.125 GHz. The magnitude response above 3.125 GHz does not exceed –11.4 dB. The ISI loss, defined as the difference in magnitude response between two frequencies, is greater than 4.0 dB between 312.5 MHz and 1.5625 GHz. The magnitude response and ISI loss limits are illustrated in Figure 47–6.

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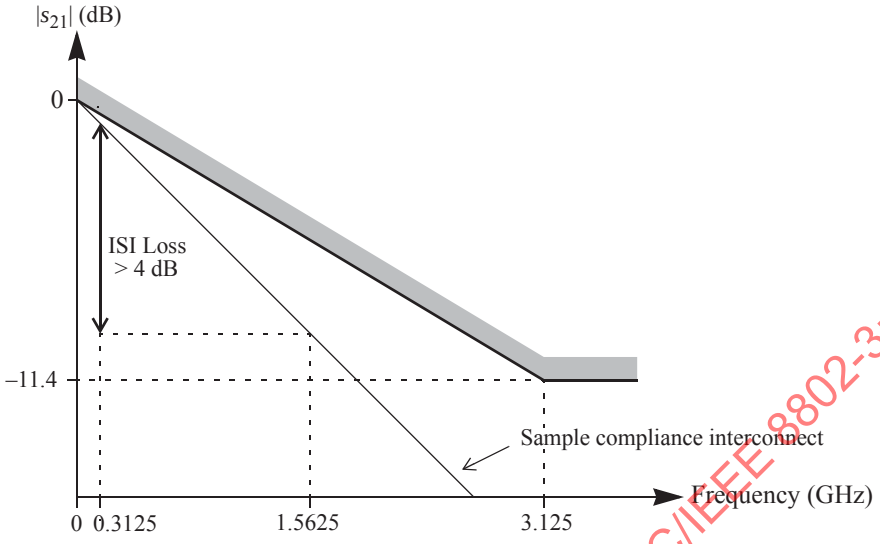

Figure 47–6—Compliance interconnect magnitude response and ISI loss

47.4.2 Eye template measurements

For the purpose of eye template measurements, the effect of a single-pole high-pass filter with a 3 dB point at 1.875 MHz is applied to the jitter. See 48B.1.3 for an explanation of this technique. The data pattern for template measurements is the CJPAT pattern defined in Annex 48A. All XAUI lanes are active in both the transmit and receive directions, and opposite ends of the link use asynchronous clocks. The amount of data represented in the data eye must be adequate to ensure a bit error ratio of less than 10^{-12}. The eye template is measured with AC-coupling and centered at 0 volts differential. The left and right edges of the template are aligned with the mean zero crossing points of the measured data eye, as illustrated in Figure 47–7. The near-end load for this test is specified in 47.3.3.1. The far-end template is measured at the end of the compliance interconnect specified in 47.4.1. The far-end load for the compliance link is specified in 47.3.3.1.

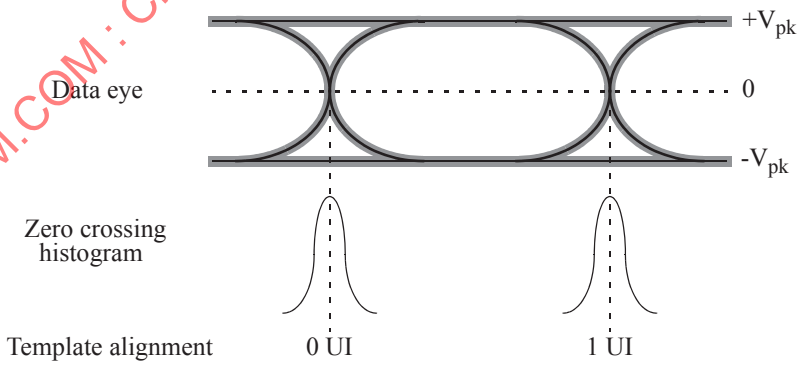

Figure 47–7—Eye template alignment

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47.4.3 Jitter test requirements

For the purpose of jitter measurement, the effect of a single-pole high-pass filter with a 3 dB point at 1.875 MHz is applied to the jitter. The data pattern for jitter measurements is the CJPAT pattern defined in Annex 48A. All four lanes of XAUI are active in both directions, and opposite ends of the link use asynchronous clocks. Jitter is measured with AC-coupling and at 0 volts differential. Jitter measurement for the transmitter (or for calibration of a jitter tolerance setup) shall be performed with a test procedure resulting in a BER bathtub curve such as that described in Annex 48B.

47.4.3.1 Transmit jitter

Transmit near-end jitter is measured at the driver output when terminated into the load specified in 47.3.3.1. Far-end jitter is measured at the end of a compliance interconnect specified in 47.4.1. The far-end load for the compliance link is specified in 47.3.3.1.

47.4.3.2 Jitter tolerance

Jitter tolerance is measured at the receiver using a jitter tolerance test signal. This signal is obtained by first producing the required sum of deterministic and random jitter defined in 47.3.4.6 and then adjusting the signal amplitude until the data eye contacts the 6 points of the driver's template shown in Figure 47–4 and Table 47–2. Note that for this to occur, the test signal must have vertical waveform symmetry about the average value and have horizontal symmetry (including jitter) about the mean of the zero crossing. If these symmetries are not achieved, then some portions of the test signal will encroach into the template and provide overstress of the receiver, and/or some points of the template may not be contacted, resulting in understress of the receiver. Eye template measurement requirements are given in 47.4.2. Random jitter is calibrated using a high-pass filter with a low-frequency corner of 20 MHz and 20 dB/decade rolloff below this. The required sinusoidal jitter specified in 47.3.4.6 is then added to the signal and the far-end load is replaced by the receiver being tested.

47.5 Environmental specifications

All equipment subject to this clause shall conform to the requirements of 14.7 and applicable sections of ISO/IEC 11801:1995.

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47.6 Protocol implementation conformance statement (PICS) proforma for Clause 47, XGMII Extender (XGMII) and 10 Gigabit Attachment Unit Interface (XAUI)[3]

47.6.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 47, XGMII Extender Sublayer (XGXS) and 10 Gigabit Attachment Unit Interface (XAUI), shall complete the following protocol implementation conformance statement (PICS) proforma. A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

47.6.2 Identification

47.6.2.1 Implementation identification

Supplier[1]	
Contact point for inquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1,3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

47.6.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 47, XGMII Extender Sublayer (XGXS) and 10 Gigabit Attachment Unit Interface (XAUI)
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	
Date of Statement	

[3]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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47.6.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
XGE	XGMII compatibility interface	46, 47.1.4	Compatibility interface is supported	O	Yes [ ] No [ ]
MD	MDIO	47.2	Registers and interface supported	O	Yes [ ] No [ ]
LPI	Implementation of LPI	47.1		O	Yes [ ] No [ ]

47.6.4 PICS Proforma tables for XGXS and XAUI

47.6.4.1 Compatibility considerations

Item	Feature	Subclause	Value/Comment	Status	Support
C1	Environmental specifications	47.5		M	Yes [ ]

47.6.4.2 XGXS and XAUI functions

Item	Feature	Subclause	Value/Comment	Status	Support
F1	XGXS PCS and PMA requirements	47.2.1	Meet all mandatory requirements of 48.2 and 48.3	M	Yes [ ]
F2	XGXS PCS and PMA options	47.2.1	Meet optional clock rate compensation in unencoded data stream per 48.2.4.2.3	O	Yes [ ] No [ ]
F3	XGMII Extender delay	47.2.2	Meets delay constraints of 48.5	M	Yes [ ]

47.6.4.3 Electrical characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
E1	XAUI Baud	47.3.3	3.125 GBd ± 100 ppm	M	Yes [ ]
E2	Driver output amplitude	47.3.3.2	Less than 1600 mV_{p-p}	M	Yes [ ]
E3	Driver output swing	47.3.3.2	Between –0.4 and +2.3 V	M	Yes [ ]
E4	Driver output impedance	47.3.3.4	s_{11} = –10 dB for 312.5 MHz < Freq (f) < 625 MHz, and –10 + 10log(f/625) dB for 625 MHz ≤ Freq (f)≤ 3.125 GHz (f is frequency in MHz)	M	Yes [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
E5	Driver near-end template and jitter	47.3.3.5	At driver output	O.1	Yes [ ] No [ ]
E6	Driver far-end template and jitter	47.3.3.5	At end of compliance interconnect	O.1	Yes [ ] No [ ]
E7	Receiver bit error ratio	47.3.4	Less than 10^{-12}	M	Yes [ ]
E8	Receive input amplitude tolerance	47.3.4.3	May be larger than 1600 mV_{p-p}	M	Yes [ ]
E9	Receiver coupling	47.3.4.4	AC-coupled	M	Yes [ ]
E10	Receiver input impedance	47.3.4.5	At least 10 dB differential and 6 dB common-mode return loss	M	Yes [ ]
E11	Total jitter tolerance	47.3.4.6	At least 0.65 UI	M	Yes [ ]
E12	Deterministic jitter tolerance	47.3.4.6	At least 0.37 UI	M	Yes [ ]
E13	Tolerance to sum of deterministic and random jitter	47.3.4.6	At least 0.55 UI	M	Yes [ ]
E14	Additional sinusoidal jitter tolerance	47.3.4.6	Per Figure 47–5	M	Yes [ ]
E15	Jitter measurement	47.4.3	Meet BER bathtub curve, See Annex 48B	M	Yes [ ]

47.6.4.4 LPI functions

Item	Feature	Subclause	Value/Comment	Status	Support
LP-01	Global signal detect	47.1.5	Meets the requirements of 47.1.5	LPI:M	Yes [ ] No [ ]
LP-02	Global transmit disable	47.1.6	Meets the requirements of 47.1.6	LPI:M	Yes [ ] No [ ]
LP-03	Transmit amplitude	47.3.3.2	Meets the requirements of 47.3.3.2	LPI:M	Yes [ ] No [ ]
LP-04	Signal detect timing	47.3.4	Meets the requirements of Table 47–3	LPI:M	Yes [ ] No [ ]

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48. Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 10GBASE-X

48.1 Overview

This clause specifies the Physical Coding Sublayer (PCS) and the Physical Medium Attachment (PMA) sublayer that are common to a family of 10 Gb/s Physical Layer implementations, collectively known as 10GBASE-X. The 10GBASE-X PHY family consists of 10GBASE-CX4 (see Clause 54), 10GBASE-KX4 (see Clause 71), and 10GBASE-LX4 (see Clause 53).

The 10GBASE-X PCS and PMA sublayers are also utilized by the XGXS specified in Clause 47.

10GBASE-X PCS and PMA sublayers map the interface characteristics of the PMD sublayer (including MDI) to the services expected by the Reconciliation Sublayer (RS) and the logical and electrical characteristics of the 10 Gigabit Media Independent Interface (XGMII). Although the XGMII is optional, it is used as the basis for the definition of the 10GBASE-X PCS and PMA sublayers.

10GBASE-X assumes the use of the MDIO interface and register set for communication between PHY and Station Management (STA) entities, see Clause 45.

10GBASE-X has the following characteristics:

a) The capability of supporting 10 Gb/s operation at the XGMII and RS
b) Clock references embedded in all data and control code-groups
c) Data paths consisting of independent serial links called lanes
d) Independent four-lane-wide transmit and receive data paths
e) Simple signal mapping to the XGMII and RS
f) Full duplex operation
g) Shared technology with other 10 Gb/s interfaces
h) Shared functionality with other 10Gb/s Ethernet blocks

48.1.1 Objectives

The following are the objectives of 10GBASE-X:

a) Support the IEEE 802.3 MAC
b) Provide a data rate of 10 Gb/s at the XGMII
c) Support cable plants using cabled optical fiber compliant with second edition of ISO/IEC 11801:1995
d) Support a BER objective of 10^{-12}
e) Support the optional XAUI
f) Support link fault and error indications

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48.1.2 Relationship of 10GBASE-X to other standards

Figure 48–1 depicts the relationships among the 10GBASE-X sublayers (shown shaded), the IEEE 802.3 MAC and RS, and the IEEE 802.2 LLC.

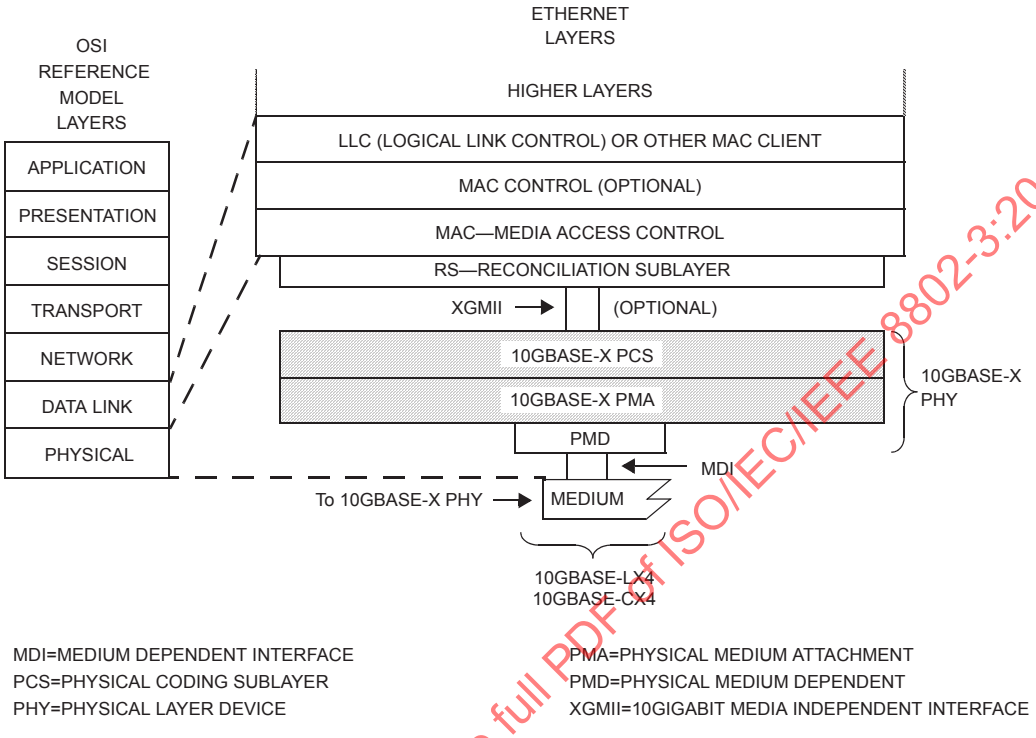

Figure 48–1—10GBASE-X PCS and PMA relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE Ethernet Model

48.1.3 Summary of 10GBASE-X sublayers

The following provides an overview of the 10GBASE-X sublayers.[4]

48.1.3.1 Physical Coding Sublayer (PCS)

The interface between the PCS and the RS is the XGMII as specified in Clause 46. The 10GBASE-X PCS provides services to the XGMII in a manner analogous to how the 1000BASE-X PCS provides services to the 1000 Mb/s GMII.

The 10GBASE-X PCS provides all services required by the XGMII and in support of the 10GBASE-X PMA, including:

a) Encoding of 32 XGMII data bits and 4 XGMII control bits to four parallel lanes conveying 10-bit code-groups each, for communication with the underlying PMA.
b) Decoding of four PMA parallel lanes, conveying 10-bit code-groups each, to 32 XGMII data bits and 4 XGMII control bits.
c) Synchronization of code-groups on each lane to determine code-group boundaries.

[4] The 10GBASE-X PHY consists of that portion of the Physical Layer between the MDI and XGMII consisting of the PCS, PMA, and PMD sublayers. The 10GBASE-X PHY is roughly analogous to the 1000BASE-X PHY.

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d) Deskew of received code-groups from all lanes to an alignment pattern.
e) Support of the MDIO interface and register set as specified in Clause 45 to report status and enable control of the PCS.
f) Conversion of XGMII Idle control characters to (from) a randomized sequence of code-groups to enable serial lane synchronization, clock rate compensation and lane-to-lane alignment.
g) Clock rate compensation protocol.
h) Link Initialization based on the transmission and reception of the Idle sequence.
i) Link status reporting for fault conditions.

48.1.3.2 Physical Medium Attachment (PMA) sublayer

The PMA provides a medium-independent means for the PCS to support the use of a range of serial-bit-oriented physical media. The 10GBASE-X PMA performs the following functions:

a) Mapping of transmit and receive code-groups between the PCS and PMA via the PMA service interface.
b) Serialization (deserialization) of code-groups for transmission (reception) on the underlying serial PMD.
c) Clock recovery from the code-groups supplied by the PMD.
d) Mapping of transmit and receive bits between the PMA and PMD via the PMD service interface.
e) Direct passing of signal_detect from the PMD to the PCS through the PMA via the PMD and PMA service interfaces.

48.1.3.3 Physical Medium Dependent (PMD) sublayer

10GBASE-X uses the PMD sublayer and MDI specified in Clause 53, Clause 54, and Clause 71. The 10GBASE-CX4, 10GBASE-KX4, and 10GBASE-LX4 perform the following functions:

a) Transmission of quad serial bit streams on the underlying medium.
b) Reception of quad serial bit streams on the underlying medium.

48.1.4 Rate of operation

The 10GBASE-X PCS and PMA support the 10 Gb/s MAC data rate. The line rate of each of four PMA lanes is 3.125 GBd ± 100 ppm.

48.1.5 Allocation of functions

PCS and PMA functions directly map onto the 10GBASE-X PMD, MDI and medium which attach, in turn, to another 10GBASE-X PHY. In addition, 10GBASE-X PCS and PMA functions embodied in the XGXS described in Clause 47 may be used to attach to alternate 10 Gb/s PHYs such as 10GBASE-R or 10GBASE-W.

The longer interconnect distances afforded through the specification of a self-clocked serial architecture enable significant implementation flexibility while imposing a requirement on those implementations to ensure sufficient signal fidelity over the link. The implementer of this standard is expected to meet the required specifications in this and related clauses through implementation methods not specified by this standard.

Certain PHYs support Energy-Efficient Ethernet (EEE) (see Clause 78). PHYs that support EEE (see 78.3) use Low Power Idle (LPI) signaling to allow systems on both sides of the link to save power during periods of low link utilization. LPI signaling may optionally be used by XGXS to extend the EEE function to attached PHYs. Both PHY and DTE XGXS may optionally use LPI signaling to control the shutdown of signals on the XAUI to reduce power for PHY attachments.

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48.1.6 Inter-sublayer interfaces

There are a number of interfaces employed by 10GBASE-X. Some (such as the PMA service interface) use an abstract service model to define the operation of the interface. Figure 48–2 depicts the relationship and mapping of the services provided by all of the interfaces relevant to 10GBASE-X.

Multiple optional physical instantiations of the PCS service interface have been defined. One is the XGMII described in Clause 46. The other is the interface to the XGXS described in Clause 47.

Physical instantiations of the 10GBASE-X PMA and PMD service interfaces are not defined in this standard.

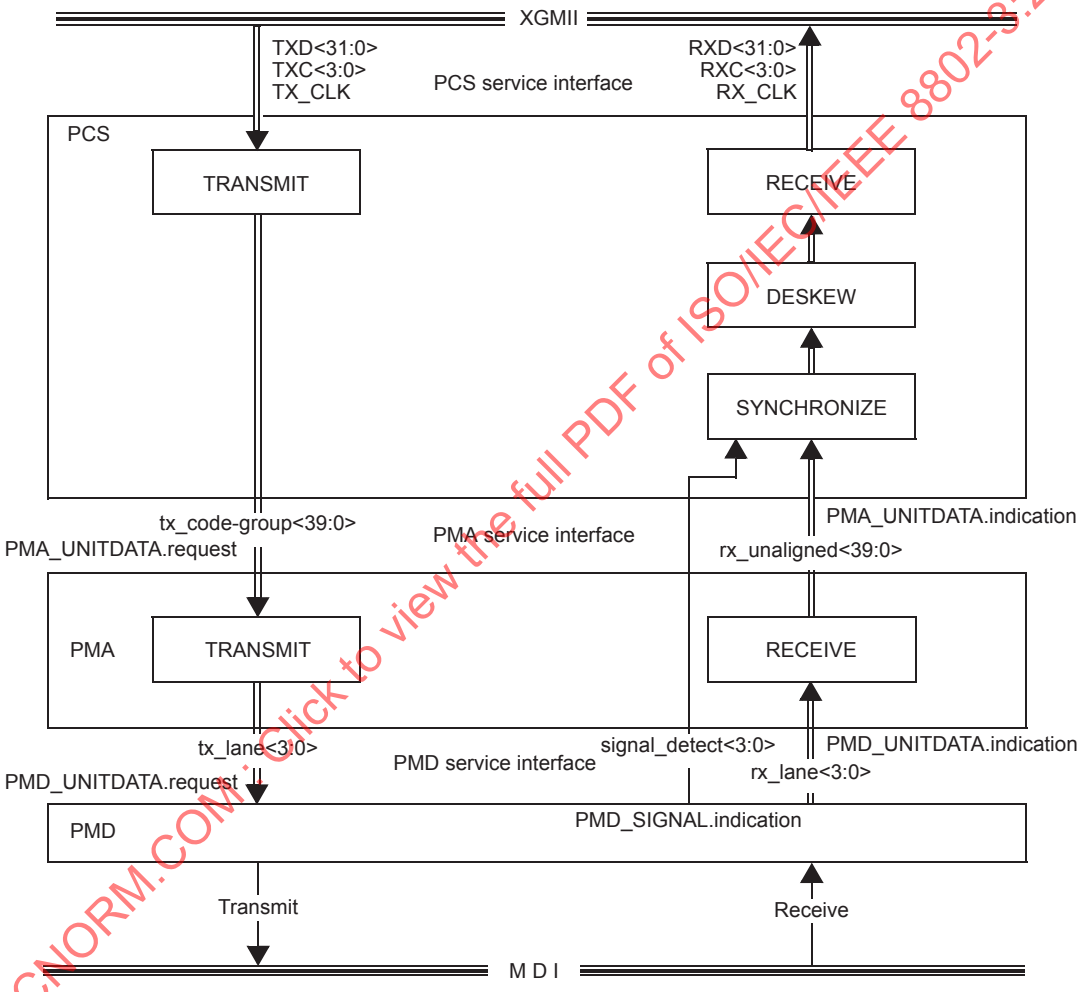

Figure 48–2—Functional block diagram

48.1.7 Functional block diagram

Figure 48–2 provides a functional block diagram of the 10GBASE-X PHY.

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48.1.8 Special symbols

/x/ The code-group x is represented by preceding and following slash characters.

||y|| Four code-groups, one each in lanes 0 through 3 inclusive, synchronous to each other and arranged in a column identified by the value y, is represented by preceding and following double bar characters.

48.2 Physical Coding Sublayer (PCS)

48.2.1 PCS service interface (XGMII)

The PCS service interface allows the 10GBASE-X PCS to transfer information to and from the PCS client. The PCS client is the RS defined in Clause 46, or the XGXS defined in Clause 47. An instantiation of the PCS service interface is the XGMII defined in Clause 46.

In the transmit direction, the 10GBASE-X PCS accepts packets from the PCS client on the XGMII. Due to the continuously signaled nature of the underlying PMA, and the encoding performed by the PCS, the 10GBASE-X PCS maps XGMII data and control characters into a code-group stream. In the receive direction, the PCS decodes the code-group stream received from the PMA, maps the code-groups to XGMII data and control characters and forwards the character stream to the XGMII to the PCS client for further processing.

48.2.2 Functions within the PCS

The PCS includes the Transmit, Receive, Synchronization, and Deskew processes for 10GBASE-X. The PCS shields the RS (and MAC) from the specific nature of the underlying channel.

When communicating with the XGMII, the PCS uses, in each direction, 32 data signals (TXD <31:0> and RXD <31:0>), four control signals (TXC <3:0> and RXC <3:0>), and a clock (TX_CLK and RX_CLK).

When communicating with the PMA, the PCS uses the data signals tx_code-group <39:0> in the transmit direction and rx_unaligned <39:0> in the receive direction. Each set of data signals conveys four lanes of 10-bit code-groups. At the PMA service interface, code-group alignment, lane-to-lane deskew, and provision for PHY clock rate compensation are made possible by embedding special non-data code-groups in the idle stream. The PCS provides the functions necessary to map packets between the XGMII format and the PMA service interface format.

The tx_code-group and rx_unaligned signals are organized into four lanes in a manner similar to that of the XGMII. On transmit, the first PCS code-group is aligned to lane 0, the second to lane 1, the third to lane 2, the fourth to lane 3, then repeating with the fifth to lane 0, etc. This lane-oriented organization extends through the PMA to the PMD service interface. (See Table 48–1.)

The PCS Transmit process continuously generates code-groups based upon the TXD <31:0> and TXC <3:0> signals on the XGMII, sending them to the PMA service interface via the PMA_UNITDATA.request primitive.

The PCS Synchronization process continuously accepts unaligned and unsynchronized code-groups via the PMA_UNITDATA.indication primitive, obtains 10-bit code-group synchronization, and conveys synchronized 10-bit code-groups to the PCS Deskew process via the SYNC_UNITDATA.indicate message. The PCS Synchronization process sets the lane_sync_status <3:0> flags to indicate whether the PMA is functioning dependably (as well as can be determined without exhaustive error-ratio analysis).

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Table 48–1—Transmit and receive lane associations

Lane	XGMII TXD RXD	XGMII TXC RXC	PMA tx_code-group rx_unaligned	PMD tx_lane rx_lane
0	<7:0>	<0>	<9:0>	<0>
1	<15:8>	<1>	<19:10>	<1>
2	<23:16>	<2>	<29:20>	<2>
3	<31:24>	<3>	<39:30>	<3>

The PCS Deskew process continuously accepts synchronized code-groups via the SYNC_UNITDATA.indicate message, aligns the code-groups to remove skew between the lanes that has been introduced by the link, and conveys aligned and synchronized code-groups to the PCS Receive process via the ALIGN_UNITDATA.indicate message. The PCS Deskew process asserts the align_status flag to indicate that the PCS has successfully deskewed and aligned code-groups on all PCS lanes. The PCS Deskew process attempts deskew and alignment whenever the align_status flag is de-asserted. The PCS Deskew process is otherwise idle.

The PCS Receive process continuously accepts code-groups from the PMA service interface via the ALIGN_UNITDATA.indicate message. The PCS Receive process monitors these code-groups and generates RXD and RXC on the XGMII. All code-groups received that represent idle are replaced with Idle characters prior to forwarding to the XGMII.

The PCS Transmit and Receive processes provide support for Link status reporting, which supports the transmit fault and receive fault conditions.

All PCS processes are described in detail in the state diagrams in 48.2.6.2.

48.2.3 Use of code-groups

The transmission code used by the PCS, referred to as 8B/10B, is identical to that specified in Clause 36. The PCS maps XGMII characters into 10-bit code-groups, and vice versa, using the 8B/10B block coding scheme. Implicit in the definition of a code-group is an establishment of code-group boundaries by a PCS Synchronization process. The 8B/10B transmission code as well as the rules by which the PCS ENCODE and DECODE functions generate, manipulate, and interpret code-groups are specified in 36.2.4. A 10GBASE-X PCS shall meet the requirements specified in 36.2.4.1 through 36.2.4.6, 36.2.4.8, and 36.2.4.9. PCS lanes are independent of one another. All code-group rules specified in 36.2.4 are applicable to each lane. The mapping of XGMII characters to PCS code-groups is specified in Table 48–2. The mapping of PCS code-groups to XGMII characters is specified in Table 48–3. PHYs that support EEE are able to transmit and receive LPI characters.

Figure 48–3 illustrates the mapping of an example XGMII character stream into a PCS code-group stream. Figure 48–4 illustrates the mapping during LPI.

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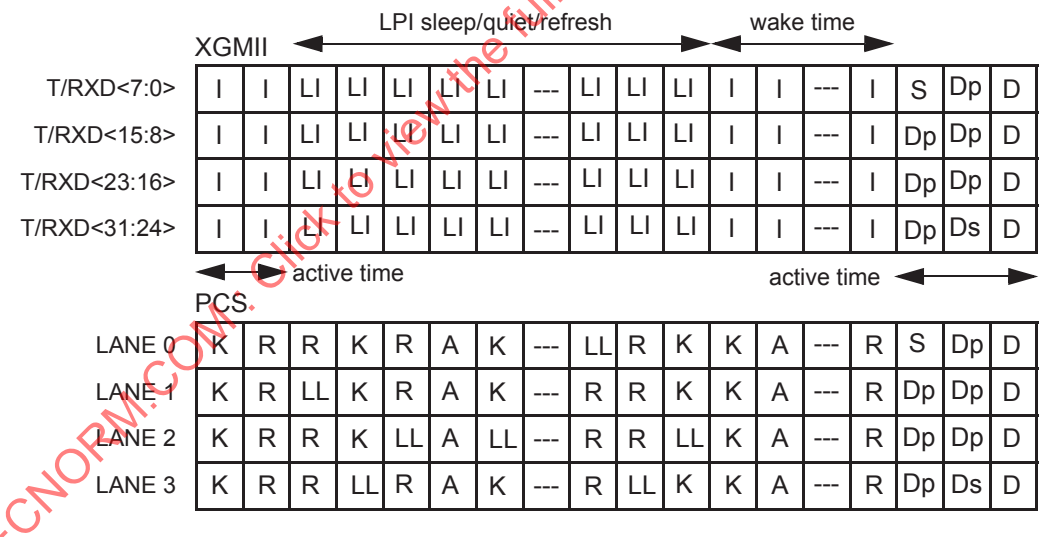
The relationship of code-group bit positions to XGMII, PCS and PMA constructs and PMD bit transmission order, exemplified for lane 0, is illustrated in Figure 48–5.

XGMII																		
T/RXD<7:0>	I	I	S	Dp	D	D	D	---	D	D	D	D	I	I	I	I	I	I
T/RXD<15:8>	I	I	Dp	Dp	D	D	D	---	D	D	D	T	I	I	I	I	I	I
T/RXD<23:16>	I	I	Dp	Dp	D	D	D	---	D	D	D	I	I	I	I	I	I	I
T/RXD<31:24>	I	I	Dp	Ds	D	D	D	---	D	D	D	I	I	I	I	I	I	I

PCS																		
LANE 0	K	R	S	Dp	D	D	D	---	D	D	D	D	A	R	R	K	K	R
LANE 1	K	R	Dp	Dp	D	D	D	---	D	D	D	T	A	R	R	K	K	R
LANE 2	K	R	Dp	Dp	D	D	D	---	D	D	D	K	A	R	R	K	K	R
LANE 3	K	R	Dp	Ds	D	D	D	---	D	D	D	K	A	R	R	K	K	R

Legend:
Dp represents a data character containing the preamble pattern
Ds represents a data character containing the SFD pattern

Figure 48–3—XGMII character stream to PCS code-group stream mapping example



Legend:
LI represents the data character containing the XGMII LPI pattern (06)
LL represents the LPI indication code-group /D20.5/
Dp represents a data character containing the preamble pattern
Ds represents a data character containing the SFD pattern

Figure 48–4—XGMII and PCS mapping example with optional LPI

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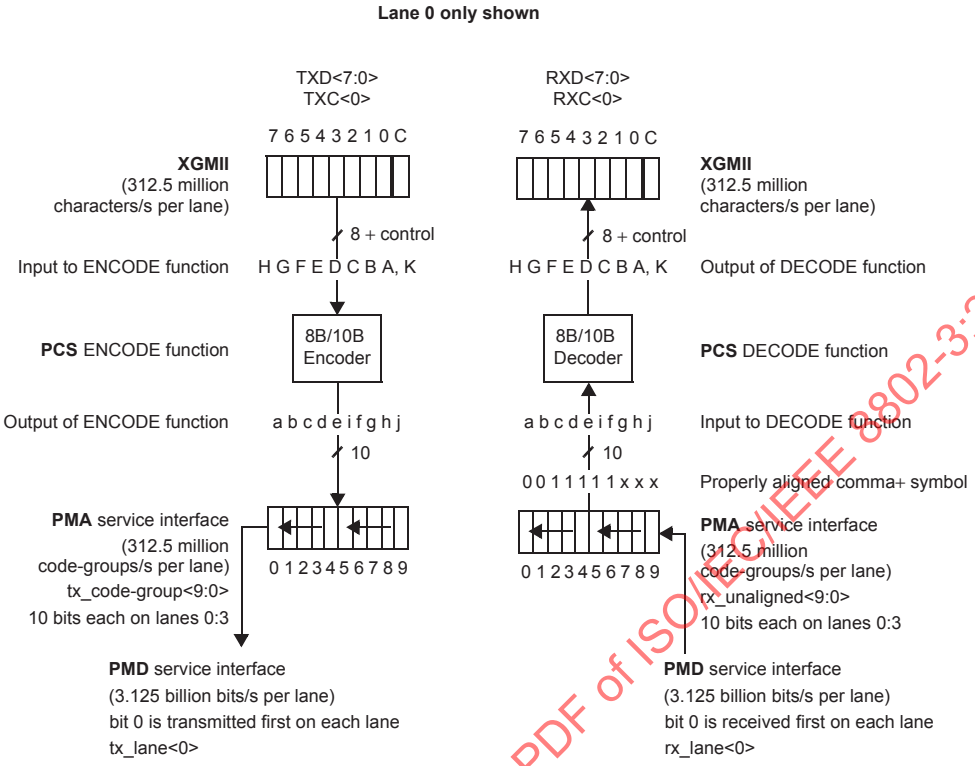

Figure 48–5—PCS reference diagram

48.2.4 Ordered sets and special code-groups

10GBASE-X PCS ordered sets consist of combinations of special and data code-groups (defined as a column of code-groups). All ordered sets are four code-groups in length and begin in lane 0. In addition to ordered sets, the PCS defines several special code-groups for control purposes. Ordered sets and special code-groups provide the following capabilities:

a) PCS Synchronization process ability to obtain bit and code-group synchronization
b) Packet delineation
c) Synchronization between the transmitter and receiver circuits at opposite ends of a link
d) Deskew of received code-groups from all serial lanes to an alignment pattern
e) Clock rate compensation protocol
f) Link status reporting protocol
g) Column fill
h) Error indication

Table 48–4 lists the defined ordered sets and special code-groups.

48.2.4.1 Data (/D/)

A data code-group, when not used to distinguish or convey information for a defined ordered set, conveys one octet of data between the XGMII and the PCS. Any data code-group can be followed by any other data code-group. Data code-groups are encoded and decoded but not interpreted by the PCS.

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Table 48–2—XGMII character to PCS code-group mapping

XGMII TXC	XGMII TXD	PCS code-group	Description
0	00 through FF	Dxx.y	Normal data transmission
1	06	K28.0 or K28.3 or K28.5 or D20.5[a]	Assert LPI
1	07	K28.0 or K28.3 or K28.5	Idle in ||I||
1	07	K28.5	Idle in ||T||
1	9C	K28.4	Sequence
1	FB	K27.7	Start
1	FD	K29.7	Terminate
1	FE	K30.7	Error
1	Other value in Table 36–2	See Table 36–2	Reserved XGMII character
1	Any other value	K30.7	Invalid XGMII character
NOTE—Values in TXD column are in hexadecimal.			

[a]Insertion of /D20.5/ is per the rules described in 48.2.4.2.

Table 48–3—PCS code-group to XGMII character mapping

XGMII RXC	XGMII RXD	PCS code-group	Description
0	00 through FF	Dxx.y	Normal data reception
1	06	K28.0 or K28.3 or K28.5 or D20.5[a]	Assert LPI
1	07	K28.0 or K28.3 or K28.5	Idle in ||I||
1	07	K28.5	Idle in ||T||
1	9C	K28.4	Sequence
1	FB	K27.7	Start
1	FD	K29.7	Terminate
1	FE	K30.7	Error
1	FE	Invalid code-group	Received code-group
1	See Table 36–2	Other valid code-group	Received reserved code-group
NOTE—Values in RXD column are in hexadecimal.			

[a]Insertion of /D20.5/ is per the rules described in 48.2.4.2.

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Table 48–4—Defined ordered sets and special code-groups

Code	Ordered set	Number of code-groups	Encoding
||I||	**Idle**		**Substitute for XGMII Idle**
||K||	Sync column	4	/K28.5/K28.5/K28.5/K28.5/
||R||	Skip column	4	/K28.0/K28.0/K28.0/K28.0/
||A||	Align column	4	/K28.3/K28.3/K28.3/K28.3/
	Encapsulation		
||S||	Start column	4	/K27.7/Dx.y/Dx.y/Dx.y/[a]
||T||	Terminate column	4	Terminate code-group in any lane
$\|\|T_0\|\|$	Terminate in Lane 0	4	/K29.7/K28.5/K28.5/K28.5/
$\|\|T_1\|\|$	Terminate in Lane 1	4	/Dx.y/K29.7/K28.5/K28.5/[a]
$\|\|T_2\|\|$	Terminate in Lane 2	4	/Dx.y/Dx.y/K29.7/K28.5/[a]
$\|\|T_3\|\|$	Terminate in Lane 3	4	/Dx.y/Dx.y/Dx.y/K29.7/[a]
	Control		
/E/	Error code-group	1	/K30.7/
	Link Status		
||Q||	Sequence ordered set	4	/K28.4/Dx.y/Dx.y/Dx.y/[a]
||LF||	Local Fault signal	4	/K28.4/D0.0/D0.0/D1.0/
||RF||	Remote Fault signal	4	/K28.4/D0.0/D0.0/D2.0/
||LINT||	Link Interruption signal	4	/K28.4/D0.0/D0.0/D3.0/
||Qrsvd||	Reserved	4	!||LF|| and !||RF|| and !||LINT||
	Reserved		
||Fsig||	Signal ordered set	4	/K28.2/Dx.y/Dx.y/Dx.y/[a,b]

[a]/Dx.y/ indicates any data code-group.
[b]Reserved for INCITS T11.

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48.2.4.2 Idle (||I||) and Low Power Idle (||LPIDLE||)

Idle ordered sets (||I||) are transmitted in full columns continuously and repetitively whenever the XGMII is idle (TXD <31:0>=0x07070707 and TXC <3:0>=0xF). ||I|| provides a continuous fill pattern to establish and maintain lane synchronization, perform lane-to-lane deskew and perform PHY clock rate compensation. ||I|| is emitted from, and interpreted by, the PCS.

A sequence of ||I|| ordered sets consists of one or more consecutively transmitted ||K||, ||R||, or ||A|| ordered sets, as defined in Table 48–4. Rules for ||I|| ordered set sequencing shall be as follows:

a) ||I|| sequencing starts with the first column following a ||T||.
b) The first ||I|| following ||T|| alternates between ||A|| or ||K|| except if an ||A|| is to be sent and less than *r* [see item d)] columns have been sent since the last ||A||, a ||K|| is sent instead.

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c) ||R|| is chosen as the second ||I|| following ||T||.

d) Each ||A|| is sent after *r* non-||A|| columns where *r* is a randomly distributed number between 16 and 31, inclusive. The corresponding minimum spacing of 16 non-||A|| columns between two ||A|| columns provides a theoretical 85-bit deskew capability.

e) When not sending an ||A||, either ||K|| or ||R|| is sent with a random uniform distribution between the two.

f) Whenever sync_status=OK, all ||I|| received during idle are translated to XGMII Idle control characters for transmission over the XGMII. All other !||I|| received during idle are mapped directly to XGMII data or control characters on a lane by lane basis, with the following exceptions for PHYs with EEE capability:
   1) /D20.5/ (LPI) being detected in any lane and the rest of the lanes in the same column being detected /K/ only or /R/ only, which will result in reporting LP_IDLE characters in all lanes.
   2) ||A|| being detected and /D20.5/ (LPI) being detected in any lane of the previous column and the rest of the lanes in the previous column being detected /K/ only or /R/ only, which will result in reporting LP_IDLE characters in all lanes.

The purpose of randomizing the ||I|| sequence is to reduce 10GBASE-X electromagnetic interference (EMI) during idle. The randomized ||I|| sequence produces no discrete spectrum. Both ||A|| spacing as well as ||K||, ||R||, or ||A|| selection shall be based on the generation of a random integer *r* generated by a PRBS based on one of the 7th order polynomials listed in Figure 48–6. ||A|| spacing is set to the next generated value of *r*. The rate of generation of *r* is once per column, 312.5 MHz ± 100 ppm. Once the ||A|| spacing count goes to zero (A_CNT=0), ||A|| is selected for transmission at the next opportunity during the Idle sequence. ||K|| and ||R|| selection follows the value of code_sel, which is continuously set according to the even or odd value of *r*. The method of generating the random integer *r* is left to the implementer. PCS Idle randomizer logic is illustrated in Figure 48–6.

||LPIDLE|| is coded in the same manner as ||I|| except that the /D20.5/ code-group replaces one code-group in each ||K|| or ||R|| (not ||A||) column with a random uniform distribution across the lanes. Insertion of /D20.5/ does not alter the distribution of ||A||, ||K|| or ||R||. Clock compensation may be performed during LPI according to the rules described in 48.2.4.2.3.

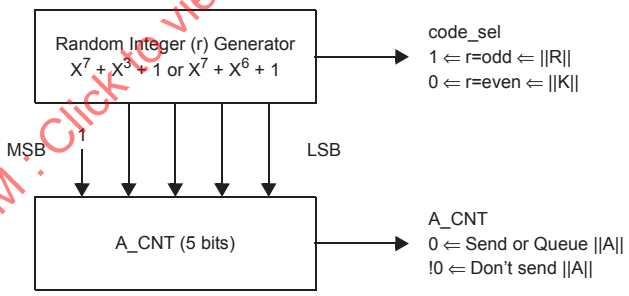

Figure 48–6—PCS idle randomizer

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48.2.4.2.1 Sync ||K||

Code-group synchronization is the process by which the receiver detects code-group boundaries in the incoming bit stream of each lane. The detection of the comma pattern in the incoming bit stream identifies a code-group boundary. The proper alignment of a comma used for code-group synchronization is depicted in Figure 48–5. The Sync or ||K|| ordered set included in the PCS Idle sequence guarantees a sufficient frequency of commas in each lane. The comma pattern is defined in 36.2.4.9. The Sync ordered set is

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defined in Table 48–4. /K/ code-groups are interpreted per lane by the PCS Synchronization process, which is described in 48.2.6.2.2. Detection of both comma+ and comma- variants of /K/ shall be required.

48.2.4.2.2 Align ||A||

Skew is introduced between lanes by both active and passive elements of a 10GBASE-X link. The PCS deskew function compensates for all lane-to-lane skew observed at the receiver. The Align or ||A|| ordered set consists of a unique special code-group, also known as Align or /A/ in each lane. /A/ is not used in any other ordered set. The definition of a 10GBASE-X ordered set guarantees that /A/ code-groups are simultaneously initiated on all lanes at the transmitter, resulting in minimal lane-to-lane skew at the transmitter. The Align ordered set is defined in Table 48–4. Allowable skew for all link elements shall be as specified in Table 48–5.

Table 48–5—Skew budget

Skew Source	Occurences	Skew	Total Skew
PMA Tx	1	1 UI[a]	1 UI
PCB	2	1 UI	2 UI
Medium	1	<18 UI	<18 UI
PMA Rx[b]	1	20 UI	20 UI
Total			<41 UI

[a]UI represents unit interval. For 10GBASE-X, 1 UI = 320 ps.
[b]Includes deserialization function, physical deserializer skew and clock boundary transition.

48.2.4.2.3 Skip ||R||

The 10GBASE-X PHY allows for multiple clock domains along a single link. The Skip or ||R|| ordered set is included in the PCS Idle sequence to allow for clock rate compensation for the case of multiple clock domains. Clock rate compensation may be performed via insertion or removal of either Idle characters in the unencoded data stream or ||R|| in the encoded Idle stream. Any ||R|| may be removed. ||R|| may be inserted anywhere in the Idle stream with the exception of the first column following ||T||.

When clock compensation is done in the unencoded data stream, rules for idle insertion and deletion shall be as follows:

a) Idle insertion or deletion occurs in groups of four consecutive Idle characters.
b) Idle characters are added following idle or ordered sets.
c) Idle characters are not added while data is being received.
d) The four characters following a Terminate control character are not deleted.
e) Sequence ordered sets are deleted to adapt between clock rates.
f) Sequence ordered set deletion occurs only when two consecutive sequence ordered sets have been received and deletes only one of the two.
g) Only idles are inserted for clock compensation.

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The disparity of the /R/ code-group is neutral, allowing its removal or insertion without affecting the current running disparity of the serial stream. The correct current running disparity version of /R/ must be inserted in each lane during Skip insertion (see Table 36–2). The Skip ordered set is defined in Table 48–4.

For EEE capability, a column containing three /R/ code-groups and one /D20.5/ code-group may be inserted or deleted in the same manner as four /R/ code-groups.

48.2.4.3 Encapsulation

The Start and Terminate ordered sets correspond to columns containing the XGMII Start and Terminate control characters, respectively.

48.2.4.3.1 Start ||S||

The Start or ||S|| ordered set directly maps to the XGMII Start control character in lane 0 followed by any three data characters in XGMII lanes 1 through 3. Normally, the three data characters will be the preamble pattern, but the PCS neither checks nor alters their contents. ||S|| indicates to the PCS that a packet has been initiated. The Start ordered set is defined in Table 48–4.

48.2.4.3.2 Terminate ||T||

The Terminate or ||T|| ordered set directly maps to the XGMII Terminate control character located in any lane, preceded by data characters if Terminate is not in lane 0, and followed by Idle characters if Terminate is not in lane 3. ||T|| indicates to the PCS that a packet has been terminated. All XGMII control characters following ||T|| are translated by the PCS until the recognition of the next XGMII Start control character. The PCS considers the MAC interpacket gap (IPG) to have begun with the reception of ||T||. The Terminate ordered set is defined in Table 48–4.

Unrecognized running disparity errors which propagate to any Idle code-groups in ||T|| or to the column following ||T|| are indicated as /E/ in the preceding column in the same lane in which the errors were recognized. All ||I|| ordered sets are selected to ensure that propagated code violations are recognized and not propagated further.

The cvtx_terminate function is used to convert all XGMII Idle control characters in the same column as the XGMII Terminate control character to /K/ code-groups. The cvrx_terminate function is used to convert all /K/ code-groups in ||T|| to XGMII Idle control characters.

48.2.4.4 Error /E/

The Error code-group is directly mapped to the XGMII Error control character. /E/ may also be generated by the PCS client to indicate a transmission error to its peer entity or deliberately corrupt the contents of the frame in such a manner that a receiver will detect the corruption with the highest degree of probability. Error is signaled per lane since code-violations are detected on a per lane basis. The Error code-group is defined in Table 48–4.

The presence of /E/ or any invalid code-group on the medium denotes an error condition. 10GBASE-X elements that detect code-group violations shall replace the invalid code-group with /E/ prior to retransmission.

48.2.4.5 Link status

Link status reporting uses the Sequence ordered-set to transport the transmit fault and receive fault link status conditions.

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48.2.4.5.1 Sequence ||Q||

The Sequence or ||Q|| ordered set directly maps to the XGMII Sequence control character on lane 0 followed by three data characters in XGMII lanes 1 through 3. ||Q|| indicates to the PCS that a link status message has been initiated. The PCS Receive process may also initiate Sequence ordered-sets upon detection of a link status condition. Sequence ordered-sets are always sent over the PMA service interface in the column that follows an ||A|| ordered-set. The Sequence ordered-sets do not otherwise interfere with the randomized ||I|| sequence. Sequence ordered-sets corresponding to Local Fault signal and Remote Fault signal are specified in Table 48–4.

48.2.5 Management function requirements

The 10GBASE-X PCS supports a set of required and optional management objects to permit it to be controlled by the Station Management entity (STA). Access to management objects within the 10GBASE-X sublayer is accomplished by means of a set of registers within the MDIO register space as defined in 45.2.4 and 45.2.5. The details of the register bit allocations and general usage are given in Clause 45. Table 48–6, Table 48–7, and Table 48–8 describe how the PCS state diagram variables map to management register bits. If an MDIO interface is provided (see Clause 45), they are accessed via that interface. If not, it is recommended that an equivalent access be provided.

Table 48–6—State diagram variable to management register mapping for PCS

State diagram variable	Management register bit
reset	3.0.15 Reset
sync_status	3.24.12 10GBASE-X lane alignment status
lane_sync_status<3>	3.24.3 Lane 3 sync
lane_sync_status<2>	3.24.2 Lane 2 sync
lane_sync_status<1>	3.24.1 Lane 1 sync
lane_sync_status<0>	3.24.0 Lane 0 sync

Table 48–7—State diagram variable to management register mapping for PHY XS

State diagram variable	Management register bit
reset	4.0.15 Reset
align_status	4.8.10 Receive fault
sync_status	4.24.12 PHY XGXS lane alignment status
lane_sync_status<3>	4.24.3 Lane 3 sync
lane_sync_status<2>	4.24.2 Lane 2 sync
lane_sync_status<1>	4.24.1 Lane 1 sync
lane_sync_status<0>	4.24.0 Lane 0 sync

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Table 48–8—State diagram variable to management register mapping for DTE XS

State diagram variable	Management register bit
reset	5.0.15 Reset
align_status	5.8.10 Receive fault
sync_status	5.24.12 PHY XGXS lane alignment status
lane_sync_status<3>	5.24.3 Lane 3 sync
lane_sync_status<2>	5.24.2 Lane 2 sync
lane_sync_status<1>	5.24.1 Lane 1 sync
lane_sync_status<0>	5.24.0 Lane 0 sync

48.2.6 Detailed functions and state diagrams

The body of this clause is comprised of state diagrams, including the associated definitions of variables, constants, and functions. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

The notation used in the state diagrams in this clause follows the conventions in 21.5. State diagram variables follow the conventions of 21.5.2 except when the variable has a default value. Variables in a state diagram with default values evaluate to the variable default in each state where the variable value is not explicitly set.

Timeless states are employed as an editorial convenience to facilitate the distribution of transition conditions from prior states. No actions are taken within these states. Exit conditions are evaluated for timeless states. There is one timeless state. It is PCS Receive state RECEIVE.

48.2.6.1 State variables

48.2.6.1.1 Notation conventions

/x/

Denotes the constant code-group specified in 48.2.6.1.2 (valid code-groups must follow the rules of running disparity as per 36.2.4.5 and 36.2.4.6).

[/x/]

Denotes the latched received value of the constant code-group (/x/) specified in 48.2.6.1.2 and conveyed by the SYNC_UNITDATA.indicate message described in 48.2.6.1.7.

||y||

Denotes the column of constant code-groups in lanes 0 through 3, inclusively, specified in 48.2.6.1.2 (valid code-groups must follow the rules of running disparity as per 36.2.4.5 and 36.2.4.6).

[||y||]

Denotes the latched received value of the column of constant code-groups in lanes 0 through 3, inclusively (||y||), specified in 48.2.6.1.2 and conveyed by the SYNC_UNITDATA.indicate message described in 48.2.6.1.7 or the ALIGN_UNITDATA.indicate message described in 48.2.6.1.7.

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48.2.6.1.2 Constants

/A/
The /K28.3/ code-group used in the Idle Align function specified in 48.2.4.2.2.

||A||
The column of four identical Idle Align code-groups corresponding to the Idle Align function specified in 48.2.4.2.2.

/COMMA/
The set of special code-groups which include a comma as specified in 36.2.4.9 and listed in Table 36–2.

/D/
The set of 256 code-groups corresponding to valid data, as specified in 48.2.4.1 and listed in Table 36–1a.

||D||
The column of four Data code-groups present during packet reception.

/Dx.y/
One of the set of 256 code-groups corresponding to valid data, as specified in 48.2.4.1 and listed in Table 36-1.

/E/
The /K30.7/ code-group corresponding to the Error function specified in 48.2.4.4.

||I||
The column of four identical Idle code-groups corresponding to the Idle function specified in 48.2.4.2. Also used to represent the corresponding XGMII control characters.

||IDLE||
Alias for ||I||.

/INVALID/
The set of invalid data or special code-groups, as specified in 36.2.4.6.

/K/
The /K28.5/ code-group used in the Idle Sync function specified in 48.2.4.2.1. Also used in the Terminate function specified in 48.2.4.3.2.

||K||
The column of four identical Idle Sync code-groups corresponding to the Idle Sync function specified in 48.2.4.2.1. For EEE capability, one lane of ||K|| is replaced by /D20.5/ during the assertion of LPI as defined in 48.2.4.2.

/Kx.y/
One of the set of 12 code-groups corresponding to valid special code-groups, as specified in Table 36–2.

LFAULT
A vector of bits RXD<31:0> and RXC<3:0> containing a Local Fault sequence ordered set. The Local Fault sequence ordered set is defined in 46.3.4.

||Q||
The column of four code-groups corresponding to the Sequence function specified in 48.2.4.5.1. Also used to represent the corresponding set of XGMII control and data characters.

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/R/
The /K28.0/ code-group used for the Idle Skip function specified in 48.2.4.2.3.

||R||
The column of four identical Idle Skip code-groups corresponding to the Idle Skip function specified in 48.2.4.2.3. For EEE capability, one lane of ||R|| is replaced by /D20.5/ during the assertion of LPI as defined in 48.2.4.2.

||S||
The column of code-groups including the Start code-group as specified in 48.2.4.3.1. Also used to represent the corresponding set of XGMII control and data characters.

||T||
The column of code-groups including the Terminate code-group as specified in 48.2.4.3.2. Also used to represent the corresponding XGMII control and data characters.

The following constants are used only for the EEE capability:

||LPIDLE||
The column consisting of three /K/ characters and one of /D20.5/, or three /R/ characters and one /D20.5/, or a column of ||A|| preceded by a column containing three /K/ characters and one /D20.5/ or three /R/ characters and one /D20.5/ as specified in 48.2.4.2.

48.2.6.1.3 Variables

align_column <39:0>
A vector of bits represented by the most recently received column of aligned 10-bit code-groups on all four lanes from the PCS Deskew process. For lane 0, the element align_column <0> corresponds to the least recently received (oldest) rx_bit of the code-group; align_column <9> corresponds to the most recently received (newest) rx_bit of the code-group. The same bit aging is applicable to the bits in align_column <39:10> with respect to rx_lane <3:1>. Code-group to lane assignment is specified in Table 48–1.

align_status
A parameter set by the PCS Deskew process to reflect the status of the lane-to-lane code-group alignment.

Values: FAIL; The deskew process is not complete.
OK; All lanes are synchronized and aligned.

NOTE—For EEE capability, this variable is affected by the LPI receive state diagram. Without EEE capability this variable is identical to deskew_align_status controlled by the deskew state diagram.

code_sel
A Boolean derived from a uniformly distributed random integer *r* generated by a PRBS based on a 7th order polynomial.

Values: 0; LSB of random number is zero.
1; LSB of random number is one.

deskew_error
A Boolean used by the PCS Deskew process to indicate that a lane-to-lane alignment error has been detected.

Values: FALSE; /A/ not recognized in any lane or recognized in all lanes simultaneously.
TRUE; /A/ recognized in fewer than all lanes.

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enable_cgalign

A Boolean that indicates the enabling and disabling of code-group comma alignment. The code-group boundary may be changed whenever code-group comma alignment is enabled. This process is known as code-group alignment.

Values: FALSE; Code-group alignment is disabled.
TRUE; Code-group alignment is enabled.

enable_deskew

A Boolean that indicates the enabling and disabling of the deskew process. Code-groups may be discarded whenever deskew is enabled. This process is known as code-group slipping.

Values: FALSE; Deskew is disabled.
TRUE; Deskew is enabled.

IDLE

A vector of bits RXD<31:0> and RXC<3:0> containing Idle. Idle is defined in Table 46–4.

lane_sync_status <3:0>

A parameter set by the PCS Synchronization process to reflect the status of the link for each lane as viewed by the receiver. lane_sync_status <n> represents lane_sync_status on lane n where n=0:3.

Values: FAIL; The receiver is not synchronized to the code-group boundary.
OK; The receiver is synchronized to the code-group boundary.

next_ifg

Controls the ||IDLE|| pattern immediately following the next frame. It is used to ensure an equal and deterministic presence of both ||A|| and ||K||

Values: A; The first ||IDLE|| following the end of the next frame will be ||A||.
K; The first ||IDLE|| following the end of the next frame will be ||K||.

reset

Condition that is true until such time as the power supply for the device that contains the PCS has reached the operating region. The condition is also true when the device has low-power mode set via Control register bit 4.0.11 or 5.0.11. The condition is also true when a reset request is detected via Control register bit 4.0.15 or 5.0.15.

Values: FALSE; The device is completely powered and has not been reset (default).
TRUE; The device has not been completely powered or has been reset.

NOTE—Reset evaluates to its default value in each state where it is not explicitly set.

RX

Alias for RXD <31:0> and RXC <3:0> representing the XGMII Receive Data and Control signals.

RXC <3:0>

Receive Control signals of the XGMII as specified in Clause 46. Set by the PCS Receive process.

RXD <31:0>

Receive Data signals of the XGMII as specified in Clause 46. Set by the PCS Receive process.

rx_lane <3:0>

A vector of bits representing the serial lanes used to convey data from the PMD to the PMA via the PMD_UNITDATA.indication service primitive as specified in Clause 53 or Clause 54.

Bit values: ZERO; Data bit is a logical zero.
ONE; Data bit is a logical one.

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rx_unaligned <39:0>

A vector of bits represented by the most recently received column of unaligned 10-bit code-groups on all four lanes from the PMA. For lane 0, the element rx_unaligned <0> is the least recently received (oldest) rx_bit from the PMD; rx_unaligned <9> is the most recently received (newest) rx_bit from the PMD. The same bit aging is applicable to the bits in rx_unaligned <39:10> with respect to rx_lane <3:1>. Code-group to lane assignment is specified in Table 48–1.

signal_detect <3:0>

A parameter set continuously and directly from the PMD_SIGNAL.indication(signal_detect <3:0>) primitive to reflect the status of the incoming link signal for each lane. Used by the PCS Synchronization process to validate the data received on rx_unaligned <39:0>. Signal_detect <n> represents signal_detect on lane n where n=0:3.

Values: FAIL; A signal is not present on the lane.
OK; A signal is present on the lane.

sync_code-group <39:0>

A vector of bits represented by the most recently received column of unaligned 10-bit code-groups on all four lanes from the PCS Synchronization process. For lane 0, the element sync_code-group <0> corresponds to the least recently received (oldest) rx_bit; sync_code-group <9> corresponds to the most recently received (newest) rx_bit. The same bit aging is applicable to the bits in sync_code-group<39:10> with respect to rx_lane <3:1>. Code-group to lane assignment is specified in Table 48–1.

sync_status

A Boolean that represents the following behavior: For all n in lane_sync_status<n>.

Values: FAIL; At least one lane is not in sync.
OK; All lanes are in sync.

TQMSG

A vector of bits representing the last link status message received over the XGMII once the link status message is recognized. Used by the PCS Transmit process to load tx_code-group <39:0>.

tx_code-group <39:0>

A vector of bits representing a column of four aligned 10-bit code-groups which has been prepared for transmission by the PCS Transmit process. This vector is conveyed to the PMA as the parameter of a PMA_UNITDATA.request(tx_lane <3:0>) service primitive. For lane 0, the element tx_code-group <0> is the first tx_bit transmitted; tx_code-group <9> is the last tx_bit transmitted. The same bit aging is applicable to the bits in tx_code-group <39:10> with respect to tx_lane <3:1>. Code-group to lane assignment is specified in Table 48–1.

TX

Alias for either TXD <31:0> and TXC <3:0> representing the XGMII Transmit Data and Control signals, or the Local Fault ordered set as defined in 46.3.4 when a fault condition is detected on the transmit path.

TXC <3:0>

Transmit Control signals of the XGMII as specified in Clause 46. Interpreted by the PCS Transmit process.

TXD <31:0>

Transmit Data signals of the XGMII as specified in Clause 46. Interpreted by the PCS Transmit process.

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tx_lane <3:0>
: A vector of bits representing the serial lanes used to convey data from the PMA to the PMD via the PMD_UNITDATA.request service primitive as specified in Clause 53 or Clause 54.

  Bit values: ZERO; Data bit is a logical zero.
  ONE; Data bit is a logical one.

The following variables are used only for the EEE capability:

deskew_align_status
: Variable used by the deskew state diagram to reflect the status of the lane-to-lane code-group alignment.

  Values: FAIL; The deskew process is not complete.
  OK; All lanes are synchronized and aligned.

rx_lpi_active
: A Boolean variable that is set to TRUE when the receiver is in a low power state and set to FALSE when it is in an active state and is not restricted by the LPI receive state diagram.

rx_quiet
: A Boolean variable set to TRUE while in the RX_QUIET state and set to FALSE otherwise. When this variable is TRUE it indicates that receive PCS and PMD may power-down nonessential functions.

tx_quiet
: A Boolean variable set to TRUE when the transmitter is in the TX_QUIET state and set to FALSE otherwise. When set to TRUE, the PMD will disable the transmitter as described in 71.6.6. When this variable is TRUE it indicates that transmit PCS and PMD may power-down nonessential functions.

48.2.6.1.4 Functions

check_end
: Prescient Terminate function used by the PCS Receive process to set the RXD<31:0> and RXC<3:0> signals to indicate Error if a running disparity error was propagated to any Idle code-groups in ||T||, or to the column following ||T||. The XGMII Error control character is returned in all lanes less than n in ||T||, where n identifies the specific Terminate ordered-set $||T_n||$, for which a running disparity error or any code-groups other than /A/ or /K/ are recognized in the column following ||T||. The XGMII Error control character is also returned in all lanes greater than n in the column prior to ||T||, where n identifies the specific Terminate ordered-set $||T_n||$, for which a running disparity error or any code group other than /K/ is recognized in the corresponding lane of ||T||. For all other lanes the value set previously is retained.

cvrx_terminate
: Conversion function used by the PCS Receive process when Terminate is indicated to convert all /K/ code-groups to Idle control characters signaled via RX. Conversion is performed for all lanes.

cvtx_terminate
: Conversion function used by the PCS Transmit process when Terminate is indicated to convert all Idle control characters signaled via TX to /K/ code-groups. Conversion is performed for all lanes.

DECODE ([||y||])
: Consists of four independent synchronous processes, one each per lane. In the PCS Receive process, this function takes as its arguments the latched value of align_column ([||y||]) and the current running disparity, and returns XGMII RX as specified in 48.2.3 and 48.2.4. When decoding

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||T||, the returned XGMII RX value is further modified by the cvrx_terminate and check_end functions, the result of the check_end function takes priority over the result of the cvrx_terminate function. DECODE also updates the current running disparity per the running disparity rules outlined in 36.2.4.4.

ENCODE(TX)
Consists of four independent synchronous processes, one each per lane. In the PCS Transmit process, this function takes as its argument the XGMII TX signals and the current running disparity for each lane, and returns four corresponding 10-bit code-groups as specified in 48.2.3 and 48.2.4. When encoding ||T||, the XGMII TX values are modified by the result of the cvtx_terminate function. ENCODE also updates the current running disparity per Tables 36-1 or 36–2.

Q_det
Function to determine the need to transmit sequence ordered sets. If TX=||Q|| then Q_det is set to true and TQMSG is set to the result of ENCODE(TX). Q_det remains true until set to false by the PCS transmit source state diagram. In the event that this function and the state diagram both attempt to modify Q_det, the setting of Q_det by this function to true will take priority.

signal_detectCHANGE <3:0>
In the PCS Synchronization process, this function monitors the signal_detect parameter on a per lane basis for a state change. The function is set upon state change detection, which is required to detect signal_detect changes which occur asynchronously to PUDI. signal_detectCHANGE <n> represents signal_detectCHANGE on lane n where n=0:3.

Values: TRUE; The output of this function changes to true when the function detects a change in signal_detect and stays true until the false condition is satisfied.
FALSE; The output of this function changes to false when the LOSS_OF_SYNC state of the PCS synchronization state diagram is entered.

48.2.6.1.5 Counters

A_CNT
A 5-bit down counter used to control Align code-group spacing. Loaded with a value between 16 and 31, inclusive, by a uniformly distributed random integer *r* generated by a PRBS based on a 7th order polynomial as described in 48.2.4.2. A_CNT is decremented once per PUDR. The count remains at zero until ||A|| is transmitted, at which time a new value is loaded.

good_cgs
A 2-bit consecutive valid code-groups received counter.

The following counter is used only for the EEE capability:

wake_error_counter
A counter that is incremented each time that the LPI receive state diagram enters the RX_WTF state indicating that a wake time fault has been detected. The counter is reflected in register 3.22 (see 45.2.3.10)

48.2.6.1.6 Timers

The following timers are used only for the EEE capability.

rx_tq_timer
This timer is started when the PCS receiver enters the RX_SLEEP state. The timer terminal count is set to T_{QR}. When the timer reaches terminal count it will set the rx_tq_timer_done = TRUE.

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rx_tw_timer
: This timer is started when the PCS receiver enters the RX_WAKE state. The timer terminal count shall be set to a value no larger than the maximum value given for T_{WR} in Table 48–10. When the timer reaches terminal count it will set the rx_tw_timer_done = TRUE.

rx_wf_timer
: This timer is started when the PCS receiver enters the RX_WTF state, indicating that the receiver has encountered a wake time fault. The rx_wf_timer allows the receiver an additional period in which to synchronize or return to the QUIET state before a link failure is indicated. The timer terminal count is set to T_{WTF}. When the timer reaches terminal count it will set the rx_wf_timer_done = TRUE.

tx_ts_timer
: This timer is started when the PCS transmitter enters the TX_SLEEP state. The timer terminal count is set to T_{SL}. When the timer reaches terminal count it will set the tx_ts_timer_done = TRUE.

tx_tq_timer
: This timer is started when the PCS transmitter enters the TX_QUIET state. The timer terminal count is set to T_{QL}. When the timer reaches terminal count it will set the tx_tq_timer_done = TRUE.

tx_tr_timer
: This timer is started when the PCS transmitter enters the TX_REFRESH state. The timer terminal count is set to T_{UL}. When the timer reaches terminal count it will set the tx_tr_timer_done = TRUE.

48.2.6.1.7 Messages

AUDI([||y||])
: Alias for ALIGN_UNITDATA.indicate(parameters).

ALIGN_UNITDATA.indicate([align_column <39:0>])
: A signal sent by the PCS Deskew process to the PCS Receive process conveying the latched value of the indicated column of code-groups over each lane ([||y||]) (see 48.2.6.2.3).

PMA_UNITDATA.indication(rx_unaligned <39:0>)
: A signal sent by the PMA Receive process to the PCS Synchronization process conveying the next code-group set received over each lane of the medium (see 48.3.2.2).

PMA_UNITDATA.request(tx_code-group <39:0>)
: A signal sent by the PCS Transmit process conveying the next code-group set for all lanes ready for transmission over the medium (see 48.3.2.1).

PMD_SIGNAL.indication(signal_detect <3:0>)
: Indicates the status of the incoming link signal. A signal mapped to the PMD_SIGNAL.indication(SIGNAL_DETECT) service primitive specified in Clause 53 or Clause 54. signal_detect <n> is set to the same value for all lanes n where n=0:3.

  Values: FAIL; A signal is not present on the lane.
  OK; A signal is present on the lane.

PUDI
: Alias for PMA_UNITDATA.indication(parameters).

PUDR
: Alias for PMA_UNITDATA.request(parameters).

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SUDI
Alias for SYNC_UNITDATA.indicate(parameters).

SYNC_UNITDATA.indicate(sync_code-group <39:0>)
A signal sent by the PCS Synchronization process to the PCS Deskew process conveying code-groups over each lane (see 48.2.6.2.2).

The following messages are used only for the EEE capability:

PMD_RXQUIET.request(rx_quiet)
A signal sent by the PCS LPI receive state diagram to the PMD. When TRUE this indicates that the receiver is in a quiet state and is not expecting incoming data.

PMD_TXQUIET.request(tx_quiet)
A signal sent by the PCS LPI transmit state diagram to the PMD. When TRUE this indicates that the transmitter is in a quiet state and may cease to transmit a signal on the medium.

48.2.6.2 State diagrams

48.2.6.2.1 Transmit

The PCS shall implement its Transmit process as depicted in Figure 48–7, including compliance with the associated state variables as specified in 48.2.6.1. This state diagram makes exactly one transition for each transmitted ordered set that is processed.

The Transmit Source process determines whether XGMII data and control information should be passed through to the PMA for serialization or converted before passing to the PMA. In all cases, XGMII data and control information is encoded before it is passed to the PMA. Data and control information may be sourced either directly from the XGMII or generated by the PCS depending on whether packet or Idle is being sourced by the XGMII. The recognition of the XGMII Start, Terminate, Idle and Sequence control characters is used to determine whether packet, Idle, or link status is being sourced by the XGMII.

The detection of a link status condition including the receipt of link status messages over the XGMII causes the PCS Transmit process to generate link status messages interspersed in an Idle sequence.

The PCS Transmit process continuously sources tx_code-group<39:0> to the PMA. The Transmit process determines the proper code-group to source on each lane based on running disparity requirements.

48.2.6.2.2 Synchronization

The PCS shall implement four Synchronization processes as depicted in Figure 48–8 including compliance with the associated state variables as specified in 48.2.6.1. The Synchronization process is responsible for determining whether the underlying receive channel is ready for operation. Failure of the underlying channel typically causes the PMA client to suspend normal actions. A Synchronization process operates independently on each lane, and synchronization is complete only when synchronization is acquired on all lanes. The synchronization process described in the following paragraphs applies to each lane.

The PCS Synchronization process continuously accepts code-groups via the PMA_UNITDATA.indication primitive and conveys received code-groups to the PCS Deskew process via the SYNC_UNITDATA.indicate message.

When in the LOSS_OF_SYNC state, the PCS may attempt to realign its current code-group boundary to one which coincides with the code-group boundary defined by a comma (see 36.2.4.9). This process is referred to in this document as code-group alignment.

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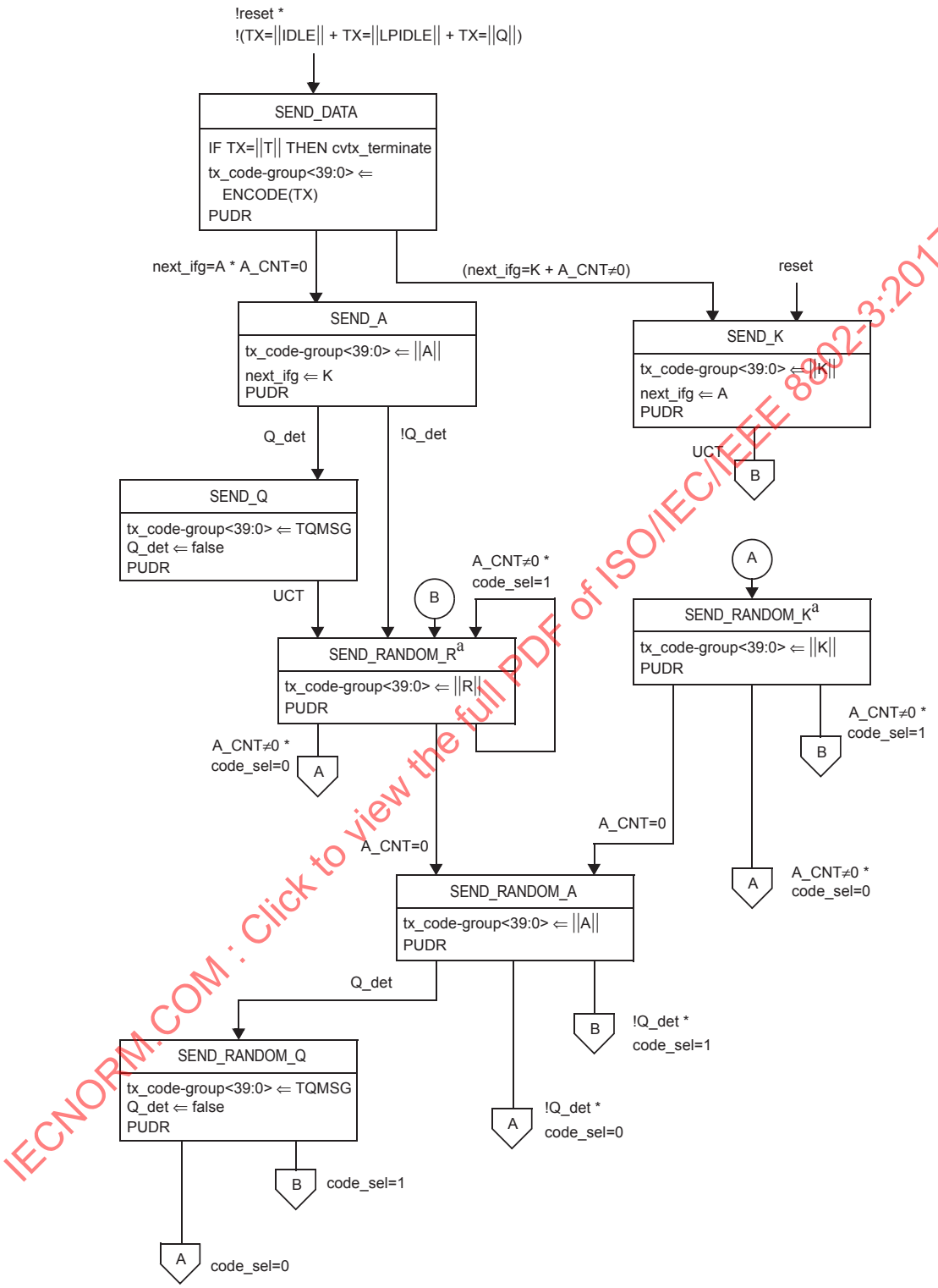

[a] If TX=||LPIDLE|| one lane is replaced by /D20.5/ as defined in 48.2.4.2.

NOTE—The state diagram makes exactly one transition for each transmit code-group processed.

Figure 48–7—PCS transmit source state diagram

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Once synchronization is acquired, the Synchronization process tests received code-groups in sets of four code-groups and employs multiple sub-states, effecting hysteresis, to move between the SYNC_ACQUIRED_1 and LOSS_OF_SYNC states. The Synchronization process sets the lane_sync_status <3:0> flags to indicate whether the PMA is functioning dependably (as well as can be determined without exhaustive error-ratio analysis). Whenever any PMA lane is not operating dependably, as indicated by the setting of lane_sync_status <3:0>, the deskew_align_status flag is set to FAIL.

48.2.6.2.3 Deskew

The PCS shall implement the Deskew process as depicted in Figure 48–9 including compliance with the associated state variables as specified in 48.2.6.1. The Deskew process is responsible for determining whether the underlying receive channel is capable of presenting coherent data to the XGMII. The Deskew process asserts the deskew_align_status flag to indicate that the PCS has successfully deskewed and aligned code-groups on all lanes. The Deskew process attempts deskew and alignment whenever the deskew_align_status flag is de-asserted. The Deskew process is otherwise idle. For the EEE capability the relationship between align_status and deskew_align_status is given by Figure 48–12, otherwise align_status is identical to deskew_align_status. Whenever the align_status flag is set to FAIL the condition is indicated as a link_status=FAIL condition in the status register bit 4.1.2 or 5.1.2.

Once alignment is acquired, the Deskew process tests received columns and employs multiple sub-states, effecting hysteresis, to move between the ALIGN_ACQUIRED_1 and LOSS_OF_ALIGNMENT states. These states monitor the link for continued alignment, tolerate alignment inconsistencies due to a reasonably low BER, and restart the Deskew process if alignment can not be reliably maintained.

48.2.6.2.4 Receive

The PCS shall implement its Receive process as depicted in Figure 48–10, including compliance with the associated state variables as specified in 48.2.6.1 and including the optional EEE capability.

The PCS Receive process continuously performs the DECODE function on the received code-groups from the PCS Deskew Process via the ALIGNED_UNITDATA.indicate message. The PCS Receive process generates the receive clock signal of the XGMII (RX_CLK) as specified in Clause 46. State transitions in the PCS Receive state diagram that generate the data and control characters (RXD<31:0> and RXC<3:0>) on the XGMII occur synchronous to RX_CLK. The Receive process operates in the following two modes:

a) Data mode during packet reception including Start and Terminate. Additionally, Data mode is active whenever !||I|| columns are received during the Idle sequence or !||I|| or !||Q|| columns are received during the Fault sequence signifying either an error or unusual or unsupported indication. Valid code-groups received while in Data mode are mapped to corresponding XGMII data or control characters regardless of whether or not the control characters are valid XGMII control characters. Invalid or Error code-groups are mapped directly to XGMII Error control characters. All code-groups are mapped on a lane by lane basis.

b) Idle mode during idle reception excluding Start and Terminate. Idle mode is active whenever ||I|| is received during idle reception. ||I|| is translated to XGMII Idle control characters.

48.2.6.2.5 LPI state diagrams

A PCS that supports the EEE capability shall implement the LPI transmit and receive processes as shown in Figure 48–11 and Figure 48–12. The transmit LPI state diagram controls tx_quiet, which disables the transmitter when TRUE. The receive LPI state diagram controls align_status during LPI and synchronizes the receive state diagram with the end of the LPI.

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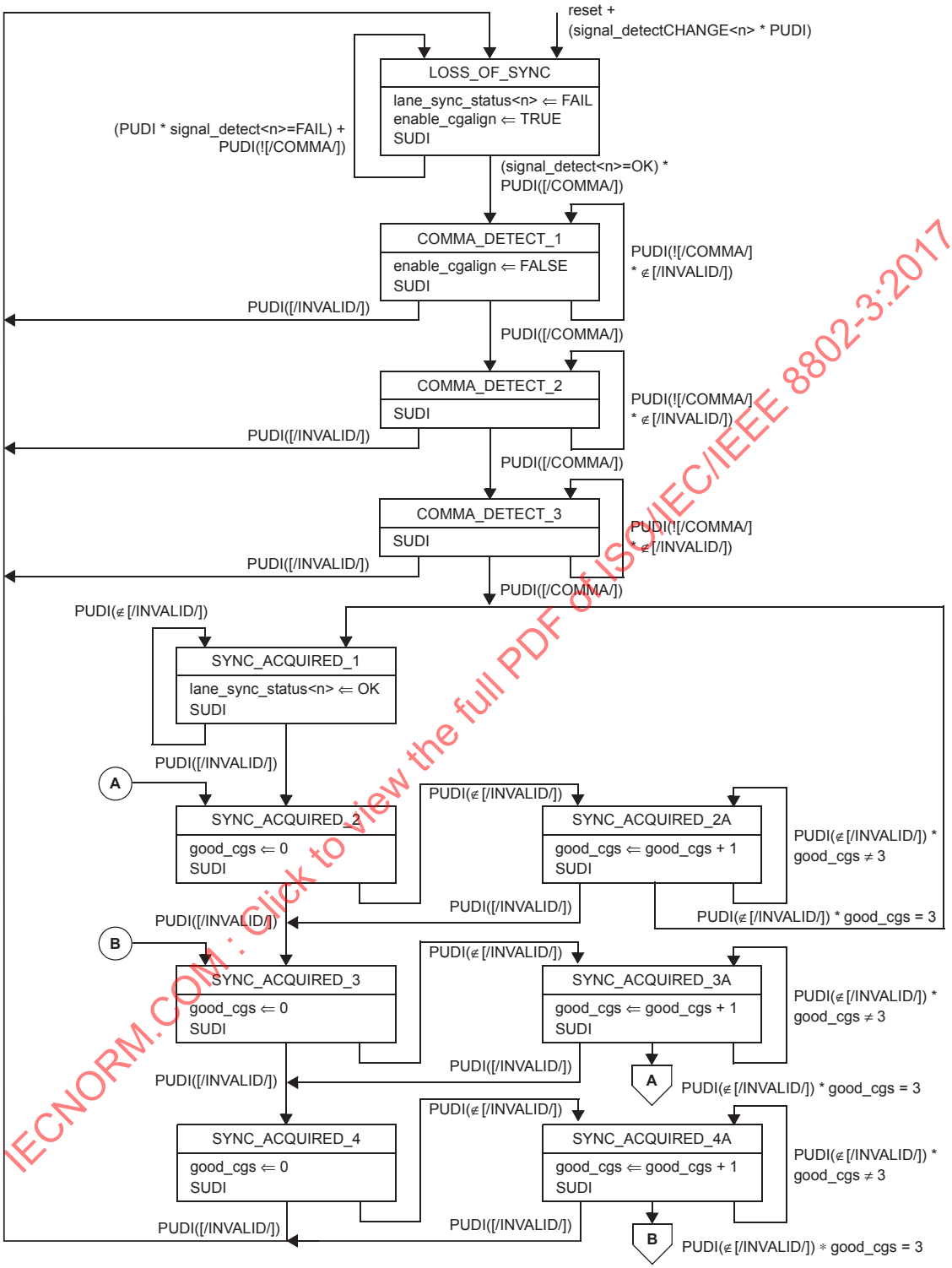

NOTE— lane_sync_status<n>, signal_detect<n> and signal_detectCHANGE<n>, refer to the number of the received lane n where n=0:3

Figure 48–8—PCS synchronization state diagram

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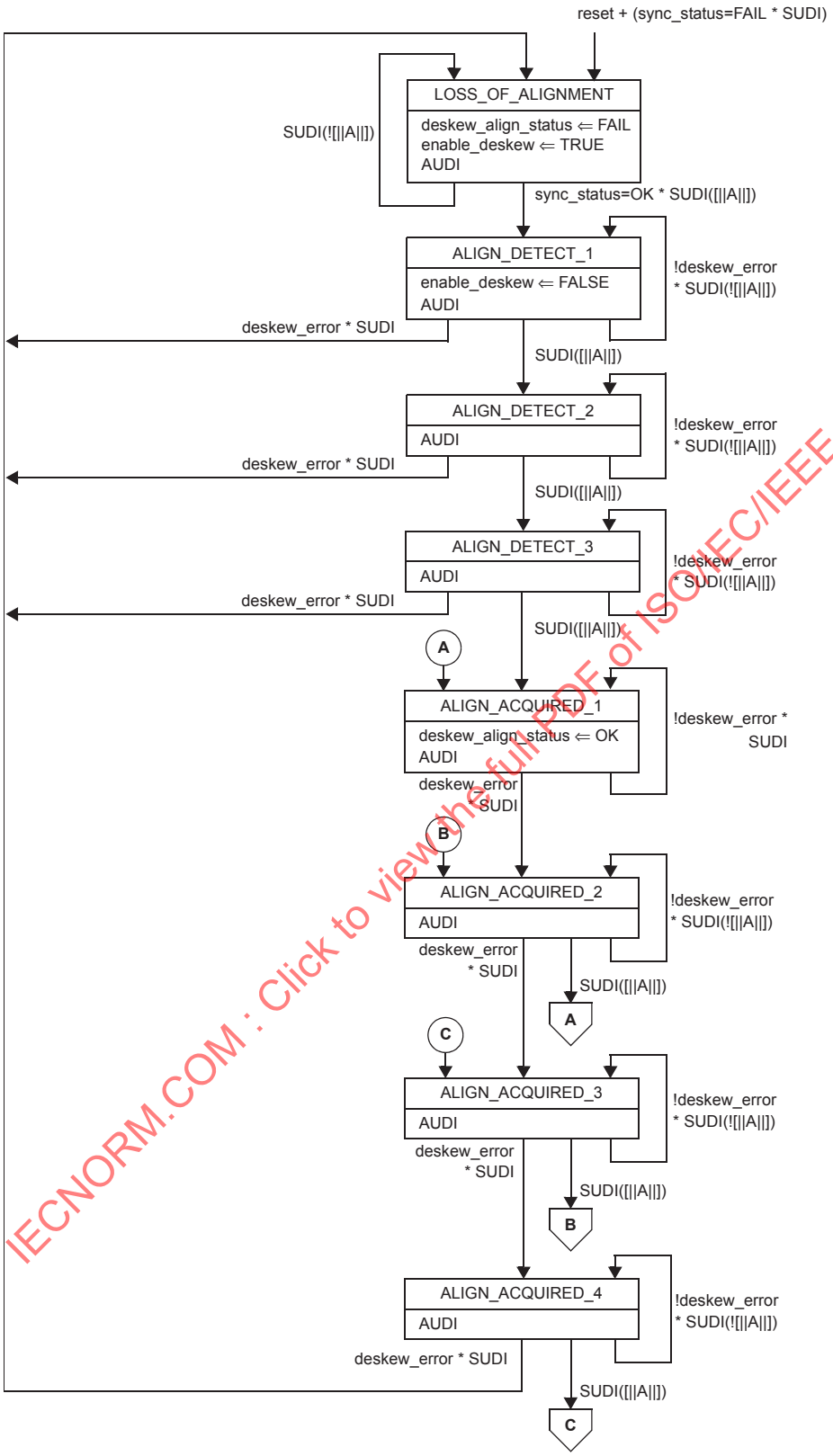

Figure 48–9—PCS deskew state diagram

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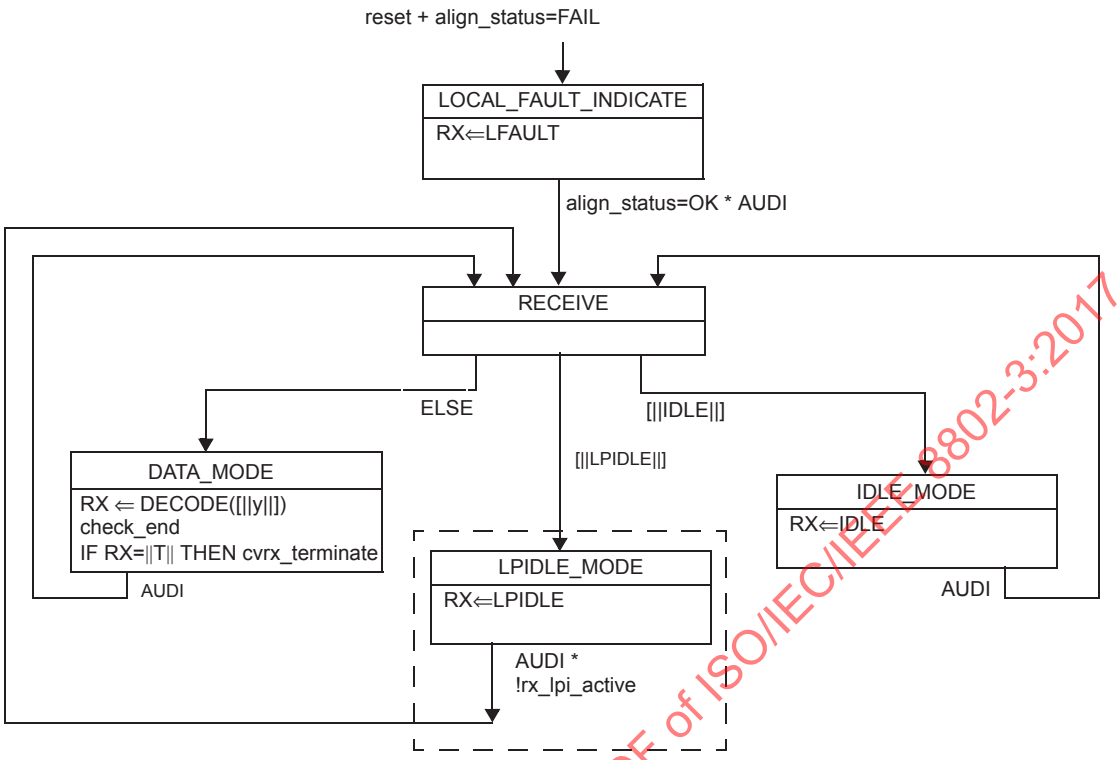

NOTE—Optional state to support LPI is shown inside the dotted box. The transition to the optional state is only possible with EEE capability.

Figure 48–10—PCS receive state diagram

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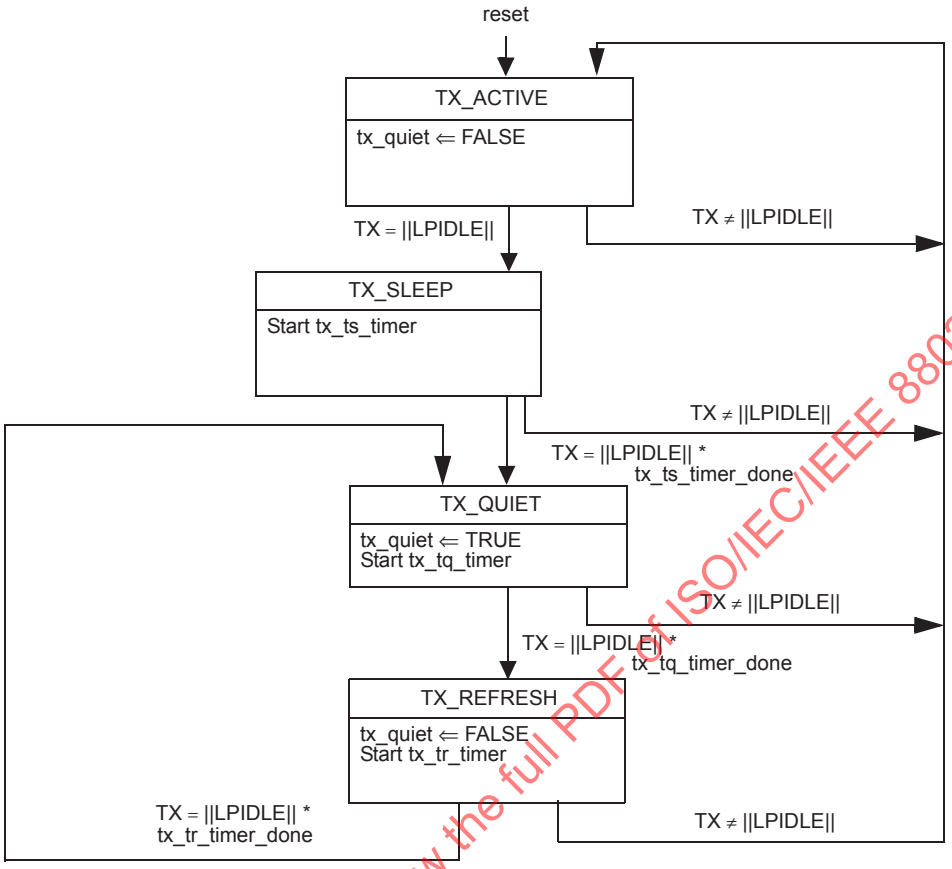

Figure 48–11—LPI Transmit state diagram

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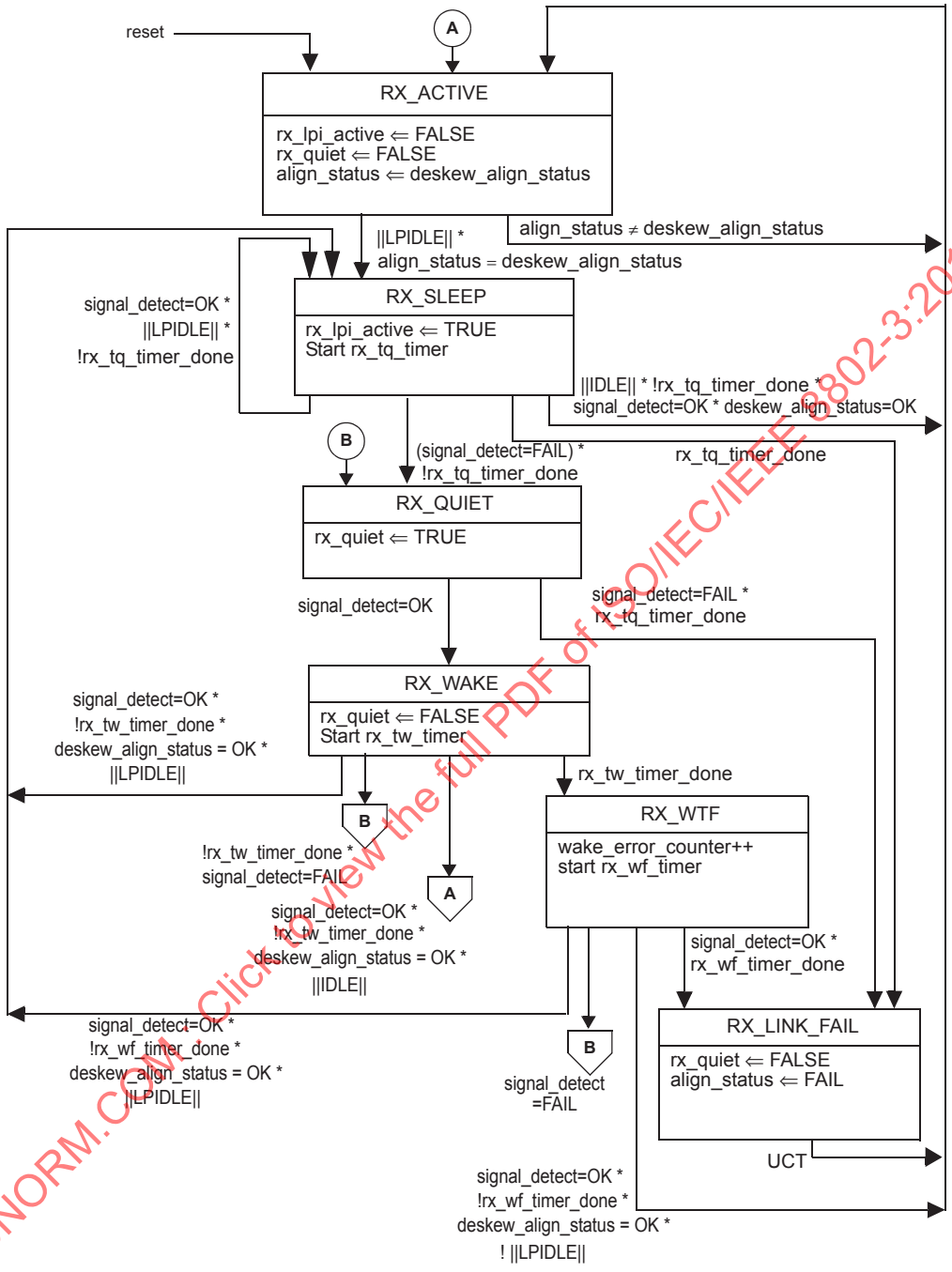

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Figure 48–12—LPI Receive state diagram

The LPI functions shall use timer values for these state diagrams as shown in Table 48–9 for transmit and Table 48–10 for receive.

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Table 48–9—Transmitter LPI timing parameters

Parameter	Description	Min	Max	Units
T_{SL}	Local Sleep Time from entering the TX_SLEEP state to when tx_quiet is set to TRUE	19.9	20.1	µs
T_{QL}	Local Quiet Time from when tx_quiet is set to TRUE to entry into the TX_REFRESH state	2.5	2.6	ms
T_{UL}	Local Refresh Time from entry into the TX_REFRESH state to entry into the TX_QUIET state	19.9	20.1	µs

Table 48–10—Receiver LPI timing parameters

Parameter	Description	Min	Max	Units
T_{QR}	The time the receiver waits for signal detect to be set to OK while in the RX_SLEEP and RX_QUIET states before asserting rx_fault	3	4	ms
T_{WR}	Time the receiver waits in the RX_WAKE state before indicating a wake time fault	—	9	µs
T_{WTF}	Wake time fault recovery time	—	1	ms

48.2.6.2.6 LPI status and management

For EEE capability, the PCS indicates to the management system that LPI is currently active in the receive and transmit directions using the status variable shown in Table 48–11.

Table 48–11—MDIO status indications

MDIO status variable	Register name	Register address	Note
Tx LPI received	PCS status register 1	3.1.11	Latched version of 3.1.9
Rx LPI received	PCS status register 1	3.1.10	Latched version of 3.1.8
Tx LPI indication	PCS status register 1	3.1.9	TRUE when not in state TX_ACTIVE
Rx LPI indication	PCS status register 1	3.1.8	TRUE when not in state RX_ACTIVE
Tx LPI received	PHY XS status register 1	4.1.11	Latched version of 4.1.9
Rx LPI received	PHY XS status register 1	4.1.10	Latched version of 4.1.8
Tx LPI indication	PHY XS status register 1	4.1.9	TRUE when not in state TX_ACTIVE
Rx LPI indication	PHY XS status register 1	4.1.8	TRUE when not in state RX_ACTIVE
Tx LPI received	DTE XS status register 1	5.1.11	Latched version of 5.1.9
Rx LPI received	DTE XS status register 1	5.1.10	Latched version of 5.1.8
Tx LPI indication	DTE XS status register 1	5.1.9	TRUE when not in state TX_ACTIVE
Rx LPI indication	DTE XS status register 1	5.1.8	TRUE when not in state RX_ACTIVE

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48.2.6.3 Initialization process

Link initialization involves the completion of the PCS Synchronization and Deskew processes and the ability to transmit and receive code-groups via the PCS Transmit and Receive processes, respectively. The status register link_status flag is set to OK whenever the align_status flag is set to OK and no errors preventing link operation are present in the PCS or PMA.

48.2.6.4 Link status reporting

Link status reporting involves detection of link status conditions and the signaling of link fault status. The purpose of link status reporting is to quickly identify and convey link status conditions to the RS which can take the necessary action to activate (deactivate) the link via the setting of the RS link_fault 2-bit variable. Link status reporting and MAC packet transmission is mutually exclusive.

48.2.6.4.1 Link status detection

10GBASE-X link status conditions include signal and deskew status conditions. Link status conditions include Local Fault and Remote Fault signals. A receive fault is recognized by the PCS Receive process whenever align_status=FAIL. Other fault conditions are not detected by the PCS or PMA and are detected only by the RS. A fault condition may also be recognized by any 10GBASE-X process upon detection of an error condition, which prevents continued reliable operation, but this is beyond the scope of this standard.

48.2.6.4.2 Link status signaling

Link status signaling follows the detection or recognition of a link status condition and involves the generation of Sequence ordered-sets (||Q||) by the PCS Transmit process. Link status signaling involves the transmission of ||Q|| following ||A|| transmission in the Idle sequence as specified in 48.2.4.2.

48.2.6.4.3 Link status messages

A 10GBASE-X link status message is a Sequence ordered-set. Ordered-sets associated with link status messages are specified in Table 48–4. Link status messages detected by the PCS Receive process are forwarded to the XGMII.

48.2.7 Auto-Negotiation for Backplane Ethernet

The following requirements apply to a PCS used with a 10GBASE-KX4 PMD. Support for the Auto-Negotiation process defined in Clause 73 is mandatory. The PCS shall support the primitive AN_LINK.indication(link_status) (see 73.9). The parameter link_status shall take the value FAIL when align_status=FAIL and the value OK when align_status=OK. The primitive shall be generated when the value of link_status changes.

48.3 Physical Medium Attachment (PMA) sublayer

The PMA is specified in the form of a service interface to the PCS. These services are described in an abstract manner and do not imply any particular implementation. The PMA service interface supports the exchange of code-group information between PCS entities. The PMA converts code-groups into bits and passes these to the PMD, and vice versa.

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48.3.1 Functions within the PMA

The PMA comprises the PMA Transmit process and PMA Receive process. Figure 48–5 depicts the mapping of the 36-bit-wide data and control path of the XGMII to the forty-bit-wide code-groups of the PMA service interface, and on to the four lane serial PMD service interface.

NOTE—Strict adherence to manufacturer-supplied guidelines for the operation and use of PMA serializer components is required to meet the jitter specifications of Clause 47, Clause 53, and Clause 54. The supplied guidelines should address the quality of power supply filtering associated with the transmit clock generator, and also the purity of the reference clock fed to the transmit clock generator.

48.3.1.1 PMA transmit process

The PMA Transmit process passes data unaltered (except for serializing) from the PCS directly to the PMD. Upon receipt of the PMA_UNITDATA.request primitive, the PMA shall individually serialize the four aligned 10-bit code-groups, one from each of four lanes, and transmit them to the PMD in the form of forty PMD_UNITDATA.request primitives, 10 each on four lanes.

Within each lane for each 10-bit code-group, the lowest numbered bit of the PMA_UNITDATA.indication parameter corresponds to the first bit transmitted to the PMD and the highest numbered bit of the PMA_UNITDATA.indication parameter corresponds to the last bit transmitted to the PMD. There is no numerical significance ascribed to the bits within a PMA code-group; that is, the code-group is simply a bit pattern that has some predefined interpretation. PMA to PMD bit and lane association is illustrated in Table 48–1. PMA to PMD bit ordering is illustrated in Figure 48–5.

PMA_UNITDATA.request primitives shall be generated with a frequency of 312.5 MHz ± 100 ppm. An internal clock multiplier unit multiplies the frequency of the 10-bit code-group based PMA_UNITDATA.request primitives by a factor of 10 to serialize the latched data out of the PMA and into the PMD.

48.3.1.2 PMA receive process

The PMA Receive process passes data unaltered (except for deserializing) from the PMD directly to the PCS. Upon receipt of forty PMD_UNITDATA.indication primitives, 10 in succession from each of four lanes, the PMA shall assemble the bits received into a 40-bit vector representing four 10-bit unaligned code-groups and pass that vector to the PCS as the parameter of four PMA_UNITDATA.indication primitives.

Within each lane for each 10-bit code-group, the lowest numbered bit of the PMA_UNITDATA.indication parameter corresponds to the first bit received from the PMD and the highest numbered bit of the PMA_UNITDATA.indication parameter corresponds to the last bit received from the PMD. There is no numerical significance ascribed to the bits within a PMA code-group; that is, the code-group is simply a bit pattern that has some predefined interpretation. Receive code-group alignment is performed by the PCS and is not applicable to PMA. PMA to PMD bit and lane association is illustrated in Table 48–1. PMA to PMD bit ordering is illustrated in Figure 48–5.

PMA_UNITDATA.indication primitives shall be generated with a frequency of 312.5 MHz ± 100 ppm. The line rate of each of four PMD lanes is 3.125 GBd ± 100 ppm. The serial data stream of the PMD includes an embedded clock that nominally operates at a frequency 10 times higher than that of a single lane code-group stream. The PMA Receive process shall recover a clock from a valid 8B/10B received data stream if the stream is within tolerance.

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48.3.2 Service interface

The following primitives are defined:

PMA_UNITDATA.request(tx_code-group <39:0>)
PMA_UNITDATA.indication(rx_unaligned <39:0>)

48.3.2.1 PMA_UNITDATA.request

This primitive defines the transfer of data in the form of aligned code-groups from the PCS to the PMA. PMA_UNITDATA.request is generated by the PCS Transmit process.

48.3.2.1.1 Semantics of the service primitive

PMA_UNITDATA.request(tx_code-group <39:0>)

The data conveyed by PMA_UNITDATA.request is the tx_code-group <39:0> parameter defined in 48.2.6.1.3.

48.3.2.1.2 When generated

The PCS continuously sends tx_code-group <39:0> to the PMA at a nominal rate of 312.5 MHz ± 100 ppm, as governed by frequency and tolerance of XGMII TX_CLK.

48.3.2.1.3 Effect of receipt

Upon receipt of this primitive, the PMA generates a series of forty PMD_UNITDATA.request primitives, 10 for each of the four PMD lanes, tx_lane <3:0>, requesting the four lane serial transmission of tx_code-group <39:0> to the PMD.

48.3.2.2 PMA_UNITDATA.indication

This primitive defines the transfer of data in the form of code-groups from the PMA to the PCS. PMA_UNITDATA.indication is used by the PCS Synchronization process.

48.3.2.2.1 Semantics of the service primitive

PMA_UNITDATA.indication(rx_unaligned <39:0>)

The data conveyed by PMA_UNITDATA.indication is the rx_unaligned <39:0> parameter defined in 48.2.6.1.3.

48.3.2.2.2 When generated

The PMA continuously sends rx_unaligned <39:0> to the PCS at a nominal rate of 312.5 MHz ± 100 ppm, as governed by frequency and tolerance of PMD_UNITDATA.indication.

48.3.2.2.3 Effect of receipt

Upon receipt of this primitive, the PCS Synchronization process attempts to achieve code-group synchronization on each lane (see 48.2.6.2.2).

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48.3.3 Loopback mode

Loopback mode shall be provided for the 10GBASE-X PMA and DTE XGXS, and optionally for the PHY XGXS, as specified in this subclause, by the transmitter and receiver of a device as a test function to the device. When Loopback mode is selected, transmission requests passed to the transmitter are shunted directly to the receiver, overriding any signal detected by the receiver on its attached link. A device is explicitly placed in Loopback mode (i.e., Loopback mode is not the normal mode of operation of a device). Loopback applies to all lanes as a group (i.e., the lane 0 transmitter is directly connected to the lane 0 receiver, the lane 1 transmitter is directly connected to the lane 1 receiver, etc.). The method of implementing Loopback mode is not defined by this standard.

Control of the Loopback function may be supported through the MDIO management interface of Clause 45 or equivalent.

NOTE—The signal path that is exercised in the Loopback mode is implementation specific, but it is recommended that this signal path encompass as much of the circuitry as is practical. The intention of providing this loopback mode of operation is to permit diagnostic or self-test functions to test the transmit and receive data paths using actual data. Other loopback signal paths may also be enabled independently using loopback controls within other devices or sublayers.

48.3.3.1 Receiver considerations

Entry into or exit from Loopback mode may result in a temporary loss of synchronization.

48.3.3.2 Transmitter considerations

While in Loopback mode, the transmitter output is not defined.

48.3.4 Test functions

A limited set of test functions may be provided as an implementation option for testing of the transmitter function or for testing of an attached receiver.

Some test functions that are not defined by this standard may be provided by certain implementations. Compliance with the standard is not affected by the provision or exclusion of such functions by an implementation. Random jitter test patterns for 10GBASE-X are specified in Annex 48A. Test-pattern capability and selection is optional and supported via MDIO register bits defined in Clause 45. Jitter Test methodology for 10GBASE-X is specified in Annex 48B. It is recommended that the capability for generating the mixed-frequency, low frequency and high frequency patterns is implemented in the PCS.

A typical test function is the ability to transmit invalid code-groups within an otherwise valid PHY bit stream. Certain invalid PHY bit streams may cause a receiver to lose word and/or bit synchronization. See ANSI/INCITS 450 (FC-PI-4), subclause 5.4 for a more detailed discussion of receiver and transmitter behavior under various test conditions.

48.4 Compatibility considerations

There is no requirement for a compliant device to implement or expose any of the interfaces specified for the PCS or PMA. Implementations of an XGMII shall comply with the requirements as specified in Clause 46.

48.5 Delay constraints

Predictable operation of the MAC Control PAUSE operation (Clause 31, Annex 31B) demands that there be an upper bound on the propagation delays through the network. This implies that MAC, MAC Control

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sublayer, and PHY implementers must conform to certain delay maxima, and that network planners and administrators conform to constraints regarding the cable topology and concatenation of devices.

The sum of transmit and receive delay contributed by the 10GBASE-X PCS shall be no more than 2048 BT.

The reference point for all MDI measurements is the 50% point of the mid-cell transition corresponding to the reference bit, as measured at the MDI.

48.6 Environmental specifications

All equipment subject to this clause shall conform to the requirements of 14.7 and applicable sections of ISO/IEC 11801:1995.

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48.7 Protocol implementation conformance statement (PICS) proforma for Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 10GBASE-X[5]

48.7.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 48, Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 10GBASE-X, shall complete the following protocol implementation conformance statement (PICS) proforma. A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

48.7.2 Identification

48.7.2.1 Implementation identification

Supplier[1]	
Contact point for inquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1, 3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

48.7.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 48, Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayer, type 10GBASE-X
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	
Date of Statement	

[5]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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48.7.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
MD	MDIO	45, 48.1.3.1	Registers and interface supported	O	Yes [ ] No [ ]
XGXS	Support of XAUI/XGXS	47, 48.1.5		O	Yes [ ] No [ ]
XGE	XGMII compatibility interface	46, 48.1.3.1	Compatibility interface is supported	O	Yes [ ] No [ ]
LX4	Support of 10GBASE-LX4 PMD	53, 48.1.3.3		O	Yes [ ] No [ ]
CX4	Support of 10GBASE-CX4 PMD	54, 48.1.3.3		O	Yes [ ] No [ ]
LPI	Implementation of LPI	48.2.3		O	Yes [ ] No [ ]

48.7.4 PICS proforma tables for the PCS and PMA sublayer, type 10GBASE-X

48.7.4.1 Compatibility considerations

Item	Feature	Subclause	Value/Comment	Status	Support
CC1	Jitter test patterns	48.3.4	As per Annex 48A	O	Yes [ ] No [ ]
CC2	Environmental specifications	48.6		M	Yes [ ]

48.7.4.2 PCS functions

Item	Feature	Subclause	Value/Comment	Status	Support
CG	Code-group usage	48.2.3	PCS support of 8B/10B code-groups	M	Yes [ ]
IOS	‖I‖ sequencing rules	48.2.4.2	All rules apply	M	Yes [ ]
PRBS	Random integer generator	48.2.4.2	$X^7 + X^3 + 1$ or $X^7 + X^6 + 1$. Used for ‖A‖ spacing. Optional and ancillary use for testing	M	Yes [ ]
CMA	Comma detection	48.2.4.2.1	comma+ and comma- for /K/	M	Yes [ ]
CKCU	Clock rate compensation in unencoded idle stream	48.2.4.2.3	Meets the requirements of 48.2.4.2.3	O	Yes [ ] No [ ]
ERR	Error indication	48.2.4.4	Replacement of invalid code-groups with /E/	M	Yes [ ]
TSD	Transmit state diagrams	48.2.6.2.1	Meets the requirements of Figures 48–7	M	Yes [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
SSD	Synchronization state diagram	48.2.6.2.2	Meets the requirements of Figure 48–8	M	Yes [ ]
DSD	Deskew state diagrams	48.2.6.2.3	Meets the requirements of Figure 48–9	M	Yes [ ]
RSD	Receive state diagrams	48.2.6.2.4	Meets the requirements of Figure 48–10	M	Yes [ ]
AN1*	Support for use with a 10GBASE-KX4 PMD	48.2.7	AN technology dependent interface described in Clause 73	O	Yes [ ]
AN2	AN_LINK.indication primitive	48.2.7	Support of the primitive AN_LINK.indication(link_status), when the PCS is used with 10GBASE-KX4 PMD	AN1:M	Yes [ ]
AN3	link_status parameter	48.2.7	Takes the value OK or FAIL, as described in 48.2.7	AN1:M	Yes [ ]
AN4	Generation of AN_LINK.indication primitive	48.2.7	Generated when the value of link_status changes	AN1:M	Yes [ ]

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48.7.4.3 PMA Functions

Item	Feature	Subclause	Value/Comment	Status	Support
PMAT	Transmit function	48.3.1.1	PMA_UNITDATA.request	M	Yes [ ]
TXRT	Transmit rate	48.3.1.1	3.125 GBd ± 100 ppm	M	Yes [ ]
PMAR	Receive function	48.3.1.2	PMA_UNITDATA.indication	M	Yes [ ]
RXRT	Receive rate	48.3.1.2	3.125 GBd ± 100 ppm	M	Yes [ ]
CDR	Clock and data recovery	48.3.1.2	Required if line rate is within 3.125 GBd ± 100 ppm	M	Yes [ ]

48.7.4.4 Interface functions

Item	Feature	Subclause	Value/Comment	Status	Support
SKEW	Allowable lane skew	48.2.4.2.2	Table 48–5	M	Yes [ ]
LBXPMA	10GBASE-X PMA Loopback mode	48.3.3		M	Yes [ ]
LBDTE	DTE XGXS Loopback mode	48.3.3		M	Yes [ ]
LBPHY	PHY XGXS Loopback mode	48.3.3		O	Yes [ ]
DLY	Delay constraints	48.5	2048 BT	M	Yes [ ]

48.7.4.5 LPI functions

Item	Feature	Subclause	Value/Comment	Status	Support
LP-01	Receive state diagrams	48.2.6.2	Support additions to Figure 48–10 for LPI operation	LPI:M	Yes [ ] No [ ]
LP-02	LPI transmit state diagrams	48.2.6.2.5	Meet the requirements of Figure 48–11	LPI:M	Yes [ ] No [ ]
LP-03	LPI receive state diagrams	48.2.6.2.5	Meet the requirements of Figure 48–12	LPI:M	Yes [ ] No [ ]
LP-04	LPI transmit timing	48.2.6.2.5	Meet the requirements of Table 48–9	LPI:M	Yes [ ] No [ ]
LP-05	LPI receive timing	48.2.6.2.5	Meet the requirements of Table 48–10	LPI:M	Yes [ ] No [ ]

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49. Physical Coding Sublayer (PCS) for 64B/66B, type 10GBASE-R

49.1 Overview

49.1.1 Scope

This clause specifies the Physical Coding Sublayer (PCS) that is common to a family of 10 Gb/s Physical Layer implementations, known as 10GBASE-R. This PCS can connect directly to one of the 10GBASE-R Physical Layers: 10GBASE-SR, 10GBASE-LR, 10GBASE-ER, 10GBASE-LRM, and 10GBASE-KR. Alternatively, this PCS can connect to a WAN Interface Sublayer (WIS), which will produce the 10GBASE-W encoding (10GBASE-R encoded data stream encapsulated into frames compatible with SONET and SDH networks) for transport by the 10GBASE-W Physical Layers: 10GBASE-SW, 10GBASE-LW, and 10GBASE-EW. The term 10GBASE-R is used when referring generally to Physical Layers using the PCS defined here.

The 10GBASE-R is based on a 64B/66B code. The 64B/66B code supports data and control characters, while maintaining robust error detection.

10GBASE-R PCS maps the interface characteristics of the WIS when present, and the PMA sublayer to the services expected by the Reconciliation and XGXS sublayers. 10GBASE-R can be extended to support any full duplex medium requiring only that the medium be compliant at the PMA level. 10GBASE-R PCS may be attached through the PMA sublayer to a LAN PMD sublayer supporting a data rate of 10 Gb/s or it may be attached to a WAN PMD through the WIS and PMA sublayers. When attached to a WAN sublayer, this PCS adapts the data stream to the WAN data rate.

49.1.2 Objectives

The following are the objectives of 10GBASE-R:

a) Support the full duplex Ethernet MAC.
b) Provide 10 Gb/s data rate at the XGMII.
c) Support LAN PMDs operating at 10 Gb/s and WAN PMDs operating at SONET STS-192c/SDH VC-4-64c rate.
d) Support cable plants using cabled optical fiber compliant with ISO/IEC 11801:1995 as specified in Clause 52 and Clause 68.
e) Allow for a nominal network extent of up to 40 km.
f) Support a BER objective of 10^{-12}.

49.1.3 Relationship of 10GBASE-R to other standards

Figure 49–1 depicts the relationships among the 10GBASE-R sublayers (shown shaded), the Ethernet MAC and reconciliation layers, and the higher layers.

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49.1.4 Summary of 10GBASE-R and 10GBASE-W sublayers

The following subclauses provide an overview of the 10GBASE-R and 10GBASE-W sublayers.[6] Figure 49–1 depicts the relationship between the 10GBASE-R PCS and its associated sublayers.

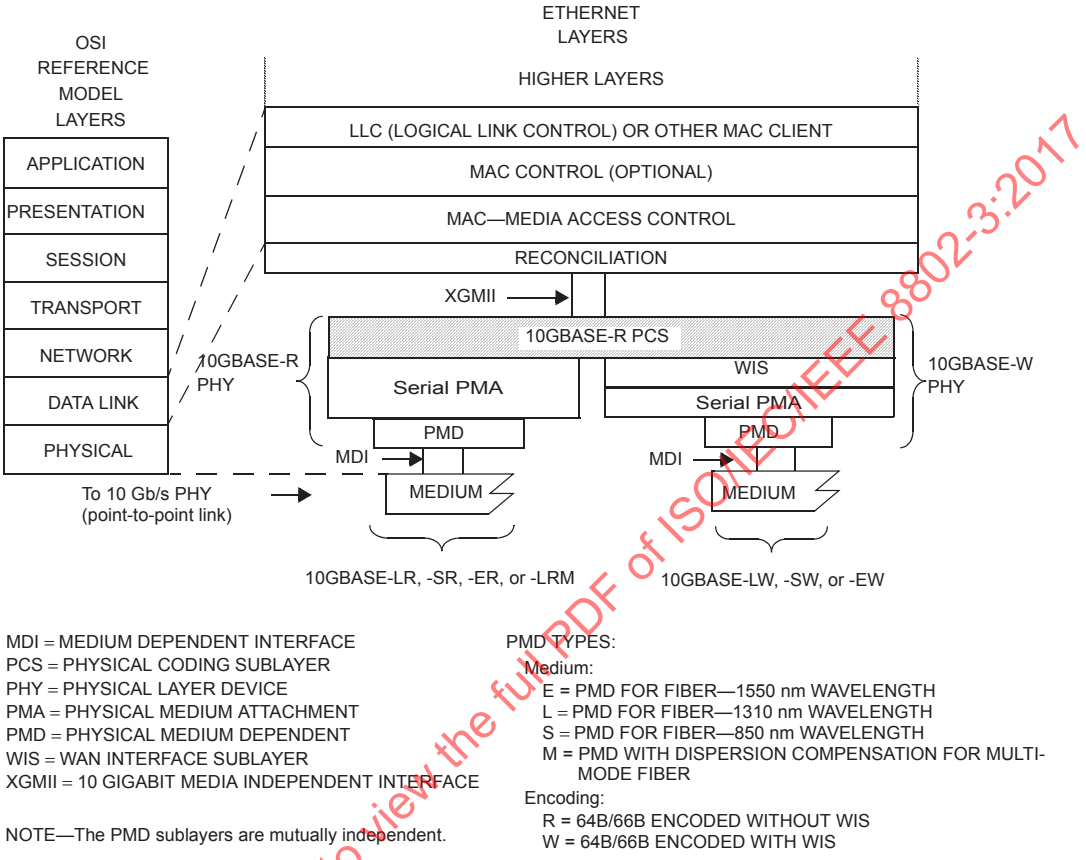

Figure 49–1—10GBASE-R PCS relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and IEEE 802.3 Ethernet model

49.1.4.1 Physical Coding Sublayer (PCS)

The PCS service interface is the 10 Gigabit Media Independent Interface (XGMII), which is defined in Clause 46. The XGMII provides a uniform interface to the Reconciliation Sublayer for all 10 Gb/s PHY implementations (e.g., not only 10GBASE-R but also other types of 10 Gigabit PHY entities).

The 10GBASE-R PCS provides all services required by the XGMII, including the following:

a) Encoding (decoding) of eight XGMII data octets to (from) 66-bit blocks (64B/66B).
b) Transferring encoded data to (from) the PMA in 16 bit transfers.
c) When connected to a WAN PMD, deleting (inserting) idles to compensate for the rate difference between the MAC and PMD.

[6] The 10GBASE-R PHY consists of that portion of the Physical Layer between the MDI and XGMII consisting of the PCS, PMA, and PMD sublayers. The 10GBASE-R PHY is roughly analogous to the 100BASE-X PHY.

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d) Determining when a functional link has been established and informing the management entity via the MDIO when the PHY is ready for use.

49.1.4.2 WAN Interface Sublayer (WIS)

The WIS provides a medium-independent means for the PCS to operate over WAN links. It creates a 10GBASE-W encoding by encapsulating the encoded data steam from the 10GBASE-R PCS in frames compatible with SONET and SDH transmission formats. The WIS is specified in Clause 50.

49.1.4.3 Physical Medium Attachment (PMA) sublayer

The PMA provides a medium-independent means for the PCS to support the use of a range of physical media. The 10GBASE-R PMA performs the following functions:

a) Mapping of transmit and receive data streams between the PCS or WIS and PMA via the PMA service interface.
b) Serialization (deserialization) of bits for transmission (reception) on the underlying serial PMD.
c) Recovery of clock from the received data stream.
d) Mapping of transmit and receive bits between the PMA and PMD via the PMD service interface.
e) Optionally provides data loopback at the PMA service interface.

The PMA is specified in Clause 51.

49.1.4.4 Physical Medium Dependent (PMD) sublayer

The PMD and its media are specified in Clause 52 and Clause 68.

The MDI, logically subsumed within each PMD subclause, is the actual medium attachment for the various supported media.

49.1.4.5 Bit ordering across 10GBASE-R and 10GBASE-W sublayers.

The ordering of bits and octets for the case when no WIS is present between the PCS and PMA is shown in Figure 49–2. The diagram depicts the bit mappings for the data path at the service interfaces.

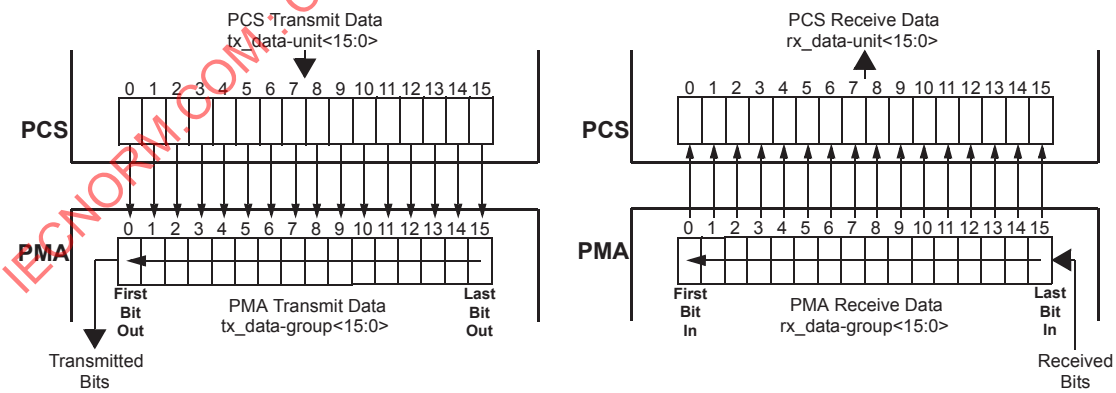

Figure 49–2—10GBASE-R PHY transmission order

The bit/octet ordering when a WIS is interposed between the PCS and PMA is shown in Figure 49–3. The details of WIS frame generation, as well as internal interfaces, have been omitted. Note that since SONET

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convention is to send the most significant bit (MSB) of each octet first and Ethernet convention is to send the least significant bit (LSB) of each octet first, the LSBs from the PCS octets are mapped into the MSBs of the WIS octets. It should be clear from the diagram that the Ethernet order of transmission (i.e., least-significant bit first), and hence the error detecting properties of the Ethernet CRC, are preserved in spite of the different bit ordering conventions followed by the WIS. Also, the SONET/SDH bit labeling conventions are different from the usual IEEE 802.3 bit labeling. The bits of a SONET/SDH octet are labeled from 1 to 8 with bit 1 being the MSB. Ethernet conventions label bits of an n-bit field from 0 to n–1 with bit 0 being the LSB. Figure 49–3 shows the results of these conventions. For example, tx_data-unit<0> through tx_data-unit<7> map to bits 1 through 8 respectively of a WIS octet.

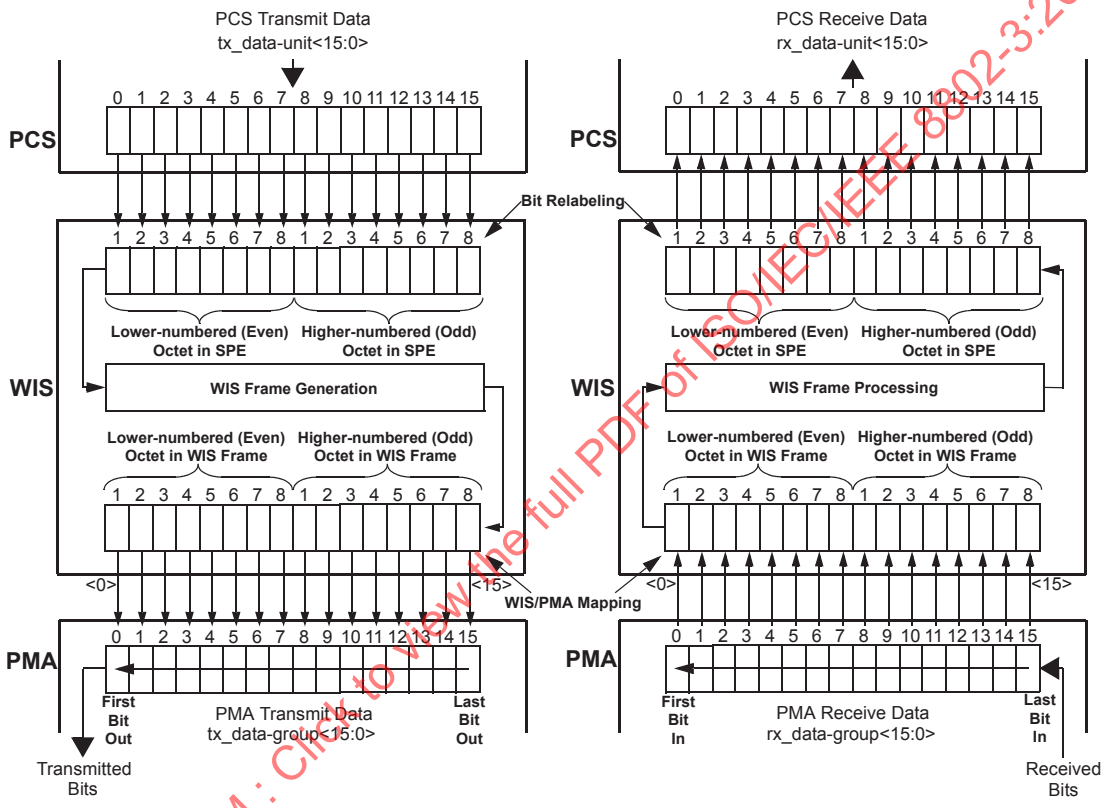

Figure 49–3—10GBASE-W PHY Transmission order

49.1.5 Inter-sublayer interfaces

There are a number of interfaces employed by 10GBASE-R. Some (such as the PMA service interface) use an abstract service model to define the operation of the interface. The PCS service interface is the XGMII that is defined in Clause 46. The XGMII has an optional physical instantiation. An optional physical instantiation of the PMA service interface has also been defined (see Clause 51). It is called XSBI (10 Gigabit Sixteen Bit Interface). Figure 49–4 depicts the relationship and mapping of the services provided by all of the interfaces relevant to 10GBASE-R.

The upper interface of the PCS may connect to the Reconciliation Sublayer through the XGMII or the PCS may connect to an XGXS sublayer. The XGXS and the Reconciliation Sublayer provide the same service interface to the PCS. The lower interface of the PCS may connect to the WIS to support a WAN PMD or to the PMA sublayer to support a 10GBASE-R LAN PMD. The WIS and PMA interfaces are functionally

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equivalent except for data rate. When the PCS is connected directly to a LAN PMA, the nominal rate of the PMA service interface is 644.53 Mtransfers/s, which provides capacity for the MAC data rate of 10 Gb/s. When the PCS is connected to a WAN PMA, the nominal rate of the WIS service interface is 599.04 Mtransfers/s and the MAC uses IFS stretch mode to ensure that there will be enough idle time that the PCS can delete idles to adjust to the lower rate. Since the data rates are different, WIS and PMA interface connections pose somewhat different constraints. The PCS shall support connection to either a WIS or to a PMA and may optionally support both.

If the optional Energy-Efficient Ethernet (EEE) capability is supported (see Clause 78, 78.3) then the interface with the PMA sublayer (or FEC sublayer) includes rx_mode and tx_mode to control power states in lower sublayers and energy_detect that indicates whether the PMD sublayer has detected a signal at the receiver. If the PHY includes an FEC sublayer, the interface includes rx_lpi_active to indicate that the LPI receive state diagram is not in RX_ACTIVE state.

It is important to note that, while this specification defines interfaces in terms of bits, octets, and frames, implementations may choose other data-path widths for implementation convenience.

49.1.6 Functional block diagram

Figure 49–4 provides a functional block diagram of the 10GBASE-R PHY.

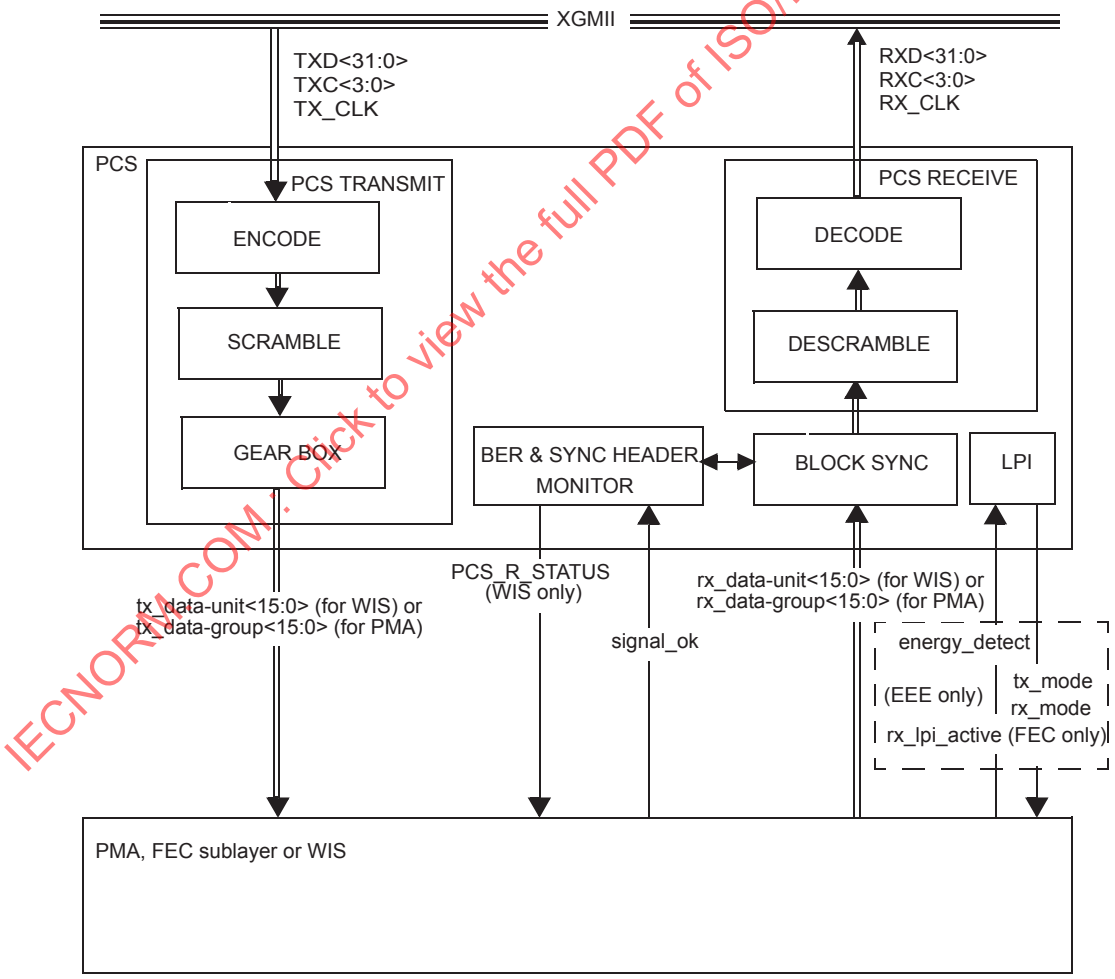

Figure 49–4—Functional block diagram

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49.2 Physical Coding Sublayer (PCS)

49.2.1 PCS service interface (XGMII)

The PCS service interface allows the 10GBASE-R PCS to transfer information to and from a PCS client. A PCS client is generally the Reconciliation Sublayer or an XGXS sublayer. The PCS Interface is precisely defined as the 10 Gigabit Media Independent Interface (XGMII) in Clause 46.

49.2.2 Functions within the PCS

The PCS comprises the PCS Transmit, Block Synchronization, PCS Receive, and BER monitor processes for 10GBASE-R. The PCS shields the Reconciliation Sublayer (and MAC) from the specific nature of the underlying channel. The PCS transmit channel and receive channel can each operate in normal mode or, when not attached to a WIS, test-pattern mode. When the PCS is attached to a WIS, the WIS provides the test-pattern functionality.

When communicating with the XGMII, the PCS uses a four octet-wide, synchronous data path, with packet delimiting being provided by transmit control signals (TXCn = 1) and receive control signals (RXCn = 1). When communicating with the PMA or WIS, the PCS uses a 16-bit wide, synchronous data path that conveys 16 encoded bits. Alignment to 64B/66B block is performed in the PCS. The WIS and PMA sublayers operate independent of block and packet boundaries. The PCS provides the functions necessary to map packets between the XGMII format and the PMA service interface format.

When the transmit channel is in normal mode, the PCS Transmit process continuously generates blocks based upon the TXD <31:0> and TXC <3:0> signals on the XGMII. The Gearbox function of the PCS Transmit process then packs the resulting bits into 16-bit transmit data-units. Transmit data-units are sent to the PMA or WIS service interface via the PMA_UNITDATA.request or WIS_UNITDATA.request primitive, respectively. When the WIS is present, the PCS Transmit process also adapts between the XGMII and WIS data rates by deleting idle characters.

When the transmit channel is in test-pattern mode, a test pattern is packed into the transmit data-units that are sent to the PMA service interface via the PMA_UNITDATA.request primitive.

When the receive channel is in normal mode, the PCS Synchronization process continuously monitors PMA_SIGNAL.indication(SIGNAL_OK) or WIS_SIGNAL.indication(SIGNAL_OK). When SIGNAL_OK indicates OK, then the PCS Synchronization process accepts data-units via the PMA_UNITDATA.indication primitive or the WIS_UNITDATA.indication primitive. It attains block synchronization based on the 2-bit synchronization headers and conveys received blocks to the PCS Receive process. The PCS Synchronization process sets the sync_status flag to indicate whether the PCS has obtained synchronization.

When the PCS Synchronization process has obtained synchronization, the BER monitor process monitors the signal quality asserting hi_ber if excessive errors are detected. When sync_status is asserted and hi_ber is de-asserted, the PCS Receive process continuously accepts blocks. The PCS Receive process monitors these blocks and generates RXD <31:0> and RXC <3:0> on the XGMII. When the WIS is present, the PCS Receive process also adapts between the WIS and XGMII data rates by inserting idle characters. The PCS Receive process also sends the WIS_SIGNAL.request(PCS_R_STATUS) primitive to the WIS to indicate its status. The primitive is sent when the value of PCS_R_STATUS changes. The value of PCS_R_STATUS shall be FAIL when the Receive state diagram is in the RX_INIT state and OK otherwise.

When the receive channel is in test-pattern mode, the BER monitor process is disabled. The Receive process will be held in the RX_INIT state. The received bits will be compared to the test pattern and errors counted.

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A PCS that supports direct connection to a PMA shall provide transmit test-pattern mode for the square wave and pseudo-random patterns, and shall provide receive test-pattern mode for the pseudo-random pattern. The PCS may provide support for the PRBS9 transmit test pattern. It may provide support for the PRBS31 test pattern. Support of the optional PRBS31 test pattern shall include both the transmit and the receive capability for that pattern. Test-pattern mode is activated separately for transmit and receive. A PCS that supports direct connection to a PMA shall support transmit test-pattern mode and receive test-pattern mode operating simultaneously (if applicable) so as to support loopback testing. Test-pattern mode is provided by the WIS when a WIS is present.

49.2.3 Use of blocks

The PCS maps XGMII signals into 66-bit blocks, and vice versa, using a 64B/66B coding scheme. The synchronization headers of the blocks allow establishment of block boundaries by the PCS Synchronization process. Blocks are unobservable and have no meaning outside the PCS. The PCS functions ENCODE and DECODE generate, manipulate, and interpret blocks as provided by the rules in 49.2.4.

49.2.4 64B/66B transmission code

The PCS uses a transmission code to improve the transmission characteristics of information to be transferred across the link and to support transmission of control and data characters. The encodings defined by the transmission code ensure that sufficient transitions are present in the PHY bit stream to make clock recovery possible at the receiver. The encoding also preserves the likelihood of detecting any single or multiple bit errors that may occur during transmission and reception of information. In addition, the synchronization headers of the code enable the receiver to achieve block alignment on the incoming PHY bit stream. The 64B/66B transmission code specified for use in this standard has a high transition density and is a run-length-limited code.

The relationship of block bit positions to XGMII, PMA, and other PCS constructs is illustrated in Figure 49–5 for transmit and Figure 49–6 for receive. These figures illustrate the processing of a block containing 8 data octets. See 49.2.4.3 for information on how blocks containing control characters are mapped. Note that the sync header is generated by the encoder and bypasses the scrambler.

49.2.4.1 Notation conventions

For values shown as binary, the leftmost bit is the first transmitted bit.

64B/66B encodes 8 data octets or control characters into a block. Blocks containing control characters also contain a block type field. Data octets are labeled D_0 to D_7. Control characters other than /O/, /S/ and /T/ are labeled C_0 to C_7. The control character for ordered set is labeled as O_0 or O_4 since it is only valid on the first octet of the XGMII. The control character for start is labeled as S_0 or S_4 for the same reason. The control character for terminate is labeled as T_0 to T_7.

Two consecutive XGMII transfers provide eight characters that are encoded into one 66-bit transmission block. The subscript in the above labels indicates the position of the character in the eight characters from the XGMII transfers.

Contents of block type fields, data octets and control characters are shown as hexadecimal values. The LSB of the hexadecimal value represents the first transmitted bit. For instance, the block type field 0x1e is sent from left to right as 01111000. The bits of a transmitted or received block are labeled TxB<65:0> and RxB<65:0> respectively where TxB<0> and RxB<0> represent the first transmitted bit. The value of the sync header is shown as a binary value. Binary values are shown with the first transmitted bit (the LSB) on the left.

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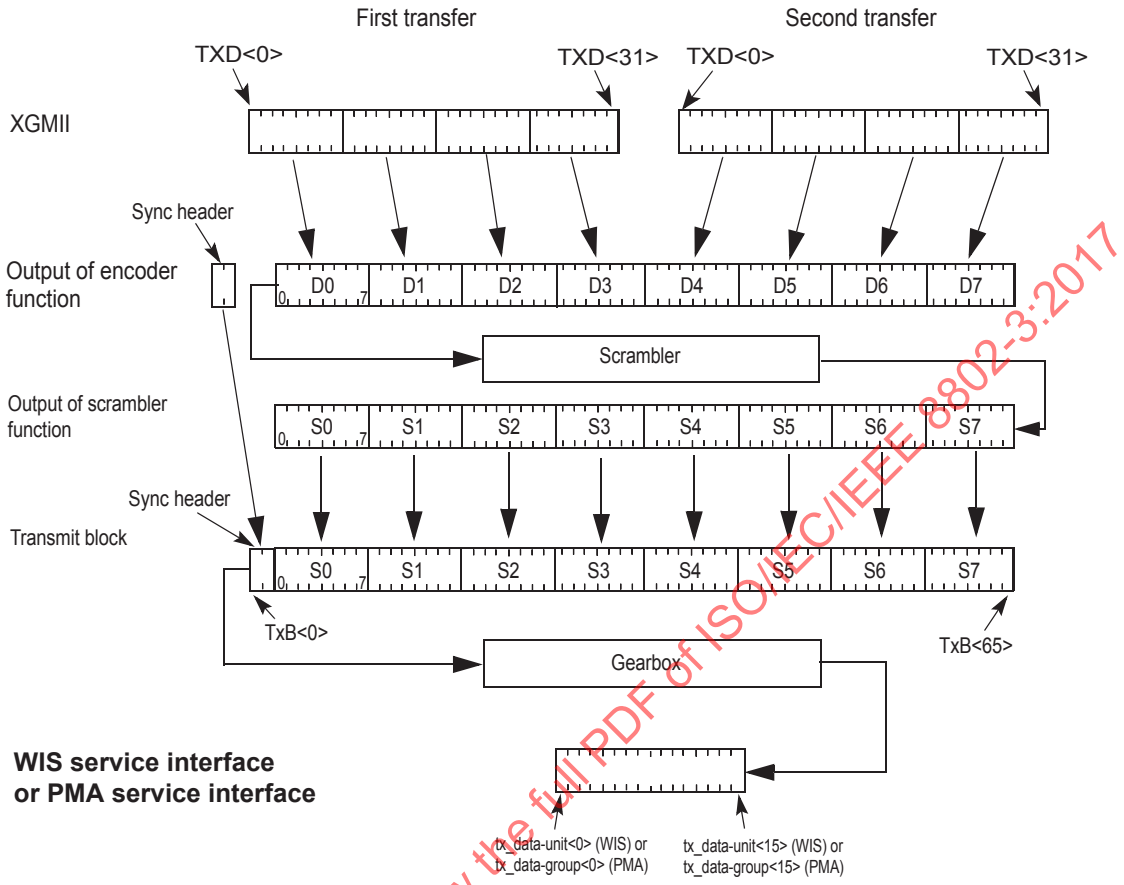

Figure 49–5—PCS Transmit bit ordering

49.2.4.2 Transmission order

Block bit transmission order is illustrated in Figure 49–5 and Figure 49–6. Note that these figures show the mapping from XGMII to 64B/66B block for a block containing eight data characters.

49.2.4.3 Block structure

Blocks consist of 66 bits. The first two bits of a block are the synchronization header (sync header). Blocks are either data blocks or control blocks. The sync header is 01 for data blocks and 10 for control blocks. Thus, there is always a transition between the first two bits of a block. The remainder of the block contains the payload. The payload is scrambled and the sync header bypasses the scrambler. Therefore, the sync header is the only position in the block that always contains a transition. This feature of the code is used to obtain block synchronization.

Data blocks contain eight data characters. Control blocks begin with an 8-bit block type field that indicates the format of the remainder of the block. For control blocks containing a Start or Terminate character, that character is implied by the block type field. Other control characters are encoded in a 7-bit control code or a 4-bit O Code. Each control block contains eight characters.

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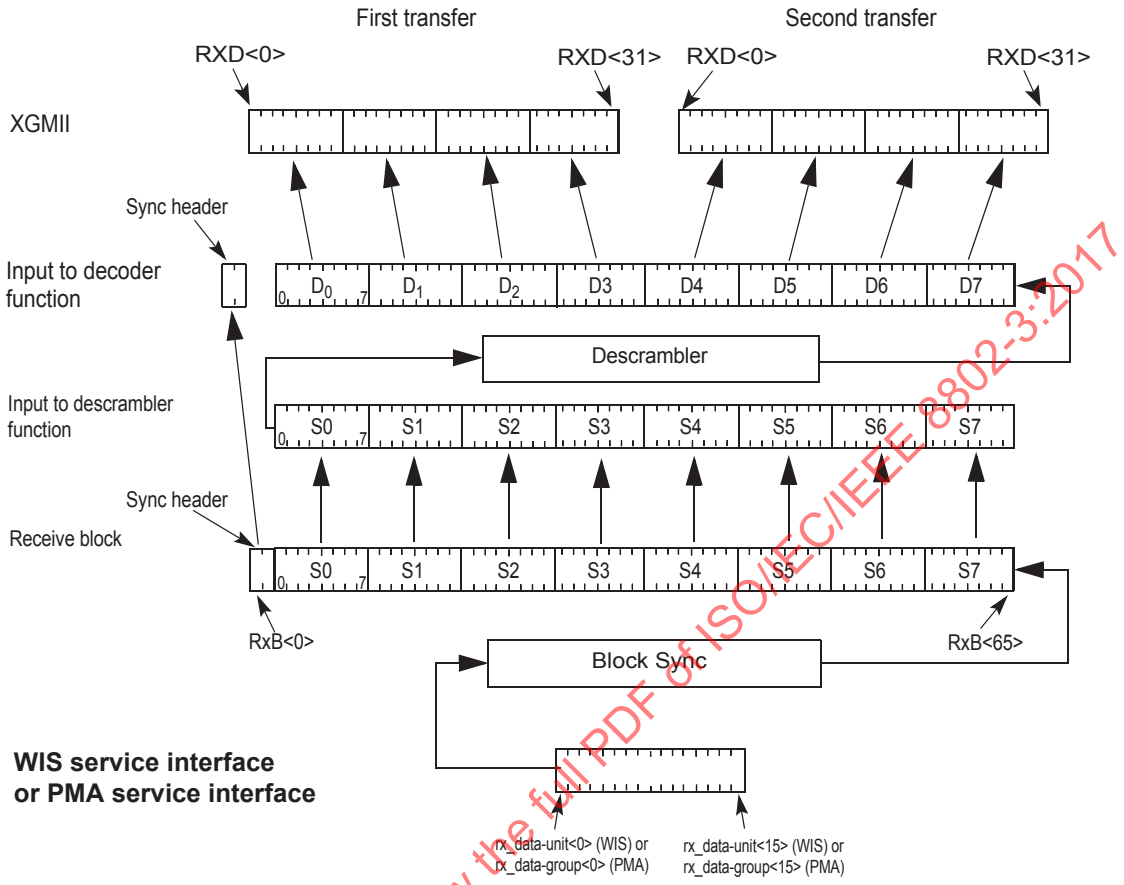

Figure 49–6—PCS Receive bit ordering

The format of the blocks is as shown in Figure 49–7. In the figure, the column labeled Input Data shows, in abbreviated form, the eight characters used to create the 66-bit block. These characters are either data characters or control characters and, when transferred across the XGMII interface, the corresponding TXC or RXC bit is set accordingly. Within the Input Data column, D_0 through D_7 are data octets and are transferred with the corresponding TXC or RXC bit set to zero. All other characters are control octets and are transferred with the corresponding TXC or RXC bit set to one. The single bit fields (thin rectangles with no label in the figure) are sent as zero and ignored upon receipt.

Bits and field positions are shown with the least significant bit on the left. Hexadecimal numbers are shown in normal hexadecimal. For example the block type field 0x1e is sent as 01111000 representing bits 2 through 9 of the 66 bit block. The least significant bit for each field is placed in the lowest numbered position of the field.

All unused values of block type field[7] are reserved.

[7]The block type field values have been chosen to have a 4-bit Hamming distance between them. The only unused value that maintains the Hamming distance is 0x00.

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49.2.4.4 Control codes

The same set of control characters are supported by the XGMII and the 10GBASE-R PCS. The representations of the control characters are the control codes. XGMII encodes a control character into an octet (an eight bit value). The 10GBASE-R PCS encodes the start and terminate control characters implicitly by the block type field. The 10GBASE-R PCS encodes the ordered set control codes using a combination of the block type field and a 4-bit O code for each ordered set. The 10GBASE-R PCS encodes each of the other control characters into a 7-bit C code.

The control characters and their mappings to 10GBASE-R control codes and XGMII control codes are specified in Table 49–1. All XGMII and 10GBASE-R control code values that do not appear in the table shall not be transmitted and shall be treated as an error if received. The ability to transmit or receive Low Power Idle (LPI) is required for PHYs that support EEE (see Clause 78). If EEE is not supported, LPI shall not be transmitted and shall be treated as an error if received.

Input Data	Sync	Block Payload							
Bit Position: / Data Block Format:	0 1	2							65
D_0 D_1 D_2 D_3/D_4 D_5 D_6 D_7	01	D_0	D_1	D_2	D_3	D_4	D_5	D_6	D_7
Control Block Formats:		**Block Type Field**							
C_0 C_1 C_2 C_3/C_4 C_5 C_6 C_7	10	0x1e	C_0	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_0 C_1 C_2 C_3/O_4 D_5 D_6 D_7	10	0x2d	C_0	C_1	C_2	C_3	O_4	D_5	D_6	D_7
C_0 C_1 C_2 C_3/S_4 D_5 D_6 D_7	10	0x33	C_0	C_1	C_2	C_3		D_5	D_6	D_7
O_0 D_1 D_2 D_3/S_4 D_5 D_6 D_7	10	0x66	D_1	D_2	D_3	O_0		D_5	D_6	D_7
O_0 D_1 D_2 D_3/O_4 D_5 D_6 D_7	10	0x55	D_1	D_2	D_3	O_0	O_4	D_5	D_6	D_7
S_0 D_1 D_2 D_3/D_4 D_5 D_6 D_7	10	0x78	D_1	D_2	D_3	D_4		D_5	D_6	D_7
O_0 D_1 D_2 D_3/C_4 C_5 C_6 C_7	10	0x4b	D_1	D_2	D_3	O_0	C_4	C_5	C_6	C_7
T_0 C_1 C_2 C_3/C_4 C_5 C_6 C_7	10	0x87		C_1	C_2	C_3	C_4	C_5	C_6	C_7
D_0 T_1 C_2 C_3/C_4 C_5 C_6 C_7	10	0x99	D_0		C_2	C_3	C_4	C_5	C_6	C_7
D_0 D_1 T_2 C_3/C_4 C_5 C_6 C_7	10	0xaa	D_0	D_1		C_3	C_4	C_5	C_6	C_7
D_0 D_1 D_2 T_3/C_4 C_5 C_6 C_7	10	0xb4	D_0	D_1	D_2		C_4	C_5	C_6	C_7
D_0 D_1 D_2 D_3/T_4 C_5 C_6 C_7	10	0xcc	D_0	D_1	D_2	D_3		C_5	C_6	C_7
D_0 D_1 D_2 D_3/D_4 T_5 C_6 C_7	10	0xd2	D_0	D_1	D_2	D_3	D_4		C_6	C_7
D_0 D_1 D_2 D_3/D_4 D_5 T_6 C_7	10	0xe1	D_0	D_1	D_2	D_3	D_4	D_5		C_7
D_0 D_1 D_2 D_3/D_4 D_5 D_6 T_7	10	0xff	D_0	D_1	D_2	D_3	D_4	D_5	D_6	

Figure 49–7—64B/66B block formats

49.2.4.5 Ordered sets

Ordered sets are used to extend the ability to send control and status information over the link such as remote fault and local fault status. Ordered sets consist of a control character followed by three data characters. Ordered sets always begin on the first octet of the XGMII. 10 Gigabit Ethernet uses one kind of ordered set: the sequence ordered set (see 46.3.4). The sequence ordered set control character is denoted /Q/. An

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additional ordered set, the signal ordered set, has been reserved and it begins with another control code. The 4-bit O field encodes the control code. See Table 49–1 for the mappings.

49.2.4.6 Valid and invalid blocks

A block is invalid if any of the following conditions exists:

a) The sync field has a value of 00 or 11.
b) The block type field contains a reserved value.
c) Any control character contains a value not in Table 49–1.
d) Any O code contains a value not in Table 49–1.
e) The set of eight XGMII characters does not have a corresponding block format in Figure 49–7.

49.2.4.7 Idle (/I/) and Low Power Idle (/LI/)

Idle control characters (/I/) are transmitted when idle control characters are received from the XGMII. Idle characters may be added or deleted by the PCS to adapt between clock rates. /I/ insertion and deletion shall occur in groups of 4. /I/s may be added following idle or ordered sets. They shall not be added while data is being received. When deleting /I/s, the first four characters after a /T/ shall not be deleted.

To communicate LPI, LPI control character /LI/ is sent continuously in place of /I/. LPI control characters are transmitted when LPI control characters are received from the XGMII. LPI characters may be added or deleted by the PCS to adapt between clock rates in a similar manner to idle control characters. /LI/ insertion and deletion shall occur in groups of four. /LI/s may only be added following other LPI characters.

Table 49–1—Control codes

Control character	Notation	XGMII Control Code	10GBASE-R Control Code	10GBASE-R O Code	8B/10B Code[a]
idle	/I/	0x07	0x00		K28.0 or K28.3 or K28.5
LPI	/LI/	0x06	0x06		K28.0 with D20.5 in one row or K28.3 or K28.5 with D20.5 in one row[b]
start	/S/	0xfb	Encoded by block type field		K27.7
terminate	/T/	0xfd	Encoded by block type field		K29.7
error	/E/	0xfe	0x1e		K30.7
Sequence ordered set	/Q/	0x9c	Encoded by block type field plus O code	0x0	K28.4
reserved0	/R/[c]	0x1c	0x2d		K28.0
reserved1		0x3c	0x33		K28.1
reserved2	/A/	0x7c	0x4b		K28.3
reserved3	/K/	0xbc	0x55		K28.5

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Table 49–1—Control codes *(continued)*

Control character	Notation	XGMII Control Code	10GBASE-R Control Code	10GBASE-R O Code	8B/10B Code[a]
reserved4		0xdc	0x66		K28.6
reserved5		0xf7	0x78		K23.7
Signal ordered set[d]	/Fsig/	0x5c	Encoded by block type field plus O code	0xF	K28.2

[a]For information only. The 8B/10B code is specified in Clause 36. Usage of the 8B/10B code for 10 Gb/s operation is specified in Clause 48.
[b]See 48.2.4.2.
[c]The codes for /A/, /K/, and /R/ are used on the XAUI interface to signal idle. They are not present on the XGMII when no errors have occurred, but certain bit errors cause the XGXS to send them on the XGMII.
[d]Reserved for INCITS T11 Fibre Channel use.

49.2.4.8 Start (/S/)

The start control character (/S/) indicates the start of a packet. This delimiter is only valid on the first octet of the XGMII (TXD<0:7> and RXD<0:7>). Receipt of an /S/ on any other octet of TxD indicates an error. Block type field values implicitly encode an /S/ as the fifth or first character of the block. These are the only characters of a block on which a start can occur.

49.2.4.9 Terminate (/T/)

The terminate control character (/T/) indicates the end of a packet. Since packets may be any length, the /T/ can occur on any octet of the XGMII interface and within any character of the block. The location of the /T/ in the block is implicitly encoded in the block type field. A valid end of packet occurs when a block containing a /T/ is followed by a control block that does not contain a /T/.

49.2.4.10 ordered set (/O/)

The ordered set control characters (/O/) indicate the start of an ordered set. There are two kinds of ordered sets: the sequence ordered set and the signal ordered set (which is reserved). When it is necessary to designate the control character for the sequence ordered set specifically, /Q/ will be used. /O/ is only valid on the first octet of the XGMII. Receipt of an /O/ on any other octet of TXD indicates an error. Block type field values implicitly encode an /O/ as the first or fifth character of the block. The 4-bit O code encodes the specific /O/ character for the ordered set.

Sequence ordered sets may be deleted by the PCS to adapt between clock rates. Such deletion shall only occur when two consecutive sequence ordered sets have been received and shall delete only one of the two. Only Idles may be inserted for clock compensation. Signal ordered sets are not deleted for clock compensation.

49.2.4.11 Error (/E/)

The /E/ is sent whenever an /E/ is received. It is also sent when invalid blocks are received. The /E/ allows physical sublayers such as the XGXS and PCS to propagate received errors. See R_BLOCK_TYPE and T_BLOCK_TYPE function definitions in 49.2.13.2.3 for further information.

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49.2.5 Transmit process

The transmit process generates blocks based upon the TXD<31:0> and TXC<3:0> signals received from the XGMII. Two XGMII data transfers are encoded into each block. It takes 4.125 PMA_UNITDATA or WIS_UNITDATA transfers to send a block of data. Therefore, if the PCS is connected to an XGMII and PMA sublayer where the ratio of their transfer rates is exactly 16:33, then the transmit process does not need to perform rate adaptation. Where the XGMII and PMA sublayer data rates are not synchronized to that ratio, the transmit process will need to insert idles, delete idles, or delete sequence ordered sets to adapt between the rates. The WIS data rate is always slower than the XGMII data rate and a PCS connected to a WIS must delete idles or sequence ordered sets to adapt between rates.

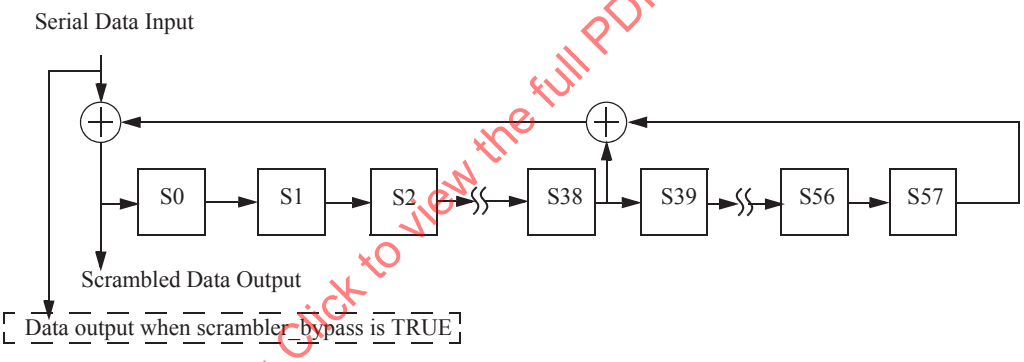
The transmit process generates blocks as specified in the transmit process state diagram. The contents of each block are contained in a vector tx_coded<65:0>, which is passed to the scrambler. tx_coded<1:0> contains the sync header and the remainder of the bits contain the block payload.

49.2.6 Scrambler

The payload of the block is scrambled with a self-synchronizing scrambler. The scrambler shall produce the same result as the implementation shown in Figure 49–8. This implements the scrambler polynomial:[8]

$$G(x) = 1 + x^{39} + x^{58} \tag{49–1}$$

There is no requirement on the initial value for the scrambler. The scrambler is run continuously on all payload bits. The sync header bits bypass the scrambler.



NOTE—Scrambler_bypass is only required to support EEE capability.

Figure 49–8—Scrambler

To aid block synchronization in the receiver for EEE capability when Clause 74 FEC is in use, when scrambler_bypass is TRUE the PCS shall pass the unscrambled data from the scrambler input rather than the scrambled data from the scrambler output. The scrambler shall continue to advance normally.

[8]The convention here, which considers the most recent bit into the scrambler to be the lowest order term, is consistent with most references and with other scramblers shown in this standard. Some references consider the most recent bit into the scrambler to be the highest order term and would therefore identify this as the inverse of the polynomial in Equation (49–1). In case of doubt, note that the conformance requirement is based on the representation of the scrambler in the figure rather than the polynomial equation.

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49.2.7 Gearbox

The gearbox adapts between the 66-bit width of the blocks and the 16-bit width of the PMA or WIS interface. It receives the 66-bit blocks. When the transmit channel is operating in normal mode, the gearbox sends 16 bits of transmit data at a time via WIS_UNITDATA.request or PMA_UNITDATA.request primitives. The UNITDATA.request primitives are fully packed with bits. For example, if one block happened to start with the sync header on bits 0 and 1 of a PMA_UNITDATA.request, then the last two bits of that block would be on bits 0 and 1 of a PMA_UNITDATA.request and the next block would begin with a sync header on bits 2 and 3 of that PMA_UNITDATA.request. When a PMA_UNITDATA.request or WIS_UNITDATA.request contains bits from two blocks, then the bits from the first block shall be placed in the lowest numbered bits of tx_data-group<15:0>. The bits shall be packed into the tx_data-group in sequence with the lowest numbered bit of the block going into the lowest numbered bit of the part of tx_data-group<15:0> bits containing bits from that block (see Figure 49–5).

The gearbox functionality is necessary when the optional PMA compatibility interface, XSBI, is implemented since that interface passes data over a 16-bit wide path. It is also necessary when connecting to a WIS since the WIS processes the data stream with 8-bit granularity. When neither the WIS nor the XSBI is implemented, the internal data-path width between the PCS and PMA is an implementation choice. Depending on the path width, the gearbox functionality may not be necessary.

49.2.8 Test-pattern generators

When the transmit channel is operating in test-pattern mode, it sends 16 bits of test pattern at a time via PMA_UNITDATA.request primitives. When the PCS allows direct connection to the PMA, the test-pattern generator shall be implemented. The test-pattern generator does not apply to a PCS, which only supports connection to the WIS. A PCS which supports both WIS and direct PMA attachment may reject or allow an attempt to activate a transmit test-pattern mode when a WIS is attached.

There are two types of required transmit test patterns: square wave and pseudo-random. The square wave pattern is intended to aid in conducting certain transmitter tests. It is not intended for receiver tests and the receiver is not expected to receive this test pattern. The pseudo-random test-pattern mode is suitable for receiver tests and for certain transmitter tests. There is an optional PRBS9 transmit test pattern that may be used for some transmitter tests. There is also an optional PRBS31 test pattern, which may be used for some transmit and receiver tests. When this option is supported, both the PRBS31 test-pattern generator and the PRBS31 test-pattern checker shall be provided. See 52.9 and 68.6 for recommendations on the appropriate pattern for tests.

When square wave pattern is selected, the PCS will send a repeating pattern of n ones followed by n zeros where n may be any number between 4 and 11 inclusive. The value of n is an implementation choice.

When pseudo-random pattern is selected, the test pattern is generated by the scrambler using the seeds loaded through the MDIO registers and the selected data pattern. The scrambler is loaded with a seed or its inverse at the start of a block every 128 blocks. The seeds are loaded in the following pattern:

Seed A
Seed A Invert
Seed B
Seed B Invert

Invert indicates that the seed is inverted for that load. Either 64 zeros or the 64-bit encoding for two Local Fault ordered sets can be selected as the data pattern. After loading Seed A or Seed B, the scrambler input shall be driven with the data pattern. After loading Seed A Invert or Seed B Invert, the scrambler input shall be driven with the inverse of the data pattern. While in pseudo-random test-pattern mode, the sync headers will be the control sync header, 10. Thus the pseudo-random test pattern is a series of blocks with the control

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sync header and a pseudo-random payload. The characteristics of the pseudo-random test pattern can be varied by varying the seed values and data input.

When the optional PRBS31 mode is selected, the PRBS31 pattern generator sends 16 bits of PRBS31 test pattern at a time via PMA_UNITDATA.request primitives. The PRBS31 test pattern is the output of a Pseudo-Random Bit Sequence of order 31 (PRBS31) generator. The PRBS31 pattern generator shall produce the same result as the implementation shown in Figure 49–9. This implements the inverted version of the bit stream produced by the polynomial shown in Equation (49–2):[9]

$$G(x) = 1 + x^{28} + x^{31} \tag{49–2}$$

The initial value of the PRBS31 pattern generator shall not be all zeros. It may be any other value.

The optional PRBS9 pattern is defined in Table 68–6.

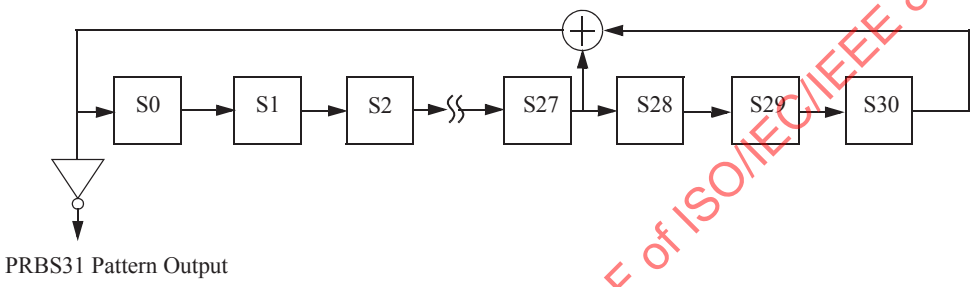

Figure 49–9—PRBS31 pattern generator

49.2.9 Block synchronization

When the receive channel is operating in normal mode, the block synchronization function receives data via 16-bit PMA_UNITDATA.request or WIS_UNITDATA.request primitives. It shall form a bit stream from the primitives by concatenating requests with the bits of each primitive in order from rx_data-group<0> to rx_data-group<15> (see Figure 49–6). It obtains lock to the 66-bit blocks in the bit stream using the sync headers and outputs 66-bit blocks. Lock is obtained as specified in the block lock state diagram shown in Figure 49–14.

If EEE is not supported then block_lock is identical to rx_block_lock. Otherwise the relationship between block_lock and rx_block_lock is given by Figure 49–13.

49.2.10 Descrambler

The descrambler processes the payload to reverse the effect of the scrambler using the same polynomial. It shall produce the same result as the implementation shown in Figure 49–10.

49.2.11 Receive process

The receive process decodes blocks to produce RXD<31:0> and RXC<3:0> for transmission to the XGMII. Two XGMII data transfers are decoded from each block. Where the XGMII and PMA sublayer data rates are not synchronized to a 16:33 ratio, the receive process will insert idles, delete idles, or delete sequence

[9]The convention here, which considers the most recent bit into the PRBS generator to be the lowest order term, is consistant with most references and with other scramblers shown in this standard. Some references consider the most recent bit into the PRBS generator to be the highest order term and would therefore identify this as the inverse of the polynomial in Equation (49–2). In case of doubt, note that the conformance requirement is based on the representation in the figure rather than the polynomial equation.

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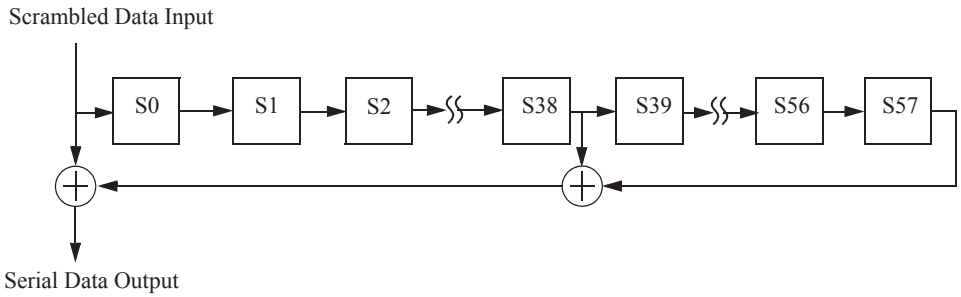

Figure 49–10—Descrambler

ordered sets to adapt between rates. The WIS data rate is always slower than the XGMII data rate and a PCS connected to a WIS will insert idles to adapt between the rates.

The receive process decodes blocks as specified in the receive state diagram shown in Figure 49–17.

49.2.12 Test-pattern checker

When the PCS allows direct connection to the PMA, the pseudo-random test-pattern checker shall be implemented. The pseudo-random test-pattern checker does not apply to a PCS, which only supports connection to the WIS. When the PRBS31 test-pattern option is supported, the PRBS31 receive test-pattern checker shall be implemented. A PCS that supports both WIS and direct PMA attachment may reject or allow an attempt to activate a receive test-pattern mode when a WIS is attached.

When the receive channel is operating in pseudo-random test-pattern mode, the pseudo-random test-pattern checker checks the bits received via PMA_UNITDATA.indication primitives.

The pseudo-random test-pattern checker utilizes the lock state diagram and the descrambler operating as they do during normal data reception. The hi_ber state diagram is disabled during receive test-pattern mode. When block_lock is true and the pseudo-random receive test-pattern mode is active, the pseudo-random test-pattern checker observes the output from the descrambler. When the output of the descrambler is the data pattern or its inverse, a match is detected. Since the transmitter's scrambler is loaded with a seed value every 128 blocks and the receiver's descrambler is running normally, a mismatch will be detected once every 128 blocks in the absence of errors. The pseudo-random test-pattern checker will count 128-block windows. When operating in pseudo-random test pattern, the test-pattern error counter counts blocks with a mismatch corrected to remove the effect of loading a new seed. The first block with a mismatch in a window shall not increment the test-pattern error counter. Any subsequent block with a mismatch in a window indicates an error and shall increment the test-pattern error counter.

When the receive channel is operating in PRBS31 test mode, the PRBS31 pattern checker checks the bits received in PMA_UNITDATA.indication primitives relative to the PRBS31 test pattern.

The PRBS31 pattern error checker is self-synchronizing. It compares each bit received to the result of the PRBS31 generator based on the prior 31 bits received. It shall produce the same result as the implementation shown in Figure 49–11. When no errors occur, the PRBS31 pattern error signal will be zero. When an isolated bit error occurs, it will cause the PRBS31 pattern error signal to go high three times; once when it is

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received and once when it is at each tap. The test-pattern error counter shall increment once for each bit time that the PRBS31 pattern error signal is high.

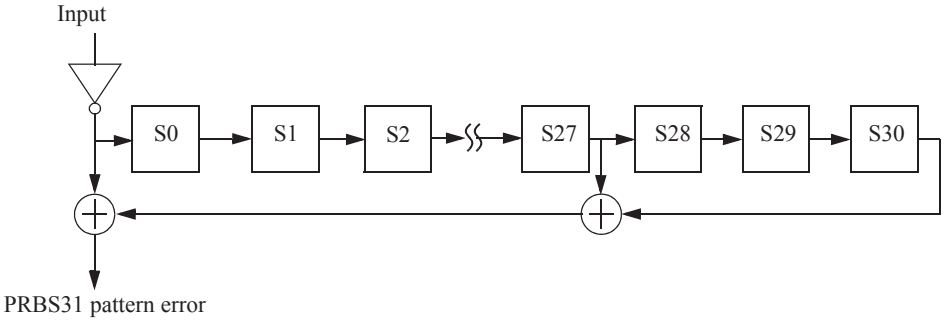

Figure 49–11—PRBS31 pattern checker

Note that the test-pattern error counter behavior is dependent on the test-pattern mode. In pseudo-random test mode, it is counting block errors. In PRBS31 test mode, it is counting bit errors at the PRBS31 pattern checker output.

49.2.13 Detailed functions and state diagrams

49.2.13.1 State diagram conventions

The body of this subclause is comprised of state diagrams, including the associated definitions of variables, constants, and functions. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

The notation used in the state diagrams follows the conventions of 21.5. State diagram timers follow the conventions of 14.2.3.2. The notation ++ after a counter or integer variable indicates that its value is to be incremented.

49.2.13.2 State variables

49.2.13.2.1 Constants

EBLOCK_R<71:0>
: 72 bit vector to be sent to the XGMII interface containing /E/ in all the eight character locations.

EBLOCK_T<65:0>
: 66 bit vector to be sent to the PMA containing /E/ in all the eight character locations.

LBLOCK_R<71:0>
: 72 bit vector to be sent to the XGMII interface containing two Local Fault ordered sets. The Local Fault ordered set is defined in 46.3.4.

LBLOCK_T<65:0>
: 66 bit vector to be sent to the PMA containing two Local Fault ordered sets.

49.2.13.2.2 Variables

ber_test_sh
: Boolean variable that is set true when a new sync header is available for testing and false when BER_TEST_SH state is entered. A new sync header is available for testing when the Block Sync process has accumulated enough bits from the PMA or the WIS to evaluate the header of the next block

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block_lock
: Boolean variable that is set true when receiver acquires block delineation

NOTE—If the EEE capability is supported, then this variable is affected by the LPI receive state diagram. If the EEE capability is not supported then this variable is identical to rx_block_lock controlled by the lock state diagram.

hi_ber
: Boolean variable which is asserted true when the ber_cnt exceeds 16 indicating a bit error ratio $>10^{-4}$

reset
: Boolean variable that controls the resetting of the PCS. It is true whenever a reset is necessary including when reset is initiated from the MDIO, during power on, and when the MDIO has put the PCS into low-power mode.

r_test_mode
: Boolean variable that is asserted true when the receiver is in test-pattern mode.

rx_block_lock
: Variable used by the lock state diagram to reflect the status of the code-group delineation. This variable is set TRUE when the receiver acquires block delineation.

rx_coded<65:0>
: Vector containing the input to the 64B/66B decoder. The format for this vector is shown in Figure 49–7. The leftmost bit in the figure is rx_coded<0> and the rightmost bit is rx_coded<65>.

rx_raw<71:0>
: Vector containing two successive XGMII transfers. RXC<0> through RXC<3> for the first transfer are placed in rx_raw<0> through rx_raw<3>, respectively. RXC<0> through RXC<3> for the second transfer are placed in rx_raw<4> through rx_raw<7>, respectively. RXD<0> through RXD<31> for the first transfer are placed in rx_raw<8> through rx_raw<39>, respectively. RXD<0> through RXD<31> for the second transfer are placed in rx_raw<40> through rx_raw<71>, respectively.

sh_valid
: Boolean indication that is set true if received block rx_coded has valid sync header bits. That is, sh_valid is asserted if rx_coded<0> ≠ rx_coded<1> and de-asserted otherwise.

signal_ok
: Boolean variable that is set based on the most recently received value of PMA_SIGNAL.indication(SIGNAL_OK) or WIS_SIGNAL.indication(SIGNAL_OK). It is true if the value was OK and false if the value was FAIL.

slip_done
: Boolean variable that is asserted true when the SLIP requested by the Block Lock state diagram has been completed indicating that the next candidate block sync position can be tested.

test_sh
: Boolean variable that is set true when a new sync header is available for testing and false when TEST_SH state is entered. A new sync header is available for testing when the Block Sync process has accumulated enough bits from the PMA or the WIS to evaluate the header of the next block

tx_coded<65:0>
: Vector containing the output from the 64B/66B encoder. The format for this vector is shown in Figure 49–7. The leftmost bit in the figure is tx_coded<0> and the rightmost bit is tx_coded<65>.

tx_raw<71:0>
: Vector containing two successive XGMII transfers. TXC<0> through TXC<3> for the first transfer are placed in tx_raw<0> through tx_raw<3>, respectively. TXC<0> through TXC<3> for the second transfer are placed in tx_raw<4> through tx_raw<7>, respectively. TXD<0> through TXD<31> for the first transfer are placed in tx_raw<8> through tx_raw<39>, respectively. TXD<0> through TXD<31> for the second transfer are placed in tx_raw<40> through tx_raw<71>, respectively.

The following variables are used only for the EEE capability:

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energy_detect
: A Boolean variable sent from the PMD that is set to TRUE when signal energy is detected at the receiver and is set to FALSE otherwise

rx_lpi_active
: A Boolean variable that is set to TRUE when the receiver is in a low power state and set to FALSE when it is in an active state and capable of receiving data.

rx_mode
: A variable set to QUIET while the receiver is in the RX_QUIET state and set to DATA otherwise

tx_mode
: A variable set to QUIET when the transmitter is in the TX_QUIET state, set to ALERT when the transmitter is in the TX_ALERT state, and set to DATA otherwise. When set to QUIET, the PMD disables the transmitter as described in 72.6.5. When set to ALERT, the PMD transmits a repeating pattern of eight ones and eight zeroes as described in 72.6.2. When set to DATA the PMD passes data as normal.

scrambler_bypass
: This Boolean variable is used to bypass the Tx PCS scrambler in order to assist rapid synchronization following low power idle. When set to TRUE, the PCS will pass the unscrambled data from the scrambler input rather than the scrambled data from the scrambler output. The scrambler will continue to operate normally, shifting input data into the delay line. When scrambler_bypass is set to FALSE the PCS will pass scrambled data from the scrambler output.

scr_bypass_enable
: A Boolean variable used to indicate to the transmit LPI state diagram that the scrambler bypass option is required. The PHY shall set scr_bypass_enable = TRUE if Clause 74 FEC is in use. The PHY shall set scr_bypass_enable = FALSE if this FEC is not in use.

49.2.13.2.3 Functions

DECODE(rx_coded<65:0>)
: Decodes the 66-bit vector returning rx_raw<71:0> that is sent to the XGMII. The DECODE function shall decode the block as specified in 49.2.4.

ENCODE(tx_raw<71:0>)
: Encodes the 72-bit vector returning tx_coded<65:0> of which tx_coded<63:0> is sent to the scrambler. The two high order sync bits bypass the scrambler. The ENCODE function shall encode the block as specified in 49.2.4.

R_BLOCK_TYPE = {C, S, T, D, E, LI}
: This function classifies each 66-bit rx_coded vector as belonging to one of the following types depending on its contents.

  Values: C; The vector contains a sync header of 10 and one of the following:
  a) A block type field of 0x1e and eight valid control characters other than /E/; and, if the EEE capability is supported, zero or four of the characters are /LI/;
  b) A block type field of 0x2d or 0x4b, a valid O code, and four valid control characters;
  c) A block type field of 0x55 and two valid O codes.

  LI; For EEE capability, the LI type is supported where the vector contains a sync header of 10, a block type field of 0x1e, and eight control characters of 0x06 (/LI/).

  S; The vector contains a sync header of 10 and one of the following:
  a) A block type field of 0x33 and four valid control characters;
  b) A block type field of 0x66 and a valid O code;
  c) A block type field of 0x78.

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T; The vector contains a sync header of 10, a block type field of 0x87, 0x99, 0xaa, 0xb4, 0xcc, 0xd2, 0xe1 or 0xff and all control characters are valid.
D; The vector contains a sync header of 01.
E; The vector does not meet the criteria for any other value.

A valid control character is one containing a 10GBASE-R control code specified in Table 49–1. A valid O code is one containing an O code specified in Table 49–1.
NOTE—A PCS that does not support EEE classifies vectors containing one or more /LI/ control characters as type E.

R_TYPE(rx_coded<65:0>)
Returns the R_BLOCK_TYPE of the rx_coded<65:0> bit vector.

R_TYPE_NEXT
Prescient end of packet check function. It returns the R_BLOCK_TYPE of the rx_coded vector immediately following the current rx_coded vector.

SLIP
Causes the next candidate block sync position to be tested. The precise method for determining the next candidate block sync position is not specified and is implementation dependent. However, an implementation shall ensure that all possible bit positions are evaluated.

T_BLOCK_TYPE = {C, S, T, D, E, LI}
This function classifies each 72-bit tx_raw vector as belonging to one of the following types depending on its contents.

Values: C; The vector contains one of the following:
a) eight valid control characters other than /O/, /S/, /T/ and /E/; and, if the EEE capability is supported, zero or four of the characters are /LI/;
b) one valid ordered set and four valid control characters other than /O/, /S/ and /T/;
c) two valid ordered sets.
LI; For EEE capability, this vector contains eight /LI/ characters.
S; The vector contains an /S/ in its first or fifth character, any characters before the S character are valid control characters other than /O/, /S/ and /T/ or form a valid ordered set, and all characters following the /S/ are data characters.
T; The vector contains a /T/ in one of its characters, all characters before the /T/ are data characters, and all characters following the /T/ are valid control characters other than /O/, /S/ and /T/.
D; The vector contains eight data characters.
E; The vector does not meet the criteria for any other value.

A tx_raw character is a control character if its associated TXC bit is asserted. A valid control character is one containing an XGMII control code specified in Table 49–1. A valid ordered set consists of a valid /O/ character in the first or fifth characters and data characters in the three characters following the /O/. A valid /O/ is any character with a value for O code in Table 49–1.
NOTE—A PCS that does not support EEE, classifies vectors containing one or more /LI/ control characters as type E.

T_TYPE(tx_raw<71:0>)
Returns the T_BLOCK_TYPE of the tx_raw<71:0> bit vector.

49.2.13.2.4 Counters

ber_cnt
Count up to a maximum of 16 of the number of invalid sync headers within the current 125 μs period.

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sh_cnt
: Count of the number of sync headers checked within the current 64 block window.

sh_invalid_cnt
: Count of the number of invalid sync headers within the current 64 block window.

The following counter is used only for the EEE capability.

wake_error_counter
: A counter that is incremented each time that the LPI receive state diagram enters the RX_WTF state indicating that a wake time fault has been detected. The counter is reflected in register 3.22 (see 45.2.3.10).

49.2.13.2.5 Timers

State diagram timers follow the conventions of 14.2.3.2.

125us_timer
: Timer that is triggered every 125 µs +1%, –25%.

The following timers are used only for the EEE capability:

one_us_timer
: A timer used to count approximately 1 µs intervals. The timer terminal count is set to T_{1U}. When the timer reaches terminal count it will set the one_us_timer_done = TRUE.

rx_tq_timer
: This timer is started when the PCS receiver enters the RX_SLEEP state. The timer terminal count is set to T_{QR}. When the timer reaches terminal count it will set the rx_tq_timer_done = TRUE.

rx_tw_timer
: This timer is started when the PCS receiver enters the RX_WAKE state. The timer terminal count shall be set to a value no larger than the maximum value given for T_{WR} in Table 49–3. When the timer reaches terminal count it will set the rx_tw_timer_done = TRUE.

rx_wf_timer
: This timer is started when the PCS receiver enters the RX_WTF state, indicating that the receiver has encountered a wake time fault. The rx_wf_timer allows the receiver an additional period in which to synchronize or return to the QUIET state before a link failure is indicated. The timer terminal count is set to T_{WTF}. When the timer reaches terminal count it will set the rx_wf_timer_done = TRUE.

tx_ts_timer
: This timer is started when the PCS transmitter enters the TX_SLEEP state. The timer terminal count is set to T_{SL}. When the timer reaches terminal count it will set the tx_ts_timer_done = TRUE.

tx_tq_timer
: This timer is started when the PCS transmitter enters the TX_QUIET state. The timer terminal count is set to T_{QL}. When the timer reaches terminal count it will set the tx_tq_timer_done = TRUE.

tx_tw_timer
: This timer is started when the PCS transmitter enters the TX_WAKE state. The timer terminal count is set to T_{WL}. When the timer reaches terminal count it will set the tx_tw_timer_done = TRUE.

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49.2.13.3 State diagrams

The Lock state diagram shown in Figure 49–14 determines when the PCS has obtained lock to the received data stream. The BER Monitor state diagram shown in Figure 49–15 monitors the received signal for high bit error ratio.

The Transmit state diagram shown in Figure 49–16 controls the encoding of transmitted blocks. It makes exactly one transition for each transmit block processed. Though the Transmit state diagram sends Local Fault ordered sets when reset is asserted, the scrambler and gearbox may not be operational during reset. Thus, the Local Fault ordered sets may not appear on the WIS or PMA service interface.

The Receive state diagram shown in Figure 49–17 controls the decoding of received blocks. It makes exactly one transition for each receive block processed.

The PCS shall perform the functions of Lock, BER Monitor, Transmit, and Receive as specified in these state diagrams, including the optional EEE capability if implemented.

49.2.13.3.1 LPI state diagrams

A PCS that supports the EEE capability shall implement the LPI transmit and receive processes as shown in Figure 49–12 and Figure 49–13. The transmit LPI state diagram controls tx_mode, which disables the transmitter when it is set to QUIET. The receive LPI state diagram controls block_lock during LPI and signals the end of LPI to the receive state diagram.

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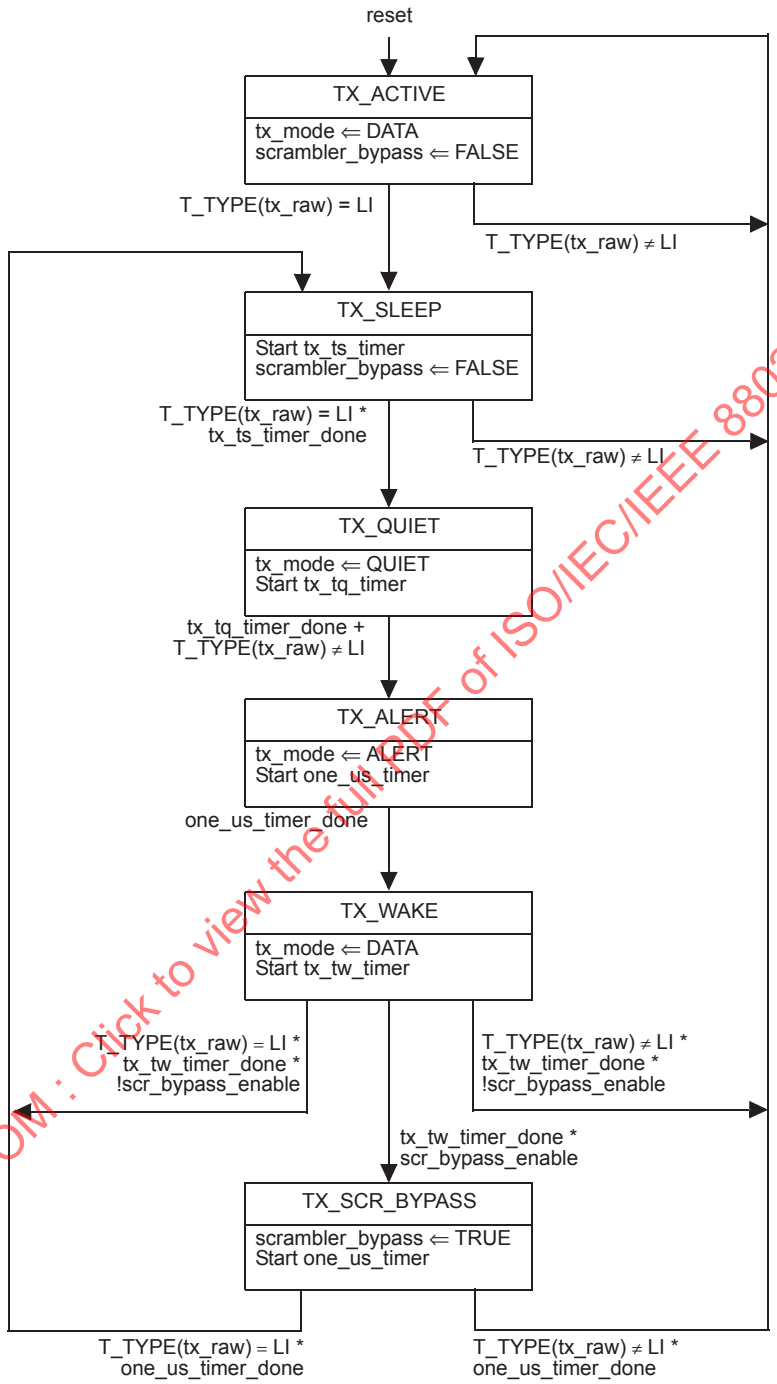

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Figure 49–12—LPI Transmit state diagram

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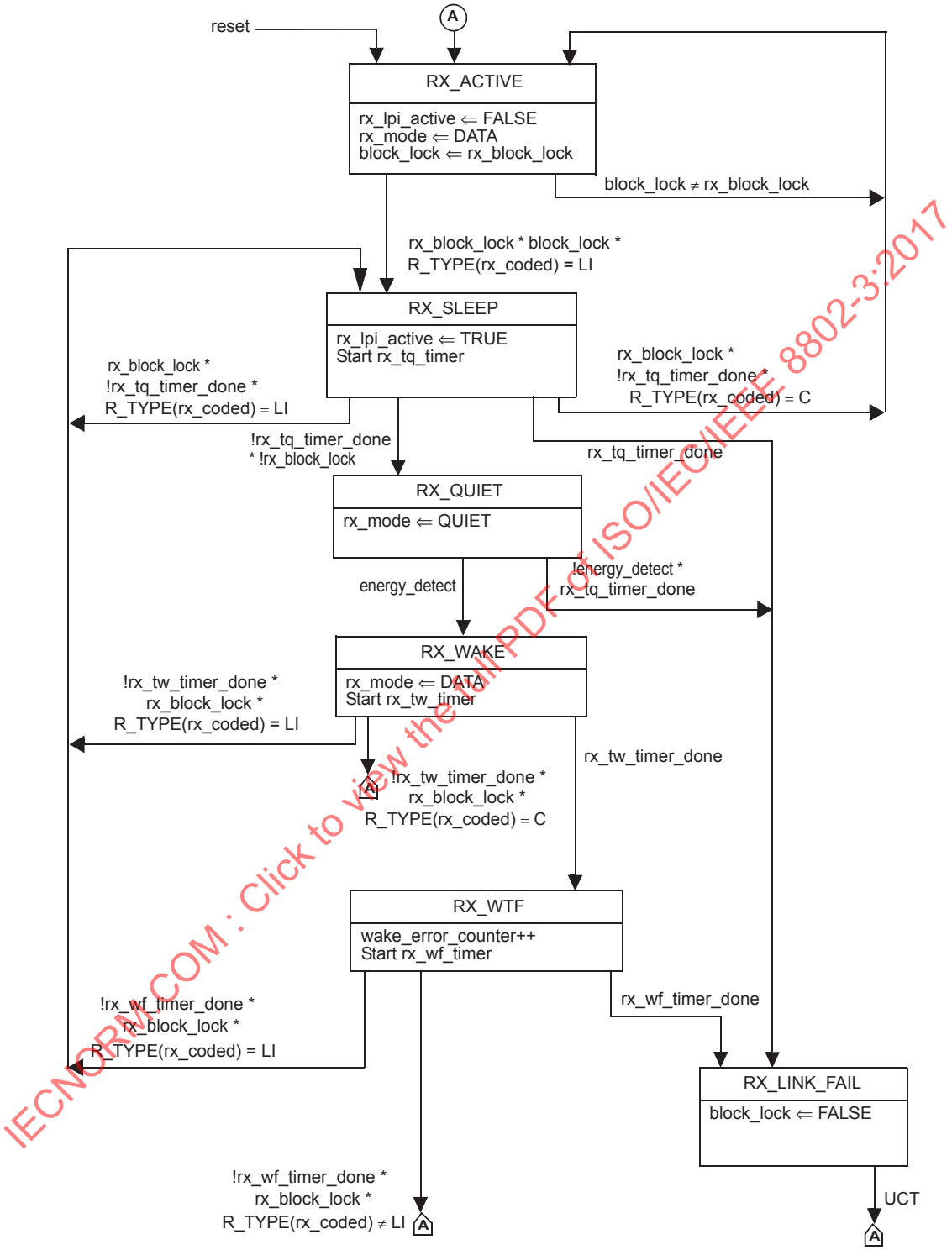

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Figure 49–13—LPI Receive state diagram

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Following a period of LPI, the receiver is required to achieve block synchronization within the wake-up time specified (see Figure 49–13). The implementation of the block synchronization state diagram should use techniques to ensure that block lock is achieved with minimal numbers of slip attempts. When the Clause 74 FEC is enabled, the receiver may use the knowledge that the link partner's transmitter will bypass the scrambler as part of the wake sequence. The idle sequence following this event will form a fixed pattern for the duration of the wake period.

The LPI functions shall use timer values for these state diagrams as shown in Table 49–2 for transmit and Table 49–3 for receive.

Table 49–2—Transmitter LPI timing parameters

Parameter	Description	Min	Max	Units
T_{SL}	Local Sleep Time from entering the TX_SLEEP state to when tx_mode is set to QUIET	4.9	5.1	µs
T_{QL}	Local Quiet Time from when tx_mode is set to QUIET to entry into the TX_ALERT state	1.7	1.8	ms
T_{WL}	Time spent in the TX_WAKE state	10.9	11.1	µs
T_{1U}	Time spent in the TX_ALERT and TX_SCR_BYPASS states	1.1	1.3	µs

Table 49–3—Receiver LPI timing parameters

Parameter	Description	Min	Max	Units
T_{QR}	The time the receiver waits for energy_detect to be set to TRUE while in the RX_SLEEP and RX_QUIET states before asserting receive fault	2	3	ms
T_{WR}	Time the receiver waits in the RX_WAKE state before indicating a wake time fault (when scr_bypass_enable = FALSE)	—	11.5	µs
T_{WR}	Time the receiver waits in the RX_WAKE state before indicating a wake time fault (when scr_bypass_enable = TRUE)	—	13.7	µs
T_{WTF}	Wake time fault recovery time	—	10	ms

49.2.14 PCS Management

The following objects apply to PCS management. If an MDIO Interface is provided (see Clause 45), they are accessed via that interface. If not, it is recommended that an equivalent access be provided.

49.2.14.1 Status

PCS_status:

Indicates whether the PCS is in a fully operational state. It is only true if block_lock is true and hi_ber is false. This status is reflected in MDIO register 3.32.12. A latch low view of this status is reflected in MDIO register 3.1.2 and a latch high of the inverse of this status, Receive fault, is reflected in MDIO register 3.8.10.

block_lock:

Indicates the state of the block_lock variable. This status is reflected in MDIO register 3.32.0. A latch low view of this status is reflected in MDIO register 3.33.15.

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hi_ber:
: Indicates the state of the hi_ber variable. This status is reflected in MDIO register 3.32.1. A latch high view of this status is reflected in MDIO register 3.33.14.

Rx LPI indication:
: For EEE capability, this variable indicates the current state of the receive LPI function. This flag is set to TRUE (register bit set to one) when the LPI receive state diagram is in any state other than RX_ACTIVE. This status is reflected in MDIO register 3.1.8. A latch high view of this status is reflected in MDIO register 3.1.10 (Rx LPI received).

Tx LPI indication:
: For EEE capability, this variable indicates the current state of the transmit LPI function. This flag is set to TRUE (register bit set to one) when the LPI transmit state diagram is in any state other than TX_ACTIVE. This status is reflected in MDIO register 3.1.9. A latch high view of this status is reflected in MDIO register 3.1.11 (Tx LPI received).

49.2.14.2 Counters

The following counters are reset to zero upon read and upon reset of the PCS. When they reach all ones, they stop counting. Their purpose is to help monitor the quality of the link.

ber_count:
: 6-bit counter that counts each time BER_BAD_SH state is entered. This counter is reflected in MDIO register bits 3.33.13:8. Note that this counter counts a maximum of 16 counts per 125 µs since the BER_BAD_SH can be entered a maximum of 16 times per 125 µs window.

errored_block_count:
: 8-bit counter. When the receiver is in normal mode, errored_block_count counts once for each time RX_E state is entered. This counter is reflected in MDIO register bits 3.33.7:0.

test_pattern_error_count:
: 16-bit counter. When the receiver is in test-pattern mode, the test_pattern_error_count counts errors as described in 49.2.12. This counter is reflected in MDIO register bits 3.43.15:0.

49.2.14.3 Test mode control

tx_test_mode:
: Boolean variable controlling transmit channel operating mode. When false, the transmit channel operates in normal mode. When true, the transmit channel operates in test-pattern mode.

rx_test_mode:
: Boolean variable controlling receive channel operating mode. When false, the receive channel operates in normal mode. When true, the receive channel operates in test-pattern mode.

49.2.14.4 Loopback

The PCS shall be placed in Loopback mode when the Loopback bit in MDIO register 3.0.14 is set to a logic one. In this mode, the PCS shall accept data on the transmit path from the XGMII and return it on the receive path to the XGMII. In addition, the PCS shall transmit a continuous stream of 0x00FF data words to the PMA or WIS sublayer, and shall ignore all data presented to it by the PMA or WIS sublayer.

49.2.15 Delay constraints

Predictable operation of the MAC Control PAUSE operation (Clause 31, Annex 31B) demands that there be an upper bound on the propagation delays through the network. This implies that MAC, MAC Control sublayer, and PHY implementers must conform to certain delay maxima, and that network planners and

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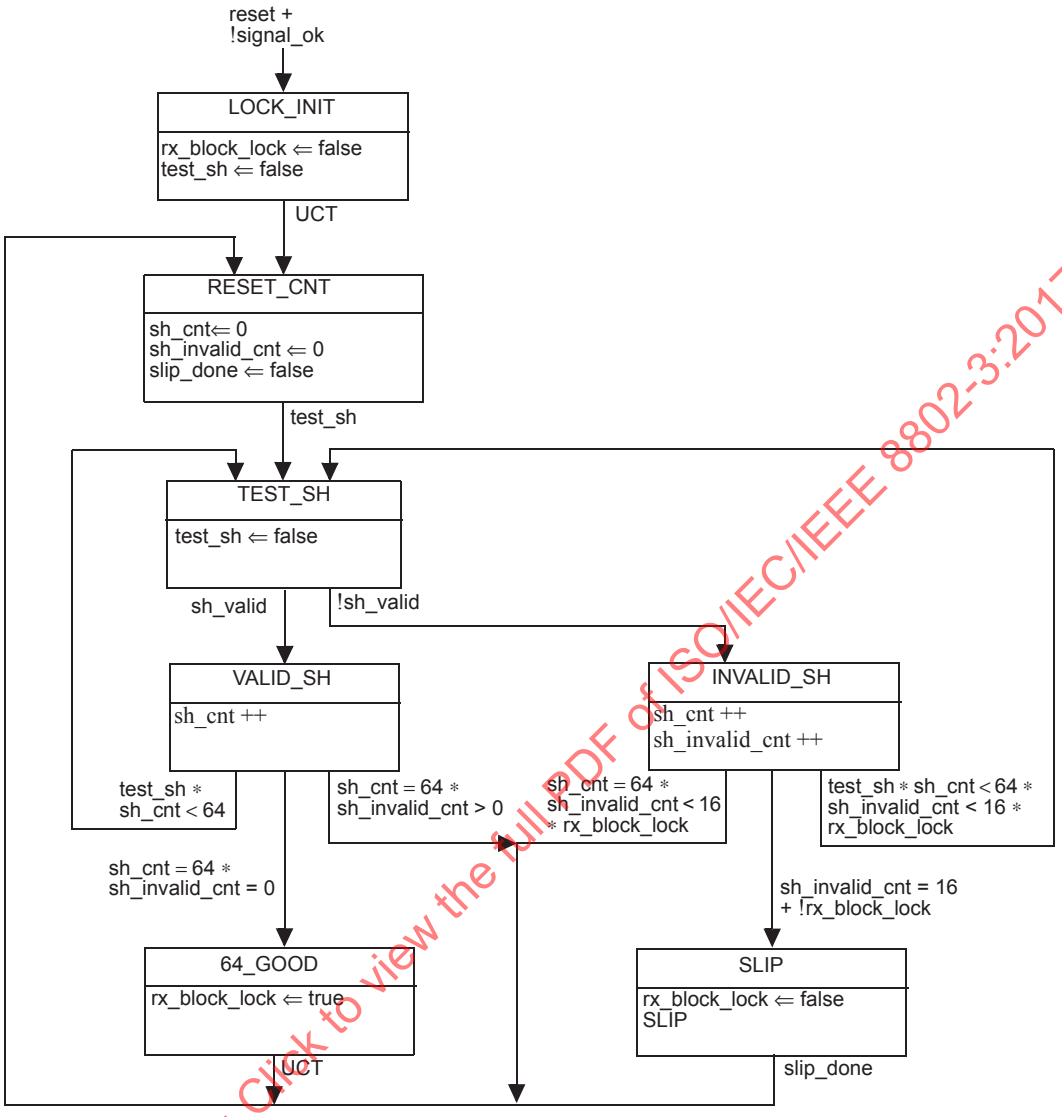

Figure 49–14—Lock state diagram

administrators conform to constraints regarding the cable topology and concatenation of devices. The sum of transmit and receive delay contributed by the 10GBASE-R PCS shall be no more than 3584 BT.

49.2.16 Auto-Negotiation for Backplane Ethernet

The following requirements apply to a PCS used with a 10GBASE-KR PMD. Support for the Auto-Negotiation process defined in Clause 73 is mandatory. The PCS shall support the primitive AN_LINK.indication(link_status) (see 73.9). The parameter link_status shall take the value FAIL when PCS_status=false and the value OK when PCS_status=true. The primitive shall be generated when the value of link_status changes.

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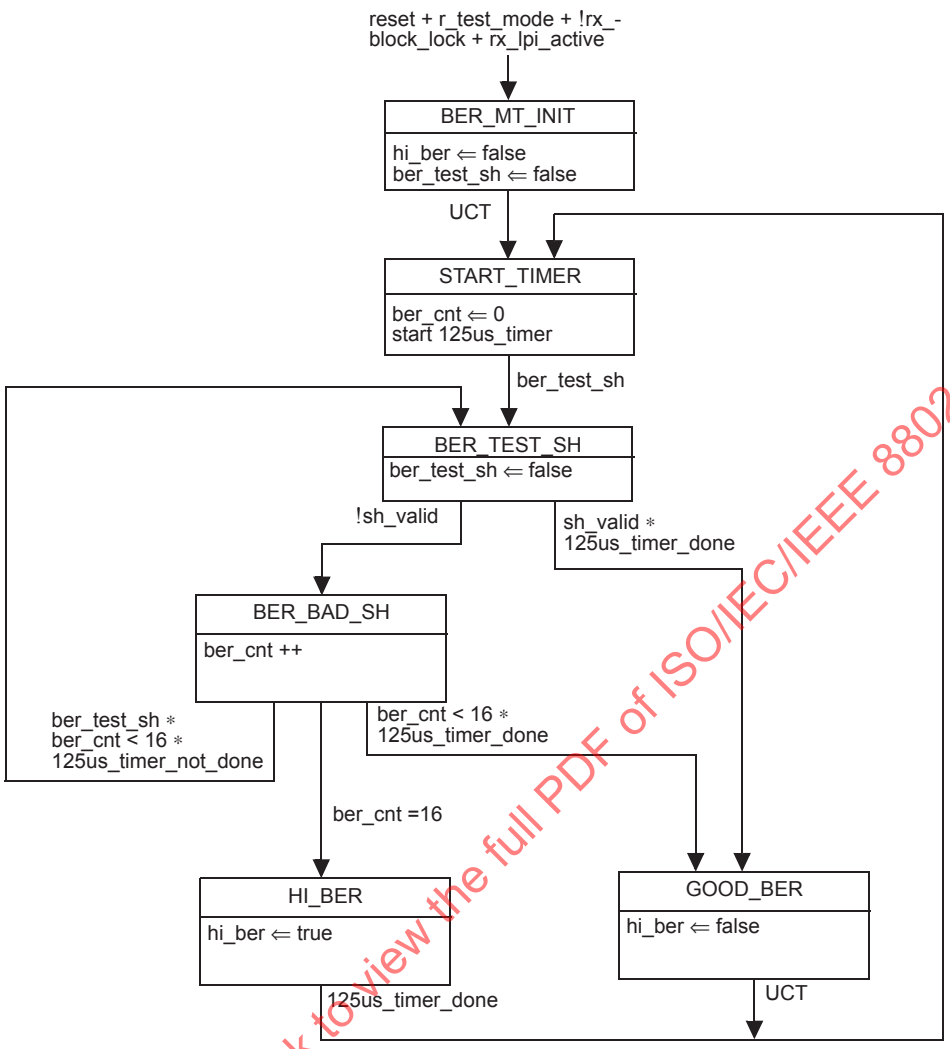

Figure 49–15—BER monitor state diagram

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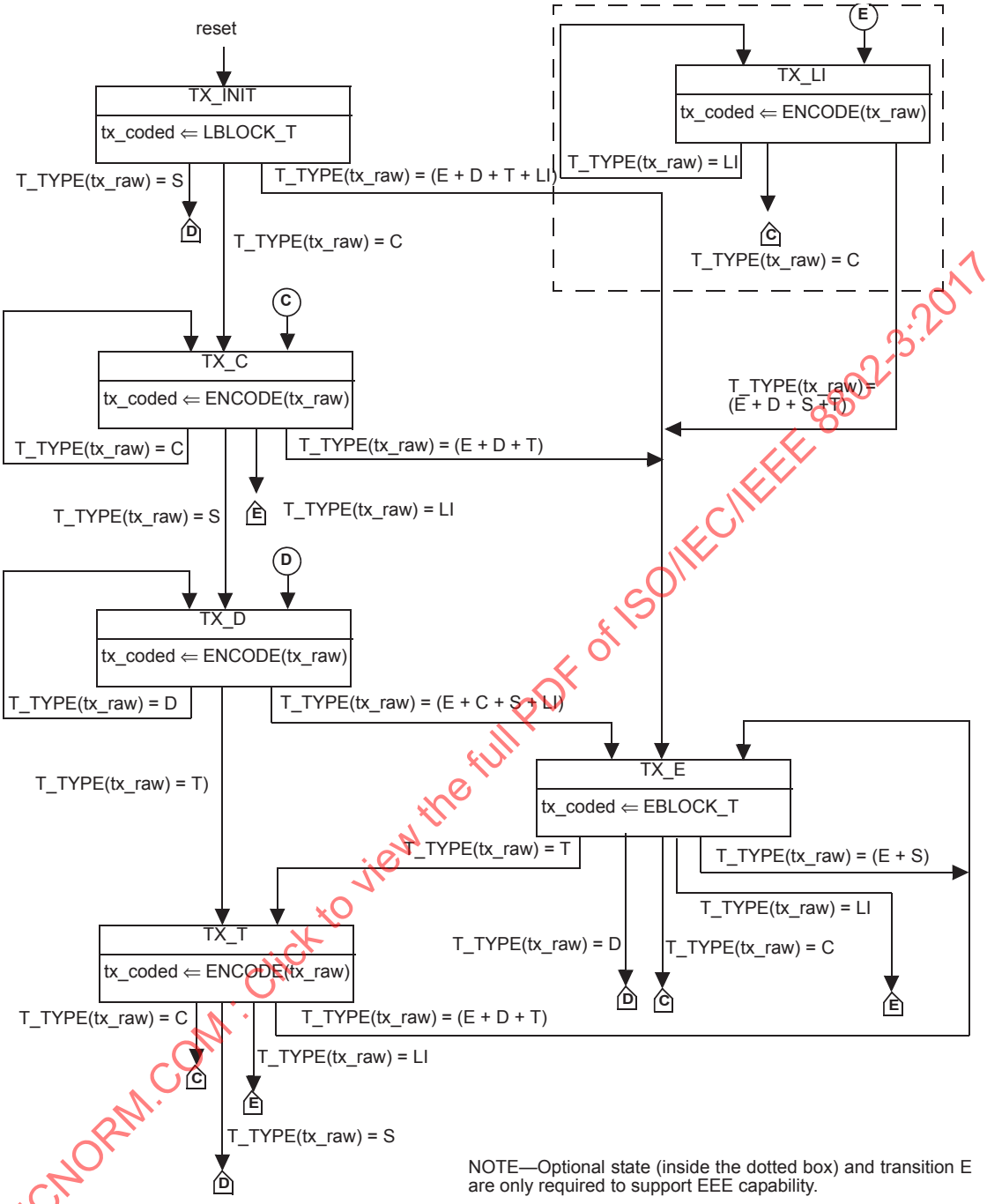

Figure 49–16—Transmit state diagram

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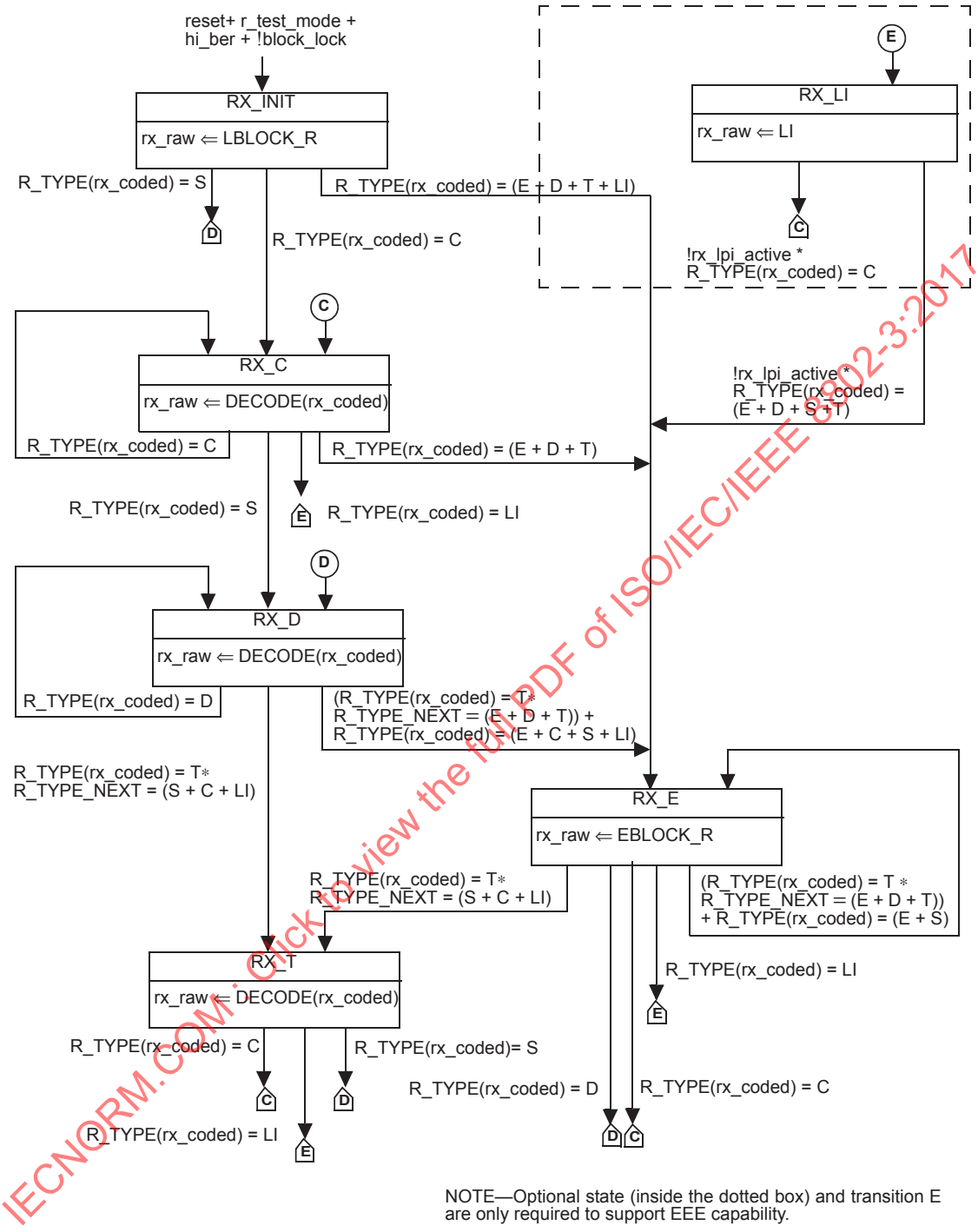

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Figure 49–17—Receive state diagram

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49.3 Protocol implementation conformance statement (PICS) proforma for Clause 49, Physical Coding Sublayer (PCS) type 10GBASE-R[10]

49.3.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 49, Physical Coding Sublayer (PCS), type 10GBASE-R, shall complete the following protocol implementation conformance statement (PICS) proforma. A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

49.3.2 Identification

49.3.2.1 Implementation identification

Supplier[1]	
Contact point for inquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1,3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

49.3.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 49, Physical Coding Sublayer (PCS), type 10GBASE-R
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	
Date of Statement	

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[10]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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49.3.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
XSBI	XBSI compatibility interface	51, 49.1.5	Compatibility interface is supported	O	Yes [ ] No [ ]
XGE	XGMII compatibility interface	46, 49.1.5	Compatibility interface is supported	O	Yes [ ] No [ ]
MD	MDIO	45, 49.2.14	Registers and interface supported	O	Yes [ ] No [ ]
*WIS	Supports operation with a WIS	49.1.5		O.1	Yes [ ] No [ ]
PMA	Supports operation directly connected to a PMA	49.1.5		O.1	Yes [ ] No [ ]
*JTM	Supports test-pattern mode	49.2.2		PMA:M	Yes [ ] No [ ] N/A[ ]
LPI	Implementation of LPI	49.2.4.4		O	Yes [ ] No [ ]

49.3.4 PICS Proforma Tables for PCS, type 10GBASE-R

49.3.4.1 Coding rules

Item	Feature	Subclause	Value/Comment	Status	Support
C1	Encoder implements the code as specified	49.2.13.2.3 and 49.2.4		M	Yes [ ] No [ ]
C2	Decoder implements the code as specified	49.2.13.2.3 49.2.4		M	Yes [ ] No [ ]
C3	IDLE control code insertion and deletion	49.2.4.7	Insertion or Deletion in groups of 4 /I/s	M	Yes [ ] No [ ]
C4	IDLE control code deletion	49.2.4.7	When deleting /I/s, the first four characters after a /T/ shall not be deleted.	M	Yes [ ] No [ ]
C5	Sequence ordered set deletion	49.2.4.10	Only one whole ordered set of two consecutive sequence ordered sets may be deleted	M	Yes [ ] No [ ]

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49.3.4.2 Scrambler and Descrambler

Item	Feature	Subclause	Value/Comment	Status	Support
S1	Scrambler	49.2.6	Performs as shown in Figure 49–8	M	Yes [ ] No [ ]
S2	Descrambler	49.2.10	Performs as shown in Figure 49–10	M	Yes [ ] No [ ]

49.3.5 Test-pattern modes

Item	Feature	Subclause	Value/Comment	Status	Support
JT1	Square wave and pseudo-random transmit test-pattern generators are implemented	49.2.8	Performs as in 49.2.8	JTM:M	Yes [ ] No [ ] N/A[ ]
JT2	Pseudo-random receive test-pattern checker is implemented	49.2.12	Performs as in 49.2.12	JTM:M	Yes [ ] No [ ] N/A[ ]
JT3	Transmit and receive test-pattern modes can operate simultaneously	49.2.2		JTM:M	Yes [ ] No [ ] N/A[ ]
JT4	Reject transmit test-pattern mode when WIS is attached	49.2.8		JTM:O	Yes [ ] No [ ] N/A[ ]
JT5	Reject receive test-pattern mode when WIS is attached	49.2.12		JTM:O	Yes [ ] No [ ] N/A[ ]
*JT6	Support for PRBS31 test pattern	49.2.8		JTM:O	Yes [ ] No [ ] N/A[ ]
JT7	PRBS31 test-pattern generator is implemented	49.2.8	Performs as in 49.2.8	JT6:M	Yes [ ] No [ ] N/A[ ]
JT8	PRBS31 test-pattern checker is implemented	49.2.12	Performs as in 49.2.12	JT6:M	Yes [ ] No [ ] N/A[ ]
*JT9	Support for PRBS9 transmit test pattern	49.2.8		JTM:O	Yes [ ] No [ ] N/A[ ]
JT10	PRBS9 transmit test pattern is implemented	49.2.8	Performs as in 49.2.8	JT9:M	Yes [ ] No [ ] N/A[ ]

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49.3.5.1 Bit order

Item	Feature	Subclause	Value/Comment	Status	Support
B1	Transmit bit order	49.2.7	Placement of bits into tx_data-group<15:0> as specified in 49.2.7	M	Yes [ ] No [ ]
B2	Receive bit order	49.2.9	Placement of bits from rx_data-group<15:0> into blocks as specified in 49.2.9	M	Yes [ ] No [ ]

49.3.6 Management

Item	Feature	Subclause	Value/Comment	Status	Support
M1	Alternate access to PCS Management objects is provided	49.2.14		O	Yes [ ] No [ ]

49.3.6.1 State diagrams

Item	Feature	Subclause	Value/Comment	Status	Support
SM1	Lock	49.2.13.3	Meets the requirements of Figure 49–14	M	Yes [ ] No [ ]
SM2	BER Monitor	49.2.13.3	Meets the requirements of Figure 49–15	M	Yes [ ] No [ ]
SM3	Transmit	49.2.13.3	Meets the requirements of Figure 49–16	M	Yes [ ] No [ ]
SM4	Receive	49.2.13.3	Meets the requirements of Figure 49–17	M	Yes [ ] No [ ]
SM5	PCS_R_Status	49.2.2	PCS_R_STATUS is FAIL in RX_INIT state; OK otherwise	M	Yes [ ] No [ ]

49.3.6.2 WIS

Item	Feature	Subclause	Value/Comment	Status	Support
W1	Supports WIS_SIGNAL.request	49.2.2	PCS_R_STATUS is FAIL when in RX_INIT state	WIS:M	Yes [ ] No [ ] N/A[ ]

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49.3.6.3 Loopback

Item	Feature	Subclause	Value/Comment	Status	Support
L1	Supports Loopback	49.2.14.4	Performs as in 49.2.14.4	M	Yes [ ] No [ ] N/A[ ]

49.3.6.4 Delay Constraints

Item	Feature	Subclause	Value/Comment	Status	Support
TIM1	PCS Delay Constraint	49.2.15	No more than 3584 BT for sum of transmit and receive path delays	M	Yes [ ] No [ ]

49.3.6.5 Auto-Negotiation for Backplane Ethernet functions

Item	Feature	Subclause	Value/Comment	Status	Support
AN1*	Support for use with a 10GBASE-KR PMD	49.2.16	AN technology dependent interface described in Clause 73	O	Yes [ ]
AN2	AN_LINK.indication primitive	49.2.16	Support of the primitive AN_LINK.indication(link_status), when the PCS is used with 10GBASE-KR PMD	AN1:M	Yes [ ]
AN3	link_status parameter	49.2.16	Takes the value OK or FAIL, as described in 49.2.16	AN1:M	Yes [ ]
AN4	Generation of AN_LINK.indication primitive	49.2.16	Generated when the value of link_status changes	AN1:M	Yes [ ]

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49.3.6.6 LPI functions

Item	Feature	Subclause	Value/Comment	Status	Support
LP-01	Insertion and deletion of LPIs in groups of four	49.2.4.7		LPI:M	Yes [ ] No [ ]
LP-02	Unscrambled data transmitted when scrambler_bypass = TRUE	49.2.6		LPI:M	Yes [ ] No [ ]
LP-03	Scrambler continues to operate as normal when scrambler_bypass = TRUE	49.2.6		LPI:M	Yes [ ] No [ ]
LP-04	scr_bypass_enable = TRUE when FEC is in use	49.2.13.2.2		LPI:M	Yes [ ] No [ ]
LP-05	Transmit state diagrams	49.2.13.3	Support additions to Figure 49–16 for LPI operation	LPI:M	Yes [ ] No [ ]
LP-06	Receive state diagrams	49.2.13.3	Support additions to for LPI operation	LPI:M	Yes [ ] No [ ]
LP-07	LPI transmit state diagrams	49.2.13.3.1	Meets the requirements of Figure 49–12	LPI:M	Yes [ ] No [ ]
LP-08	LPI receive state diagrams	49.2.13.3.1	Meets the requirements of Figure 49–13	LPI:M	Yes [ ] No [ ]
LP-09	LPI transmit timing	49.2.13.3.1	Meets the requirements of Table 49–2	LPI:M	Yes [ ] No [ ]
LP-10	LPI receive timing	49.2.13.3.1	Meets the requirements of Table 49–3	LPI:M	Yes [ ] No [ ]

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50. WAN Interface Sublayer (WIS), type 10GBASE-W

50.1 Overview

The WAN Interface Sublayer (WIS) is an optional PHY sublayer that may be used to create a 10GBASE-W PHY that is data-rate and format compatible with the SONET STS-192c transmission format defined by ANSI, as well as the Synchronous Digital Hierarchy (SDH) VC-4-64c container specified by ITU. The purpose of the WIS is to allow 10GBASE-W equipment to generate Ethernet data streams that may be mapped directly to STS-192c or VC-4-64c streams at the PHY level, without requiring MAC or higher-layer processing. The WIS therefore specifies a subset of the logical frame formats in the SONET and SDH standards. In addition, the WIS constrains the effective data throughput at its service interface to the payload capacity of STS-192c / VC-4-64c, i.e., 9.58464 Gb/s. Multiplexed SONET/SDH formats are not supported.

The WIS does not render a 10GBASE-W PHY compliant with either SONET or SDH at any rate or format. A 10GBASE-W interface is not intended to interoperate directly with interfaces that comply with SONET or SDH standards, or other synchronous networks. Such interoperation would require full conformance to the optical, electrical, and logical requirements specified by SONET or SDH, and is outside the scope and intent of this standard. Operation over electrically multiplexed payloads of a transmission network is outside the scope of this standard.

From the perspective of the 10 Gb/s MAC layer, a 10GBASE-W PHY does not appear different (in either the functions or service interface) from a PHY without a WIS, with the exception of sustained data rate. However, a 10GBASE-W interface may interoperate only with another 10GBASE-W interface.

50.1.1 Scope

This clause specifies the functions, features, services, and protocol of the WIS. The WIS may be used with any of the PCS, PMA, and PMD sublayers that are defined for 10GBASE-W, as shown in Figure 50–1, it is placed between the PCS and PMA sublayers within the 10GBASE-W PHY. The WIS is common to all members of the family of 10GBASE-W WAN-compatible PHY implementations. There are currently three embodiments within this family: 10GBASE-SW, 10GBASE-LW, and 10GBASE-EW.

The definition of the WIS is based on the subset of signaling rates and data formats standardized by ATIS-0600416.1999(R2010), which in turn is based on ATIS-0900105.2008. The WIS maps the encoded Ethernet data received (transmitted) from (to) the PCS into a frame structure that has the same format as that defined by ATIS-0600416.1999(R2010), implementing a minimal number of the standard SONET overhead fields and functions. The WIS does not adhere to the electrical and optical aspects of SONET specified by ATIS-0600416.1999(R2010), as it is intended to be used with PHYs that conform to the corresponding parameters defined by the 10GBASE-W standard.

The WIS shall meet all requirements of ATIS-0600416.1999(R2010) except those that are specifically excluded by this clause. The following sections of ATIS-0600416.1999(R2010) are excluded in their entirety:

a) Section 5 (Jitter)
b) Section 6 (Synchronization)
c) Section 7.2.2 (VT1.5 rate—Electrical Interface)
d) Section 7.4.2 (VT1.5 rate)
e) Section 7.6 (Performance and failure alarm monitoring)
f) Section 7.7 (Performance monitoring functions)
g) Annex A (SONET VT1.5 Line Interface Common Criteria)
h) Annex B (SONET maintenance signals for the NI)

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i) Annex C (Receiver jitter tolerance and transfer)

For convenience and clarity of explanation, this clause employs the notational conventions, nomenclature, and acronyms of SONET as defined by ATIS-0600416.1999(R2010). This should not, however, be taken as implying that the WIS excludes compatibility with ITU-defined SDH rates and formats.

50.1.2 Objectives

The following are the objectives for the WIS:

a) To support the full duplex mode of operation of the Ethernet MAC
b) To support the PCS, PMA and PMD sublayers defined for 10GBASE-W
c) To provide a 9.95328 Gb/s effective data rate at the service interface presented by the PMA sublayer, conforming with the requirements of SONET STS-192c and SDH VC-4-64c frame rates
d) To implement the framing, scrambling, and defect/anomaly detection to allow minimal compatibility with the requirements of both SONET and SDH transmission networks
e) To preserve the full duplex behavior and BER objectives of the PCS and PMD sublayers with which it may be used

NOTE—This clause will always use the term “WIS frames” when referring to the SONET-compatible frame format that is generated and terminated by the WIS, in order to distinguish such frames from those generated and terminated by the MAC. The WIS has no involvement with, or visibility into, the MAC framing processes. The “WIS frames” handled by the WIS are not propagated to higher layers via the WIS service interface; they are only exchanged between WIS peer entities on either side of a point-to-point link, and are unobservable and have no meaning outside WIS entities.

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50.1.3 Relationship to other sublayers

Figure 50–1 depicts the relationships among the WIS (shown shaded), the 10 Gb/s MAC and Reconciliation Sublayers, the 10GBASE-R PCS and PMA, the ISO/IEC 8802-2 LLC, and the ISO/IEC Open System Interconnection (OSI) reference model.

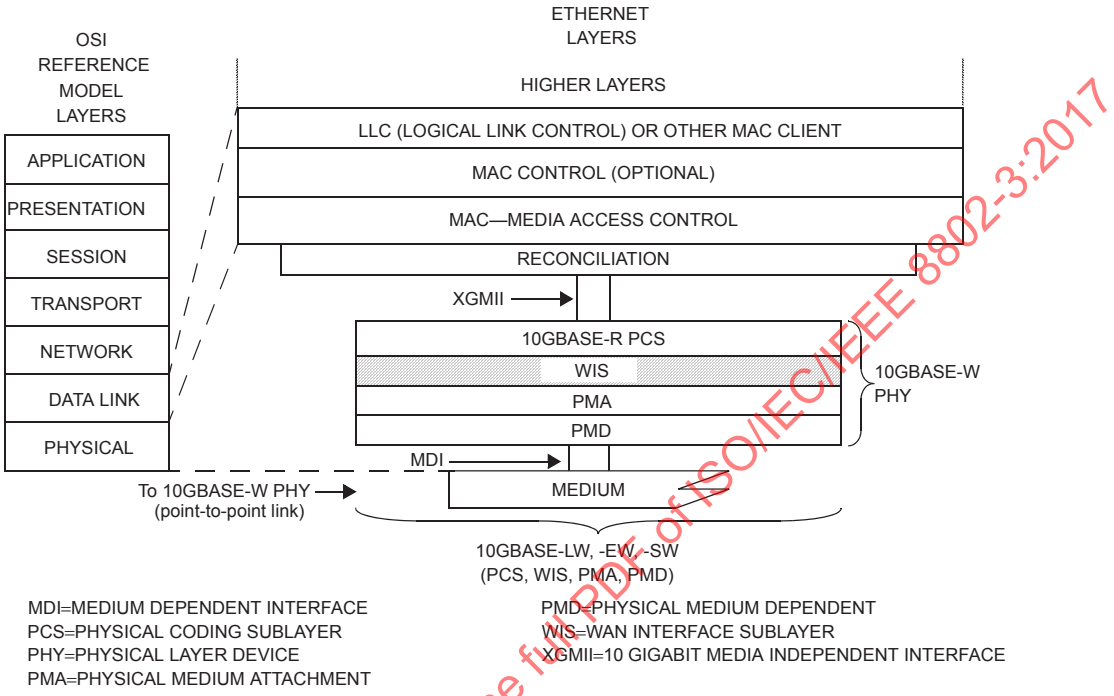

Figure 50–1—WIS relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

50.1.4 Summary of functions

The following provides a summary of the principal functions implemented by the WIS.

In the transmit direction (i.e., when transferring data from the PCS to the PMA), the WIS performs the following functions:

a) Mapping of data-units received from the PCS via the WIS Service Interface to the payload capacity of the Synchronous Payload Envelope (SPE) defined for STS-192c
b) Addition of Path Overhead and fixed stuff octets to generate the actual SPE
c) Creation of frames consisting of Line Overhead and Section Overhead octets plus the SPE, and the generation and insertion of Section, Line, and Path Bit Interleaved Parity (BIP)
d) Scrambling of the generated WIS frames
e) Transmission of these frames to the PMA sublayer via the PMA Service Interface

In the receive direction, the functions performed by the WIS include the following:

f) Reception of data from the PMA sublayer via the PMA Service Interface
g) Delineation of octet boundaries as well as STS-192c frame boundaries within the unaligned data stream from the PMA
h) Descrambling of the payload and overhead fields within the incoming frames

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i) Processing of the pointer field within the Line Overhead, and delineation of the boundaries of the Synchronous Payload Envelopes (SPE) within the received WIS frames
j) Generation and checking of Bit Interleaved Parity (BIP) within the Section, Line, and Path Overheads
k) Removal of Line, Section, and Path Overhead columns, as well as fixed stuff columns, in order to extract the actual payload field
l) Handling of errors and exception conditions detected within the incoming WIS frame stream, and reporting these errors to Layer Management
m) Mapping of octets extracted from the payload capacity of the incoming SPE to data-units that are passed to the PCS via the WIS Service Interface

50.1.5 Sublayer interfaces

A WIS Service Interface is provided to allow the WIS to transfer information to and from the 10GBASE-R PCS, which is the sole WIS client. An abstract service model is used to define the operation of this interface. In addition, the WIS utilizes the service interface provided by the PMA sublayer to transfer information to and from the PMA. This standard defines these interfaces in terms of bits, octets, data-units and signals; however, implementers may choose other data-path widths and other control mechanisms for implementation convenience, provided that the logical models of the service interfaces are adhered to.

NOTE—The PMA service interface may be optionally instantiated as an actual physical interface, referred to as the XSBI; in this case, the WIS must also implement the client portion of the XSBI, as defined in 51.4, and conform to its data-path widths and control mechanisms.

50.1.6 Functional block diagram

Figure 50–2 provides a functional block diagram of the WIS.

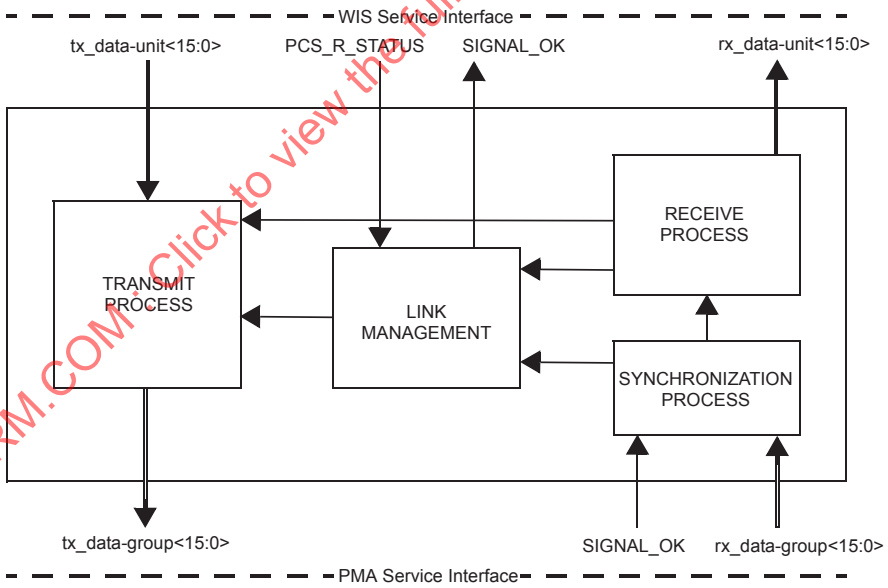

Figure 50–2—Functional block diagram

50.1.7 Notational conventions

The state diagrams within the body of this clause follow the notations and conventions of 21.5. State diagram timers follow the conventions of 14.2.3.2.

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The Path, Line, and Section Overhead fields handled by the WIS are referenced using the standard terminology given in Section 4.2 of ATIS-0600416.1999(R2010). Nomenclature relating to SONET Defects and Anomalies that must be processed by the WIS, as well as other definitions and abbreviations required by this clause, are defined by Section 3 of ATIS-0600416.1999(R2010).

The labeling and transmission order of bits within an octet is different between the SONET/SDH and Ethernet protocol families. SONET numbers bits within an octet from 1 to 8 inclusive, with the bit labeled 1 being the most-significant bit (MSB) and the bit labeled 8 being the least-significant bit (LSB); when serialized, bits are transmitted in order from MSB to LSB (i.e., the bit numbered 1 is transmitted first and the bit numbered 8 is transmitted last). The Ethernet numbering scheme, on the other hand, normally numbers bits from 0 to 7 inclusive, with bit 0 being the LSB and bit 7 being the MSB; bits are transmitted from LSB to MSB. This clause employs the SONET numbering scheme throughout, with the exception of the WIS service interface, which utilizes the Ethernet numbering scheme. Special provisions are made when mapping payload data into the WIS frame (see 50.3.1.1 and 50.3.1.2) to ensure that the reversed transmission order does not impact the properties of the Ethernet FCS.

50.2 WIS Service Interface

The WIS Service Interface is provided to allow the 10GBASE-R PCS to transfer information to and from the WIS. These services are defined in an abstract manner and do not imply any particular implementation. The WIS Service Interface supports the exchange of data-units between PCS entities on either side of a 10GBASE-W link using request and indicate primitives. Data-units are mapped into WIS frames by the WIS and passed to the PMA, and vice versa.

The following primitives are defined within the WIS Service Interface:

WIS_UNITDATA.request(tx_data-unit<15:0>)
WIS_UNITDATA.indication(rx_data-unit<15:0>)
WIS_SIGNAL.request(PCS_R_STATUS)
WIS_SIGNAL.indication(SIGNAL_OK)

50.2.1 WIS_UNITDATA.request

This primitive defines the transfer of data, in the form of constant-width data-units, from the PCS to the WIS. The data supplied via WIS_UNITDATA.request is mapped by the WIS Transmit process into the payload capacity of the outgoing WIS frame stream.

50.2.1.1 Semantics of the service primitive

WIS_UNITDATA.request(tx_data-unit<15:0>)

The data conveyed by WIS_UNITDATA.request is a 16-bit vector representing a single data-unit which has been prepared for transmission by the 10GBASE-R PCS Transmit process. The element tx_data-unit<0> shall be interpreted as the least significant bit of the vector, and tx_data-unit<7:0> shall be interpreted as the least significant octet of the vector. The least significant octet of the vector is assumed to be generated first by the PCS; when the WIS transfers the provided data to the PMA, it is mapped such that the least significant octet is also transmitted first.

50.2.1.2 When generated

The 10GBASE-R PCS sends tx_data-unit<15:0> to the WIS at a nominal rate of 599.04 Mtransfers/s, corresponding to the STS-192c payload rate of 9.58464 Gb/s.

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NOTE—The mapping of a constant-rate data stream into the payload capacity of a SONET-compatible SPE may require buffering in order to absorb the effects of periodically inserting overhead fields. In addition, the WIS and PCS may require some form of clock synchronization between the data-unit generation process and the normal SONET framing process. Both of these mechanisms are considered to be implementation-specific and outside the scope of this standard.

50.2.1.3 Effect of receipt

Upon receipt of this primitive, the WIS Transmit process maps the data conveyed by the tx_data-unit<15:0> parameter into the payload of the transmitted WIS frame stream, adds overhead octets as necessary, scrambles the data, and transfers the result to the PMA via one or more PMA_UNITDATA.request primitives.

50.2.2 WIS_UNITDATA.indication

This primitive defines the transfer of received data, in the form of constant-width data-units, from the WIS to the PCS. WIS_UNITDATA.indication is generated by the WIS Receive process in response to WIS frame data received from the PMA.

50.2.2.1 Semantics of the service primitive

WIS_UNITDATA.indication(rx_data-unit<15:0>)

The rx_data-unit<15:0> parameter is a 16-bit vector that represents the data-unit transferred by the WIS to the 10GBASE-R PCS. The element rx_data-unit<0> shall be interpreted as the least significant bit of the vector, and rx_data-unit<7:0> shall be interpreted as the least significant octet of the vector. The least significant octet of the vector is assumed to be processed first by the PCS; when the WIS obtains the data from the PMA, it is mapped such that the least significant octet was also received first.

50.2.2.2 When generated

The WIS sends one rx_data-unit<15:0> to the 10GBASE-R PCS whenever it has delineated exactly 16 bits of valid payload information from the incoming data stream received from the PMA sublayer. The nominal rate of generation of the WIS_UNITDATA.indication primitive is 599.04 Mtransfers/s, as governed by the recovered bit clock and the reduction in data rate imposed by the removal and discard of overhead fields from the incoming WIS frame stream. This corresponds to the STS-192c payload rate of 9.58464 Gb/s.

NOTE—The removal of overhead fields creates variations in data rate that may have to be removed by suitable buffering before data are transferred to the PCS. These buffering and rate adaptation mechanisms are implementation dependent and outside the scope of this standard.

50.2.2.3 Effect of receipt

The effect of receipt of this primitive by the WIS client is unspecified by the WIS.

50.2.3 WIS_SIGNAL.request

This primitive is sent by the 10GBASE-R PCS to the WIS to indicate when the PCS has acquired or lost frame delineation, i.e., synchronization with respect to the codewords present in the received data transferred from the WIS to the PCS.

50.2.3.1 Semantics of the service primitive

WIS_SIGNAL.request(PCS_R_STATUS)

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The PCS_R_STATUS parameter can take one of two values: OK or FAIL. A value of OK denotes that the PCS is successfully delineating valid codewords from the incoming data stream transferred to it by the WIS via the WIS_UNITDATA.indication primitive. A value of FAIL denotes that errors have been detected by the PCS that prevent synchronization to these codewords.

50.2.3.2 When generated

The 10GBASE-R PCS generates the WIS_SIGNAL.request primitive to the WIS whenever there is a change in the value of the PCS_R_STATUS parameter.

50.2.3.3 Effect of receipt

The receipt of this primitive causes the WIS to identify the presence or absence of a Loss of Code-group Delineation condition, and to report this condition to the remote WIS entity via an LCD-P defect indication, as described in 50.3.5.3.

50.2.4 WIS_SIGNAL.indication

This primitive is sent by the WIS to the PCS to indicate the status of the Receive process. WIS_SIGNAL.indication is generated by the WIS Receive process in order to propagate the detection of severe error conditions (e.g., no valid signal being received from the PMA sublayer) to the PCS.

50.2.4.1 Semantics of the service primitive

WIS_SIGNAL.indication(SIGNAL_OK)

The SIGNAL_OK parameter can take one of two values: OK or FAIL. A value of OK denotes that the WIS Receive process is successfully delineating valid payload information from the incoming data stream received from the PMA sublayer, and this payload information is being presented to the PCS via the WIS_UNITDATA.indication primitive. A value of FAIL denotes that errors have been detected by the Receive process that prevent valid data from being presented to the PCS, as described in 50.3.5; in this case the WIS_UNITDATA.indication primitive and its associated rx_data-unit<15:0> parameter are meaningless.

50.2.4.2 When generated

The WIS generates the WIS_SIGNAL.indication primitive to the 10GBASE-R PCS whenever there is a change in the value of the SIGNAL_OK parameter.

50.2.4.3 Effect of receipt

The effect of receipt of this primitive by the WIS client is unspecified by the WIS.

50.3 Functions within the WIS

As shown in Figure 50–2, the WIS comprises the WIS Transmit and WIS Receive processes for 10GBASE-W, together with a Synchronization process and a Link Management function. Figure 50–3 depicts a conceptual view of the functions within each of the Transmit and Receive processes. Note that the figure does not show the interfaces to the Link Management function.

The WIS Transmit process accepts fixed-width tx_data-units from the PCS via the WIS Service Interface, and maps them into the payload capacity of the transmitted WIS frame stream. Fixed stuff octets are added, together with a set of Path Overhead octets, to create a Synchronous Payload Envelope (SPE). Line and Section Overhead octets are combined with the SPE and then scrambled using a frame-synchronous

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scrambler to produce the final transmitted WIS frame. The WIS continuously generates one SONET-compatible WIS frame, comprising overhead fields, fixed stuff and payload, every 125 microseconds. No gaps are present between WIS frames. The data produced by the Transmit process, depicted as tx_data-group<15:0> in Figure 50–2, are passed to the PMA via the PMA Service Interface.

The WIS Synchronization process accepts data from the PMA (via the PMA Service Interface, depicted as rx_data-group<15:0> in Figure 50–2) and performs an alignment operation to delineate both octet and frame boundaries within the received data stream. Aligned and framed data are passed to the WIS Receive process (depicted as sync_bits<15:0> in Figure 50–3), where Section and Line Overhead octets are extracted from the WIS frames and processed after de-scrambling the frame data. The payload pointer within the Line Overhead is used to delineate the start and end of the received SPE, and the Path Overhead is extracted from the SPE and processed. Finally, the fixed stuff is removed from the SPE as well, and the resulting data stream is conveyed to the PCS via the WIS Service Interface. Severe errors detected by the Synchronization and Receive processes (e.g., loss of WIS frame synchronization) cause a WIS_SIGNAL.indication primitive to be sent to the PCS with a parameter of FAIL (see 50.2.4).

The WIS Link Management function implements the management registers defined in 45.2.2. These registers allow the local Station Management entity to control and monitor the operational status of the WIS Transmit and Receive processes. In addition, SONET Defects and Anomalies detected during the processing of the incoming data are sent to the management registers for reporting.

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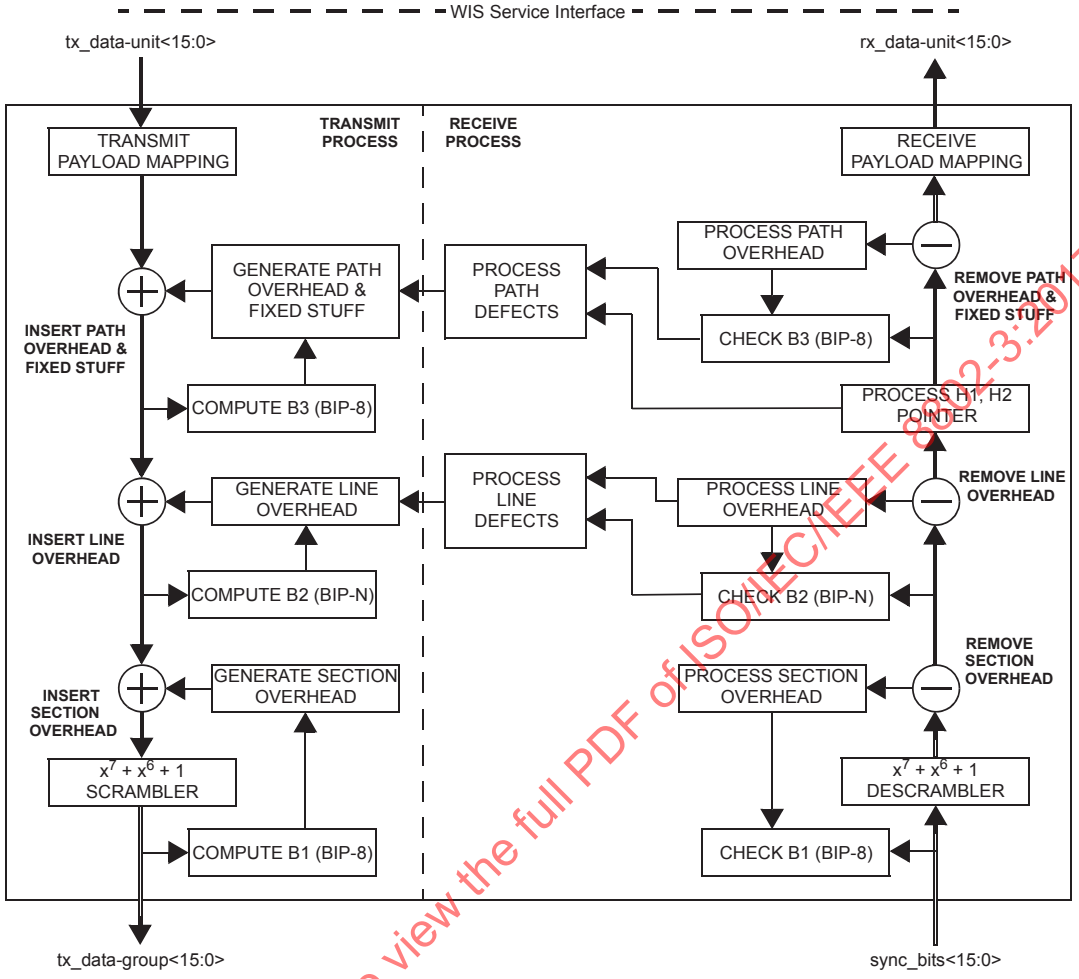

Figure 50–3—WIS Transmit and Receive processes

50.3.1 Payload mapping and data-unit delineation

The WIS maps the tx_data-unit<15:0> and rx_data-unit<15:0> parameters that are transferred via its service interface to/from the payload capacity of a standard STS-192c Synchronous Payload Envelope (SPE) structure. This structure is shown in Figure 50–4 for informative purposes. It is represented as a two-dimensional array with 9 rows and 16 704 columns, each row consisting of one octet of Path Overhead (added and removed as per 50.3.2.1 and 50.3.2.4), 63 octets of fixed stuff, and 16 640 octets of actual payload capacity.

The total payload capacity of the SPE comprises 149 760 octets (per WIS frame). As depicted in Figure 50–4, the octets of the payload capacity are numbered from left to right, starting at 0 (zero). The transmission order is also from left to right, i.e., lower-numbered octets are transmitted before higher-numbered octets.

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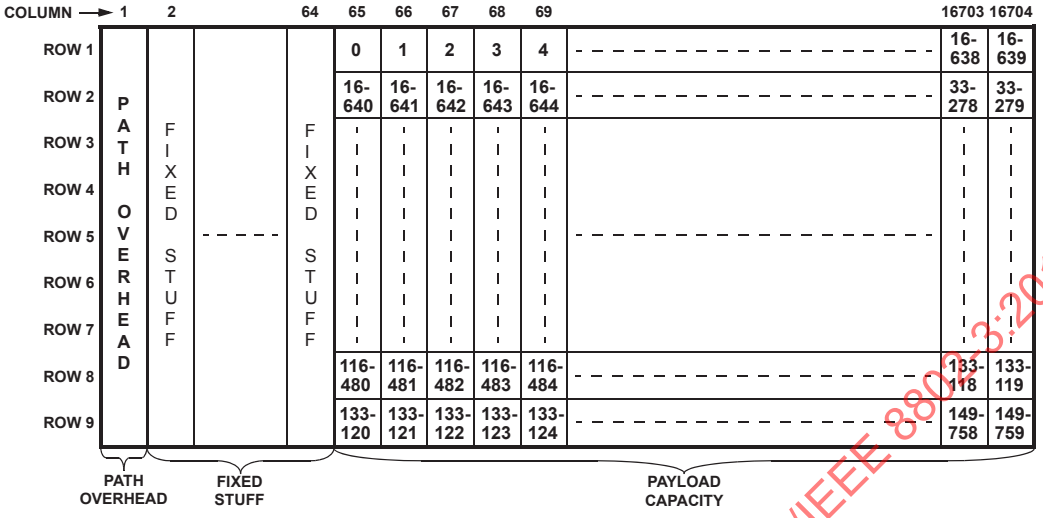

Figure 50–4—Structure of Synchronous Payload Envelope (informative)

50.3.1.1 Transmit payload mapping

The WIS Transmit function accepts a continuous stream of data-units from the PCS, conveyed by the tx_data-unit<15:0> parameter of the WIS_UNITDATA.request primitive of the WIS Service Interface. These data units shall be mapped to the SPE payload capacity and passed to the frame generation process described in 50.3.2 for insertion of the fixed stuff and Path Overhead columns. For each data-unit, tx_data-unit<7:0> shall be mapped to a lower-numbered (even) octet in the SPE payload capacity, and tx_data-unit<15:8> shall be mapped to the next higher-numbered (odd) octet.

A bit relabeling function is performed to map the bit numbering and ordering conventions followed by the WIS Service Interface to those implemented by the Transmit process (which follows the bit numbering and ordering conventions of SONET/SDH). The relabeling function shall be performed as shown in Figure 50–5. Bit 0 of tx_data-unit<15:0> is renumbered as bit 1 of the lower-numbered (even) octet within the SONET SPE, bit 15 of tx_data-unit<15:0> is renumbered as bit 8 of the higher-numbered octet within the SONET SPE, and the rest of the bits are renumbered in corresponding sequence.

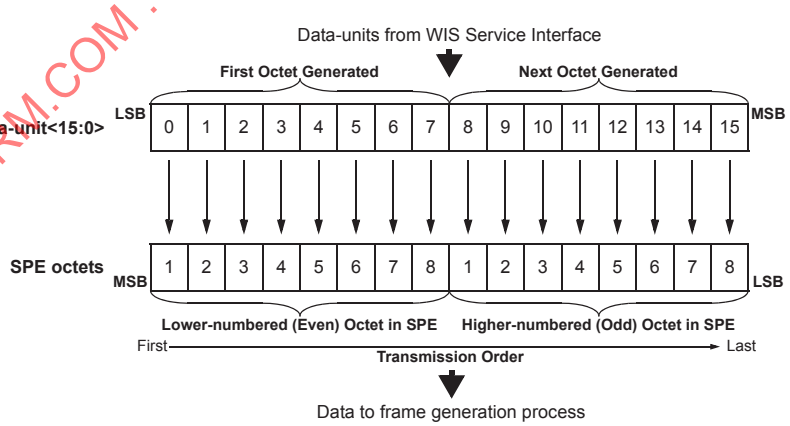

Figure 50–5—Transmit bit relabeling function

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NOTE—The transmit bit relabeling function is required because SONET transmission order is from MSB to LSB (i.e., bit 1 to bit 8 of each octet, in the SONET numbering convention) while the Ethernet transmission order is from LSB to MSB (i.e., bit 0 to bit 7 of each octet, in the Ethernet numbering convention). It is necessary to maintain the expected transmission order of Ethernet in order to preserve the error detection properties of the Ethernet FCS. Therefore, the renumbering scheme causes the payload portion of the SPE to be transmitted from LSB to MSB with reference to incoming data accepted from the WIS Service Interface, but the Path, Line, and Section Overhead octets are transmitted from MSB to LSB as required by SONET.

50.3.1.2 Receive payload mapping

The WIS Receive function accepts a continuous stream of octets from the frame reception process described in 50.3.2, corresponding to the payload capacity of the SPE as illustrated in Figure 50–4. It shall map the octets in the SPE payload capacity to a continuous stream of data-units that are supplied to the PCS via the rx_data-unit<15:0> parameter of the WIS_UNITDATA.indication primitive of the WIS Service Interface. Within each data-unit, rx_data-unit<7:0> shall be mapped to a lower-numbered (even) octet in the SPE payload capacity, and rx_data-unit<15:8> shall be mapped to the next higher-numbered (odd) octet.

A bit relabeling function is performed to map the bit numbering and ordering conventions followed by the Receive process (which follows the bit numbering and ordering conventions of SONET/SDH) to those required by the WIS Service Interface. The relabeling function shall be performed as shown in Figure 50–6. Bit 1 of the lower-numbered (even) octet within the received SONET SPE is renumbered as bit 0 of rx_data-unit<15:0> at the WIS Service Interface, bit 8 of the higher-numbered octet within the SONET SPE is renumbered as bit 15 of rx_data-unit<15:0>, and the rest of the bits are renumbered in corresponding sequence.

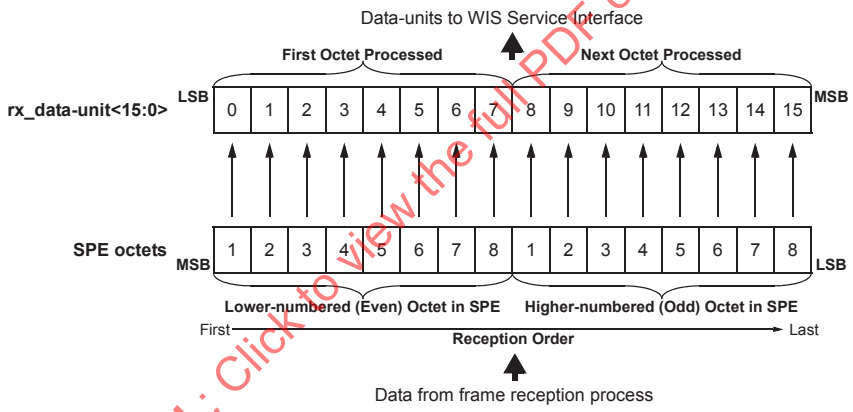

Figure 50–6—Receive bit relabeling function

NOTE—The receive bit relabeling function is required for the same reasons as the transmit bit relabeling function described in 50.3.1.1, i.e., to preserve the error detection properties of the Ethernet FCS in the face of the different transmission order required by SONET framing.

50.3.2 WIS frame generation

As part of the Transmit process, the WIS encapsulates the payload generated by the payload mapping function within a series of WIS frames. The Receive process performs the reverse operation, extracting payload from the incoming WIS frame stream and submitting it to the payload mapping function. SONET compatibility in the WIS follows ATIS-0600416.1999(R2010), with the exception of the superseding specifications in this document.

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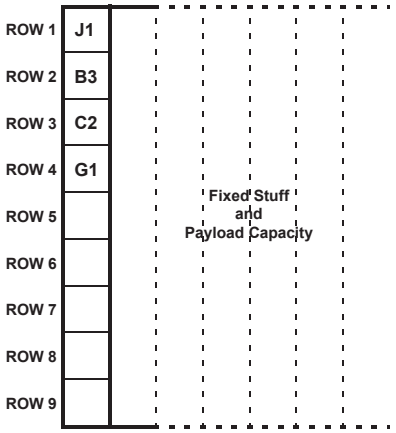
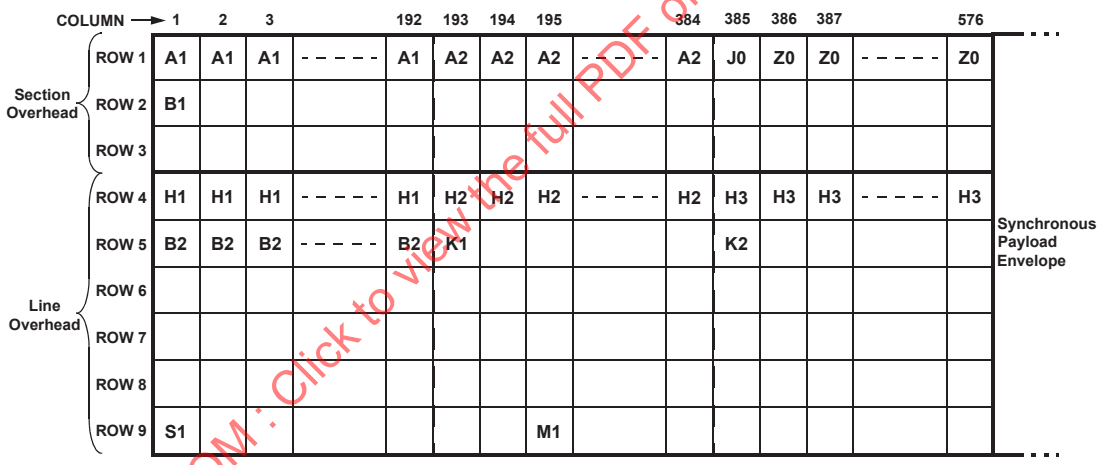
Frame generation in both the transmit and receive directions is performed in three stages. Figure 50–3 illustrates the sequence of stages. The relevant octets in the Path Overhead portion of the frame are shown in Figure 50–7, and Figure 50–8 illustrates the Section and Line Overhead generated by the WIS.



NOTE—The Path Overhead comprises 9 octets in total. Only 4 octets are defined for the WIS.
Octets that are undefined and unused by the WIS are indicated as blank boxes in this figure.

Figure 50–7—Structure of Path Overhead Generated by WIS (informative)



NOTE—The Section and Line Overhead comprise 5184 octets in total (576 x 9). Only 1349 octets are defined for the WIS.
Octets that are undefined and unused by the WIS are indicated as blank boxes in this figure.

Figure 50–8—Structure of Section and Line Overhead Generated by WIS (informative)

NOTE—Figures 50–8 and 50–7 are provided for informative purposes only. In the event of any discrepancy observed between the figures and the normative portions of ATIS-0600416.1999(R2010), the latter shall take precedence.

50.3.2.1 Transmit Path Overhead insertion

The WIS Transmit process shall insert Path Overhead fields as defined in Section 4.2 of ATIS-0600416.1999(R2010), and specified in Table 50–1 of this standard. For the fields where the "Coding" column of Table 50–1 contains "per 416," the field is inserted according to the specifications of ATIS-0600416.1999(R2010). For the fields where the "Coding" column of Table 50–1 contains a specific value or "see text," this document supersedes the corresponding values in Table 1, "SONET overhead at NIs" in the ATIS document.

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Table 50–1—STS Path Overhead

Overhead octet	Function	Usage	Coding (bits 1..8)
B3	STS Path error monitoring (Path BIP-8)	supported	per 416
C2	STS Path signal label	specified value	00011010
F2	Path user channel	unsupported	00000000
G1	Path status	supported	per 416
H4	Multiframe indicator	unsupported	00000000
J1	STS Path trace	specified value	see text
N1	Tandem connection maintenance/Path data channel	unsupported	00000000
Z3-Z4	Reserved for Path growth	unsupported	00000000
NOTE—SONET/SDH and IEEE 802.3 differ in bit ordering conventions. The values in this table follow SONET bit ordering, in which bit index values range from 1 to 8, from left to right, and bit 8 is the least significant bit.			

NOTE—The value assigned to the C2 octet corresponds to the provisional Path signal label value assigned for 10 Gigabit Ethernet. The fixed stuff octets that follow the Path Overhead column in the SPE are transmitted as 00000000 and are not checked on receive.

The J1 octet shall transport a 16-octet continuously repeating Path Trace Message that is formatted as defined by Section 5 and Annex A of ANSI T1.269-2000. Each successive octet of the Path Trace Message, starting from the first, is placed in the J1 octet of a successive WIS frame; after all 16 octets have been transmitted in this way, the process repeats. The Station Management entity may modify the Path Trace Message being transmitted via the Link Management register facilities provided in 50.3.11.1. If the Station Management entity is not currently transmitting a Path Trace Message, a default Path Trace Message consisting of 15 octets of zeros and a header octet formatted according to Section 5 of ANSI T1.269-2000 shall be transmitted.

NOTE—The bit representation of the header octet of the default Path Trace Message is 10001001 (89 hexadecimal). This value is provided here for informational purposes only; ANSI T1.269-2000 shall take precedence in case of any discrepancy.

50.3.2.2 Transmit Line Overhead insertion

The WIS Transmit process shall insert Line Overhead fields as defined in Section 4.2 of ATIS-0600416.1999(R2010), and specified in Table 50–2 of this document. For the fields where the "Coding" column of Table 50–2 contains "per 416," the field is inserted according to the specifications of ATIS-0600416.1999(R2010). For the fields where the "Coding" column of Table 50–2 contains a specific value or "see text," this document supersedes the corresponding values in Table 1, "SONET overhead at NIs" in the ATIS document. In addition, Line Overhead octets not listed in the latter table shall be set to 00000000 by the Transmit process.

The H1 and H2 pointer octets shall be set by the Transmit process, in accordance with the pointer mechanism defined by ATIS-0600416.1999(R2010), to indicate a constant pointer value of 522 decimal, and shall also indicate a concatenated payload.

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The K1 octet shall be set to 00000000 by the Transmit process. In addition, bits 1 to 5 inclusive of the K2 octet shall be set to 00000 binary. Bits 6 through 8 inclusive shall either transport an RDI-L encoding, as defined by Section 7.4.1 of ATIS-0600416.1999(R2010), or be set to 000 binary. No other encodings of the K2 octet are allowed to be transmitted by the WIS Transmit process.

Table 50–2—Line Overhead

Overhead octet	Function	Usage	Coding (bits 1..8)
B2	Line error monitoring (Line BIP-1536)	supported	per 416
D4-D12	Line Data Communications Channel (DCC)	unsupported	00000000
E2	Orderwire	unsupported	00000000
H1-H2	Pointer	specified value	See text.
H3	Pointer action	specified value	00000000
K1, K2	Automatic protection switch (APS) channel and Line Remote Defect Identifier (RDI-L)	specified value	See text.
M0	STS-1 Line Remote Error Indication (REI)	unsupported	00000000
M1	STS-*N* Line Remote Error Indication (REI)	supported	per 416
S1	Synchronization messaging	unsupported	00001111
Z1	Reserved for Line growth	unsupported	00000000
Z2	Reserved for Line growth	unsupported	00000000
NOTE—SONET/SDH and IEEE 802.3 differ in bit ordering conventions. The values in this table follow SONET bit ordering, in which bit index values range from 1 to 8, from left to right, and bit 8 is the least significant bit.			

NOTE—The setting of the constant portions of the K1 and K2 octets denotes that the interface containing the WIS is acting as a working channel. The RDI-L encoding within the K2 octet serves to support the fault processing specified in 50.3.2.5. The setting of the S1 octet signifies that the transmit clock should not be used for synchronization. The bit numbering for these octets follows the SONET convention, in which bit index values range from 1 to 8, from left to right, and bit 8 is the least significant bit.

50.3.2.3 Transmit Section Overhead insertion

The WIS Transmit process shall insert Section Overhead fields as defined in Section 4.2 of ATIS-0600416.1999(R2010), and specified in Table 50–3 of this document. For the fields where the "Coding" column of Table 50–3 contains "per 416," the field is inserted according to the specifications of ATIS-0600416.1999(R2010). For the fields where the "Coding" column of Table 50–3 contains a specific value or "see text," this document supersedes the corresponding values in Table 1, "SONET overhead at NIs" in the ATIS document. In addition, Section Overhead octets not listed in the latter table shall be set to 00000000 by the Transmit process.

The J0 octet shall transport a 16-octet continuously repeating Section Trace Message that is formatted as defined by Section 5 and Annex A of ANSI T1.269-2000. Each successive octet of the Section Trace Message, starting from the first, is placed in the J0 octet of a successive WIS frame; after all 16 octets have

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been transmitted in this way, the process repeats. The Station Management entity may modify the Section Trace Message being transmitted via the Link Management register facilities provided in 50.3.11.1. If the Station Management entity is not currently transmitting a Section Trace Message, a default Section Trace Message consisting of 15 octets of zeros and a header octet formatted according to Section 5 of ANSI T1.269-2000 shall be transmitted.

NOTE—The bit representation of the header octet of the default Section Trace Message is 10001001 (89 hexadecimal). This value is provided here for informational purposes only; ANSI T1.269-2000 shall take precedence in case of any discrepancy.

Table 50–3—Section Overhead

Overhead octet	Function	Usage	Coding (bits 1..8)
A1	Frame alignment	supported	per 416
A2	Frame alignment	supported	per 416
B1	Section error monitoring (Section BIP-8)	supported	per 416
D1-D3	Section Data Communications Channel (DCC)	unsupported	00000000
E1	Orderwire	unsupported	00000000
F1	Section User Channel	unsupported	00000000
J0	Section trace	specified value	See text
Z0	Reserved for Section growth	unsupported	11001100
NOTE 1—The bit representations of the octet values assigned to A1 and A2 are 11110110 (F6 hexadecimal) and 00101000 (28 hexadecimal), respectively. These values are provided here for informational purposes only. ATIS-0600416.1999(R2010) shall take precedence in case of any discrepancy. NOTE 2—SONET/SDH and IEEE 802.3 differ in bit ordering conventions. The values in this table follow SONET bit ordering, in which bit index values range from 1 to 8, from left to right, and bit 8 is the least significant bit.			

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50.3.2.4 Receive Path, Line, and Section Overhead extraction

The WIS Receive process shall extract Path, Line and Section Overhead fields as defined in Section 4.2 of ATIS-0600416.1999(R2010), and specified in Table 50–1, Table 50–2, and Table 50–3 of this document. For the fields where the "Coding" columns of Table 50–1, Table 50–2, and Table 50–3 contain "per 416," the field is extracted according to the specifications of ATIS-0600416.1999(R2010). For the fields where the "Coding" columns contain a specific value or "see text," this document supersedes the corresponding values in Table 1, "SONET overhead at NIs" in the ATIS document. Overhead octets marked as unsupported in Table 50–1, Table 50–2, and Table 50–3 shall be ignored by the Receive process. In addition, overhead octets not listed in Table 1, "SONET overhead at NIs" in ATIS-0600416.1999(R2010) shall also be ignored by the Receive process.

The J0 octet in the received WIS frames shall be interpreted as transporting a 16-octet continuously repeating Section Trace Message. This Section Trace Message is extracted from the incoming WIS frame stream and passed to the Station Management entity via dedicated registers within the WIS MDIO register space (50.3.11.1). The WIS Receive process is not required to delineate Section Trace Message boundaries or process them in any way.

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Extraction of valid Section Trace Message data shall begin after the WIS Receive process has successfully synchronized to the incoming WIS frame stream. Each successive J0 octet received thereafter is placed in a successive octet of the WIS J0 receive register set, until 16 J0 octets have been received, after which the process repeats from the first octet of the register set. As the incoming Section Trace Message is 16 octets in size, the contents of the WIS J0 receive register set will remain static as long as the same message is being received. Extraction of Section Trace Messages in this fashion is performed continuously as long as valid WIS frames are being received. The WIS Receive process is not required to interpret or process the extracted message in any way.

The J1 octet in the received WIS frames shall be interpreted as transporting a 16-octet continuously repeating Path Trace Message. This Path Trace Message is extracted from the incoming WIS frame stream and passed to the Station Management entity via dedicated registers within the WIS MDIO register space (50.3.11.1). The WIS Receive process is not required to delineate Path Trace Message boundaries or process them in any way.

Extraction of valid Path Trace Message data shall begin after the WIS Receive process has successfully synchronized to the incoming WIS frame stream. Each successive J1 octet received thereafter is placed in a successive octet of the WIS J1 receive register set, until 16 J1 octets have been received, after which the process repeats from the first octet of the register set. As the incoming Path Trace Message is 16 octets in size, the contents of the WIS J1 receive register set will remain static as long as the same message is being received. Extraction of Path Trace Messages in this fashion is performed continuously as long as valid WIS frames are being received. The WIS Receive process is not required to interpret or process the extracted message in any way.

Bits 6 through 8, inclusive, of the K2 octet in the received Line Overhead shall be interpreted by the WIS Receive process as carrying the Line Alarm Indication Signal (AIS-L) or Line Remote Defect Indication (RDI-L) signals (see 50.3.2.5). All other encodings of these bits shall be ignored by the Receive process.

NOTE—Values of overhead fields encoded by the Transmit process within a WIS entity at one end of a link may be changed by intervening Line and Section equipment before it reaches the peer WIS entity at the other end of the link. In particular, the H1, H2, and H3 fields may take on values different from those originally encoded. The receive process must be able to handle these situations in accordance with ATIS-0600416.1999(R2010), and therefore must contain a pointer interpreter function compliant with the latter. Bits 5 and 6 of the H1 octet are ignored by the receiver.

50.3.2.5 Fault processing

Defects and anomalies detected by the Receive process are classified as defined in Section 7.1 of ATIS-0600416.1999(R2010). Section, Line, and Path defects and anomalies listed in Table 50–4 of this document shall be detected and processed as defined by Sections 7.3, 7.4.1, and 7.5 of ATIS-0600416.1999(R2010). Defects and anomalies not listed in Table 50–4 are ignored.

NOTE—The description of the LOP-P defect in Section 7.5 of ATIS-0600416.1999(R2010) is in error, and deviates from the underlying definitive reference, which is ANSI T1.231-1997. The reader should therefore consult section 8.1.2.4.1 of ANSI T1.231-1997 for the specification of the LOP-P defect until ATIS-0600416.1999(R2010) has been corrected.

The WIS shall additionally support the PLM-P (Path Label Mismatch) and LCD-P (Loss of Code-group Delineation) defects. The detection and reporting of the PLM-P defect follows Section 7.5 of ATIS-0600416.1999(R2010). The LCD-P defect shares the same coding value and reporting method as the PLM-P defect, but is detected according to 50.3.5.3.

The Receive process shall detect a Loss Of Signal (LOS) defect as defined by Section 7.2.1 of ATIS-0600416.1999(R2010) without using any services provided by the PMA or PMD sublayers for this purpose. The parameters *T* and *T'* in Section 7.2.1 of ATIS-0600416.1999(R2010) shall both be set to a value ranging between 2.3 and 100 microseconds.

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Table 50–4—WIS supported Near end events and Far end reports

	Physical media	Section		Line		Path	
	Defect	Anomaly	Defect	Anomaly	Defect	Anomaly	Defect
Near end	LOS	BIP-N(S)	SEF/LOF	BIP-N(L)	AIS-L	BIP-N(P)	LOP-P AIS-P
Far end	N/A	N/A	N/A	REI-L	RDI-L	REI-P	ERDI-P

NOTE—Section 7.2.2, "VT1.5 rate–Electrical Interface," Section 7.4.2 "VT1.5 Rate," Section 7.6, "Performance and Failure Monitoring," and Section 7.7 "Performance Monitoring Functions" of ATIS-0600416.1999(R2010) are not applicable and are not supported. Also, the AIS-L defect is only processed and reported by the WIS Receive process; it is never transmitted by the WIS Transmit process. In addition, a PLM-P defect is indistinguishable from an LCD-P defect at the far end, as the two defects are coded identically in the outgoing WIS frame stream; however, as both defects indicate a payload defect, this is of no consequence. They are detected separately for local reporting purposes.

50.3.3 Scrambling

The WIS shall implement a frame-synchronous scrambler within the Transmit process, and shall also implement a frame-synchronous descrambler within the Receive processes, both of sequence length 127 and as specified by Section 10.3 of ATIS-0900105.2008. The use of the scrambler is intended to provide for DC balance (i.e., an equal number of 1's and 0's on average) and for sufficient transition density within the bit stream transmitted on the medium. The scrambler is run over each bit of the entire WIS frame prior to transmission to the PMA, with the exception of all the A1, A2, J0 and Z0 octets (576 octets in total, per WIS frame), which are transmitted and received unscrambled. The scrambling function implemented by the Transmit process is identical in logical construction to the corresponding descrambling function in the Receive process.

Figure 50–9 illustrates the functional diagram of the frame-synchronous scrambler, in bit-serial form.

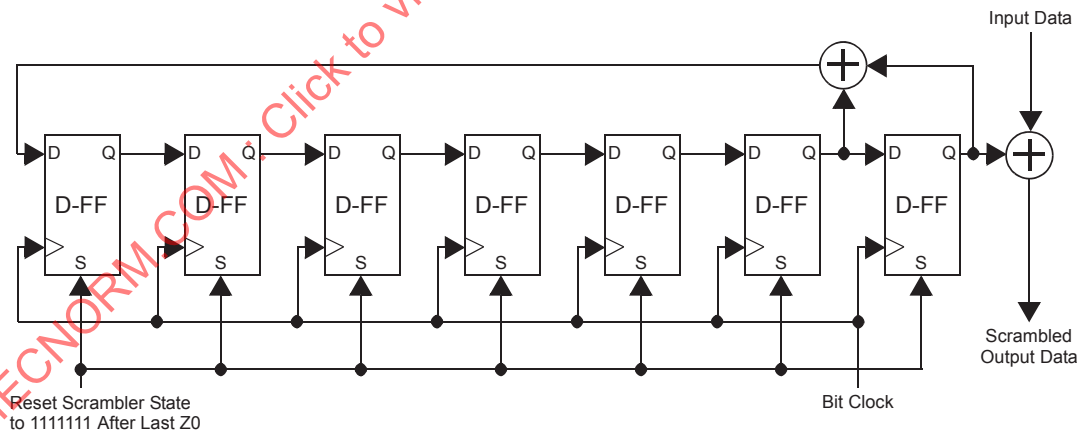

Figure 50–9—Scrambling function (informative)

NOTE—The diagram in Figure 50–9 is intended for reference and informative purposes only. Implementations may select any conforming means of realizing the scrambler function described herein. If a discrepancy is observed between the descriptions and diagram in this section and ATIS-0900105.2008, the latter takes precedence.

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50.3.3.1 Scrambler polynomial

The scrambler polynomial used follows that specified in Section 10.3 of ATIS-0900105.2008. The scrambler state is reset, as specified in the latter, to binary 1111111 prior to processing the octet immediately following the last Z0 octet in every WIS frame.

50.3.3.2 Scrambler bit ordering

The bit ordering considerations for the frame-synchronous scrambler in the WIS are illustrated in Figure 50–10. As shown, the scrambler in effect processes the transmitted (received) WIS frame octet-by-octet, starting with the most-significant (leftmost) bit of the first octet following the last Z0 octet in the WIS frame. The scrambler then proceeds bit-by-bit until the least-significant bit has been reached, after which it continues with the most-significant bit of the second octet.

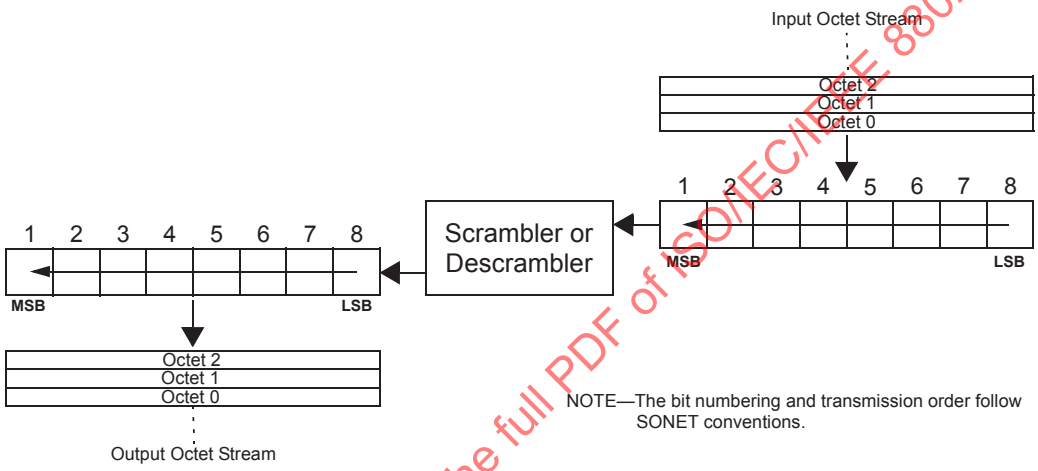

Figure 50–10—Scrambler bit ordering (informative)

NOTE—The above description and diagram are informative.

50.3.4 Octet and frame delineation

The WIS is required to delineate both octet and WIS frame boundaries within the stream of received data words presented by the PMA via its service interface to the Receive process. Delineation of these boundaries and alignment of the received data are done prior to performing the descrambling function (as opposed to the SPE delineation process, which is done after descrambling the received data). The delineation process employs the A1 and A2 octets in the Section Overhead portion of the received WIS frame stream, and searches for valid transitions between A1 and A2 patterns.

The WIS shall implement the synchronization process described in 50.4.2 to delineate octet and WIS frame boundaries. Failure to achieve or maintain synchronization shall result in Severely Errored Frame (SEF) or Loss Of Frame (LOF) Defects being indicated as described in 50.3.2.5.

50.3.5 Error propagation

The WIS Receive and Synchronization processes detect specific errors during reception that prevent delineation of valid data from the incoming WIS frame stream, and cause these errors to be propagated to the 10GBASE-R PCS. Error propagation shall be performed by generating a WIS_SIGNAL.indication primitive with the SIGNAL_OK parameter set to FAIL, regardless of the actual contents of any payload that may be extracted from the incoming WIS frame stream. A subsequent WIS_SIGNAL.indication primitive

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with SIGNAL_OK set to OK shall be issued only after the WIS determines that none of these particular errors exist, subject to the error propagation timing below.

In addition, the WIS Receive process detects a Loss of Code-group Delineation condition, and report it to the far end WIS as an LCD-P defect by the method described in 50.3.2.5.

50.3.5.1 Propagated errors

The following conditions shall be detected as errors and reported to the 10GBASE-R PCS via the mechanism of 50.3.5:

a) The Synchronization process is not in the SYNC state, as defined by the state diagram of 50.4.2.
b) A PLM-P defect is detected (50.3.2.5).
c) An AIS-P defect is detected (50.3.2.5).
d) An LOP-P defect is detected (50.3.2.5).

NOTE—The error propagation mechanism may also be used to indicate when the WIS is unable to supply valid data to the PCS for any other reason, such as an internal error, a reset condition, or when disabled via layer management. This is considered to be implementation specific and is outside the scope of this clause.

50.3.5.2 Error propagation timing

Propagation of errors to the PCS according to the mechanism of 50.3.5 begins as soon as possible after the detection of one or more of the error conditions specified in 50.3.5.1. Error propagation shall terminate, and valid data shall be transferred to the PCS, within 125 microseconds of the removal of all of the error conditions in 50.3.5.1.

50.3.5.3 Loss of Code-group Delineation

The WIS Receive process shall identify a Loss of Code-group Delineation condition if the 10GBASE-R PCS signals, via the WIS_SIGNAL.request(PCS_R_STATUS) primitive of the WIS Service Interface (50.2.3), that synchronization has been lost and valid code-groups are no longer being delineated from the received payload stream being passed to the PCS. The LCD-P defect shall be reported to the far end WIS if this condition persists continuously for at least 3 ms. In addition, re-initialization of the WIS shall cause the LCD-P defect to be reported, with the same timing specification, until the PCS signals that valid code-groups are being delineated. The 3 millisecond timer is not allowed to start timing the false condition of WIS_SIGNAL.request(PCS_R_STATUS) while WIS_SIGNAL.indication is false, thus inhibiting the reporting of the LCD-P defect whenever the WIS is unable to supply valid received data to the PCS.

The WIS Receive process shall identify the absence of a Loss of Code-group Delineation condition if the 10GBASE-R PCS signals, also via the WIS_SIGNAL.request(PCS_R_STATUS) primitive, that synchronization has been regained and valid code-groups are being delineated from the received payload stream. Reporting of the LCD-P defect to the far end WIS shall terminate if the condition has been absent continuously for at least 1 ms.

50.3.6 Mapping between WIS and PMA

As a client of the PMA sublayer, the WIS utilizes the PMA Service Interface to transfer transmitted (received) data-groups to (from) the PMA sublayer. The PMA Service Interface is described in 51.2. Note that the PMA Service Interface may optionally be instantiated as a physical interface, referred to as the XSBI. In this case, the WIS must implement the client portion of the XSBI, including the logical formats and protocols as well as the physical signals and electrical timing, conforming with the XSBI specification in 51.4.

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The WIS Transmit process transfers a continuous stream of 16-bit data-groups, containing the transmit WIS frame data generated as in 50.3.2, to the PMA via the PMA Service Interface. The octet boundaries in the transmit WIS frames shall be aligned to those in the data-groups, and the first data-group transmitted shall contain the first two octets in the Section Overhead (i.e., the first two A1 octets, as illustrated in Figure 50–8). Figure 50–11 depicts the transmission order required from the PMA for the data-groups. Each 16-bit data-group shall be transmitted from left to right, with lower-numbered bits being transmitted before higher-numbered bits. The data-groups themselves shall be transmitted in the sequence in which they are presented to the PMA by the WIS Transmit process.

A similar ordering is required during the reception process, as shown in Figure 50–11. Successive received bits shall be ordered from left to right in the 16-bit data-groups that are passed to the WIS (i.e., lower-numbered bits are received before higher-numbered bits), and the data-groups must be presented in the sequence in which they were received. The PMA sublayer is not required to align the data being presented to the WIS on any boundary.

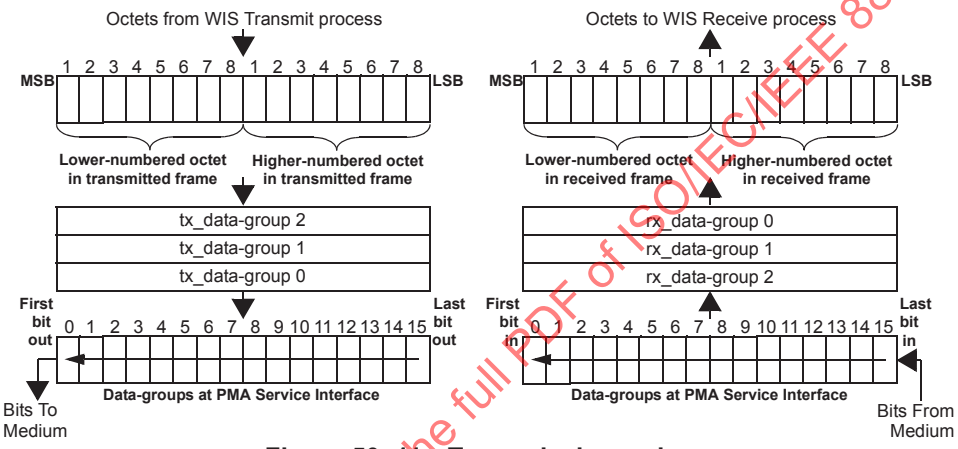

Figure 50–11—Transmission order

The WIS also utilizes the PMA_SIGNAL.indication primitive received from the PMA sublayer to determine when the PMA is unable to provide valid data to the WIS via its service interface. This primitive is used to unlock the state diagram implemented in the Synchronization process and force it to re-synchronize, as described in 50.4.

NOTE—The PMA_SIGNAL.indication primitive received from the PMA differs from the Loss of Signal (LOS) defect described in 50.3.2.5. LOS is a status condition that is reported to Layer Management for error monitoring purposes, but otherwise does not affect the internal functioning of the Receive Process or the Synchronization Process. The PMA primitive, however, acts as a control signal that directly affects all parts of the WIS receive functionality.

50.3.7 WIS data delay constraints

The sum of the transmit and receive data delays for any implementation of the WIS shall not exceed 14336 BT. Transmit data delay is measured from the input of a given unit of data by the PCS at the WIS service interface to the presentation of the same unit of data by the WIS to the PMA at the PMA service interface. Receive data delay is measured from the input of a given unit of data by the PMA at the PMA service interface to the presentation of the same unit of data by the WIS to the PCS at the WIS service interface. The time required to insert or process any necessary overhead or stuff octets must be included as part of the data delay incurred by the WIS. No constraint is placed on the individual values of the transmit and receive data delays for a given implementation, provided their sum falls within the above limit.

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50.3.8 WIS test-pattern generator and checker

The WIS shall incorporate a test-pattern generator and a test-pattern checker to permit in-circuit testing using test patterns. These serial test patterns allow the 10GBASE-W PMA and PMD sublayers to be tested for compliance while in a system environment. Three patterns have been defined for testing: a fixed square wave pattern, an optional PRBS31 pattern, and a framed mixed frequency pattern. The patterns may be implemented at a bit or frame level and may be used for transmitter testing. The test-pattern checker has the ability to synchronize to the PRBS31 and mixed-frequency test patterns and report bit errors detected within the payload to the Station Management entity. The test-pattern checker is not required to synchronize to or analyze the square wave pattern.

The transmit and receive portions of the WIS can be placed in test-pattern mode separately by means of the WIS Transmit test-pattern enable and WIS Receive test-pattern enable control bits supported within its management registers (see 45.2.2.6). In addition, the three different types of transmit test pattern (square-wave, PRBS31 and mixed frequency) may be selected by means of the test-pattern control bits. (The test-pattern receiver only operates in PRBS31 and mixed-frequency test-pattern modes.) Errors detected during PRBS31 testing are recorded and provided to the Station Management entity via the 10G WIS test-pattern error counter register (45.2.2.8), while errors detected during mixed frequency testing are recorded and provided to the Station Management entity via the 10G WIS Section BIP Error Count register (45.2.2.17), the 10G WIS Line BIP Errors register (45.2.2.15), and the 10G WIS Path Block Error Count register (45.2.2.16). The WIS Service Interface is inoperative when either the WIS Transmit process or WIS Receive process is placed in test-pattern mode, regardless of the type of test pattern selected.

When the WIS transmit function is operating in test-pattern mode, the test-pattern generator produces a continuous test pattern that is sent 16 bits at a time to the underlying PMA sublayer via PMA_UNITDATA.request primitives. When the WIS receive function is operating in test-pattern mode, 16-bit data-groups received from the underlying PMA sublayer by means of PMA_UNITDATA.indication primitives are accepted and processed by the test-pattern checker.

50.3.8.1 Square wave test pattern

In the square-wave test-pattern mode, the WIS Transmit process is disabled or otherwise prevented from processing data, and a square wave as defined in 52.9.1 shall be continuously transferred to the PMA via the PMA Service Interface. No checking is performed on the 16-bit data-groups received from the PMA sublayer in this mode.

50.3.8.2 PRBS31 test pattern

The PRBS31 test-pattern mode is optional. When the transmit portion of the WIS is operating in PRBS31 test-pattern mode, the WIS Transmit process is disabled or otherwise prevented from processing data, and the output of a Pseudo-Random Bit Sequence (PRBS) generator shall be continuously transferred to the PMA via the PMA Service Interface. The PRBS generator functionality is described in 49.2.8.

When the receive portion of the WIS is operating in PRBS31 test-pattern mode, the WIS Receive Process is disabled or otherwise prevented from processing data, and a PRBS pattern checker shall check the bits received from the PMA via the PMA Service Interface. The PRBS checker functionality is described in 49.2.12.

If no errors have occurred, the test-pattern error signal from the pattern checker will be zero. An isolated bit error will cause the test-pattern error signal to be asserted three times; once when it is received and once when it is at each tap. The 10G WIS test-pattern error counter register (45.2.2.8) shall be incremented whenever the test-pattern error signal is asserted.

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50.3.8.3 Mixed-frequency test pattern

In the mixed-frequency test-pattern mode, the WIS Transmit process is utilized to generate a transmitted test pattern (if activated by the WIS Transmit test-pattern enable control bit) and the WIS Synchronization and Receive processes are utilized to check a received test pattern (if separately activated by the WIS Receive test-pattern enable control bit). Figure 50–12 provides a functional diagram of the WIS when operating in this mode.

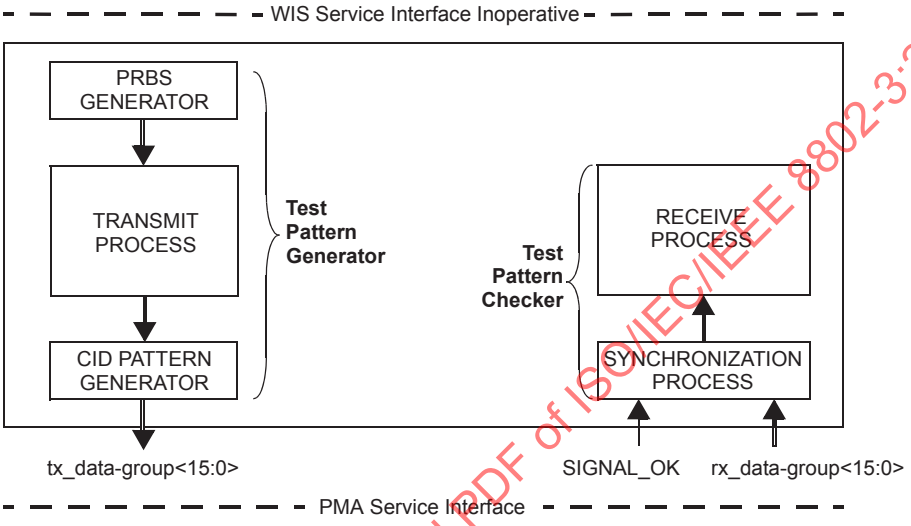

Figure 50–12—Mixed-frequency test-pattern mode operation

The mixed-frequency test pattern has the Test Signal Structure (TSS) described by 50.3.8.3.1, with a Consecutive Identical Digit (CID) pattern described by 50.3.8.3.2. The pattern is generated using the WIS Transmit process, with the SPE payload capacity being filled with a (2^{23}– 1) pseudo-random bit sequence (PRBS) as defined by ITU-T Recommendation O.150, 1996, in conjunction with a CID pattern generator that overwrites the last nine Z0 octets of the Section Overhead (see Figure 50–8) with an alternating pattern. The WIS Synchronization and Receive processes operate normally. Bit errors in the received pattern shall be detected by means of the Section, Line and Path BIP checking facilities, and reported to Station Management by means of the corresponding error counters within the MDIO register space (see 50.3.8).

NOTE 1—The PRBS is substituted for the payload data that would normally be sent to the WIS Transmit process from the 10GBASE-R PCS. The CID pattern is selected to stress the lock range of the receiver circuitry, and is placed in the Z0 octet locations as these are not scrambled by the WIS Transmit process. The values of the Z0 octets are required to be ignored by the WIS Receive process (see 50.3.2.4), and therefore no change to the latter is necessary.

The WIS Transmit, Receive and Synchronization processes shall function as described in 50.3.2, 50.3.3, and 50.3.4, with the exception that fault processing as per 50.3.2.5 and error propagation as per 50.3.5 shall not be carried out, the Z0 octets shall be overwritten with a CID pattern as specified, and the data output by the PRBS generator shall be used as the data source in place of the PCS.

NOTE 2—The implied re-use of the WIS Transmit, Receive, and Synchronization processes to implement the mixed-frequency test pattern functions is not a required attribute; implementations may select any physical means of realizing the test-pattern transmit and receive functionality, provided that the external behavior of the WIS conforms to that described herein.

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50.3.8.3.1 Test Signal Structure (TSS)

The TSS is defined as a repeating set of two consecutive WIS frames, i.e., 300 672 octets in length, and shall be formatted as shown in Figure 50–13. The first frame of the set has a CID pattern set to all zeros, and the second frame has the pattern set to all ones. The PRBS generator shall be reset to all ones prior to the start of the payload capacity of each SPE contained within the TSS. In addition, the PRBS generator output shall be placed directly into the payload capacity of the first SPE, and inverted before being placed into the second SPE. Both WIS frames include the Section, Line, and Path Overhead and fixed stuff as normally generated by the Transmit process. All overhead octets except for J1 shall be set to their default values.

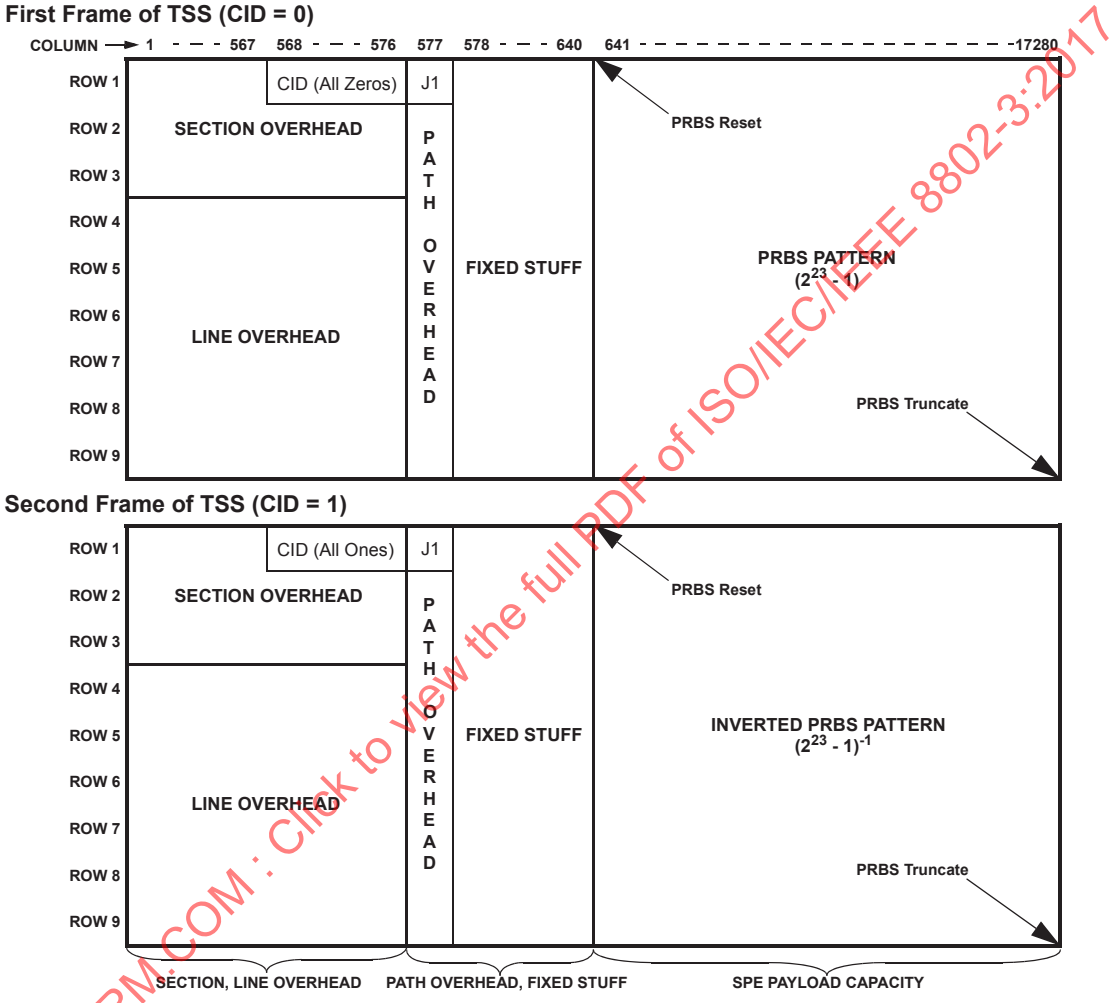

Figure 50–13—Test Signal Structure

As shown in Figure 50–13, the J1 octet of the Path Overhead is located immediately following the last octet of the CID pattern, and is hence the point of maximum stress with respect to the 10GBASE-W PMA and PMD. The J1 octet may therefore be programmed via the 10G WIS J1 transmit Registers (45.2.2.12) to a fixed value that, after scrambling, provides optimal stress to the PMA/PMD transmitter and receiver. If not used for this purpose, it shall be set to a value of 89 hexadecimal in both the WIS frames comprising the TSS.

NOTE—Standard SONET test equipment may not support the WIS test-pattern generator and checker as the PRBS is re-synchronized on every WIS frame, instead of the free-running PRBS described in ITU-T Recommendation O.172. Pattern-based bit error ratio testers will require 300 672 bytes of pattern storage memory to hold the complete TSS.

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50.3.8.3.2 Continuous Identical Digits

The CID pattern shall comprise 9 octets (72 bits) overwriting the Z0 octets at the end of the first row of the Section Overhead, as shown in Figure 50–14. The pattern shall alternate in consecutive WIS frames; in the first frame of the TSS, the pattern consists of 72 bits of zeros, and in the second frame the pattern consists of 72 bits of all ones.

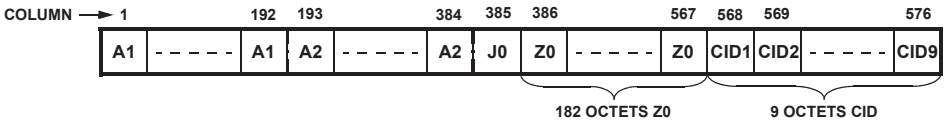

Figure 50–14—CID pattern structure

As the CID pattern is not scrambled, the string of ones (and, alternately, the string of zeros) forming the pattern produce transition-free areas within the TSS that stress the transmitter and receiver. Errors (eye closure at the transmitter or sampling errors at the receiver) are reflected as bit errors that are detected and reported via the BIP checking functionality in the WIS.

50.3.9 Loopback

The WIS is placed in Loopback mode when the Loopback bit in the WIS Control 1 register (45.2.2.1.2) is set to a logic one. In this mode, the WIS shall accept data on the transmit path from the 10GBASE-R PCS and return it on the receive path to the 10GBASE-R PCS. In addition, the WIS shall transmit a constant pattern to the PMA sublayer, and shall ignore all data presented to it by the PMA sublayer. The pattern output to the PMA transmit path at this time shall consist of a sequence of 8 logic zero bits and 8 logic one bits, forming the 16-bit word 00-FF hexadecimal. No SONET overhead or fixed stuff is output to the PMA at this time.

NOTE—The signal path through the WIS that is exercised in the Loopback mode of operation is implementation specific, but it is recommended that this signal path encompass as much of the WIS circuitry as is practical. The intention of providing this Loopback mode of operation is to permit diagnostic or self-test functions to test the transmit and receive data paths using actual data, while ensuring that remote entities do not interpret this test data as valid information. Other loopback signal paths may also be enabled independently using loopback controls within other devices or sublayers.

50.3.10 Link status

The WIS link status, as reported in the Link status bit of the WIS status 1 register (see 45.2.2.2.2), shall be set to down if a PLM-P, AIS-P, or LOP-P defect is detected (50.3.5.1), an AIS-L defect is detected (50.3.2.5), or the Synchronization process is not in the SYNC state (50.4.2). Otherwise, the WIS link status is set to up.

50.3.11 Management interface

The WIS supports a set of required and optional management objects to permit it to be controlled by the Station Management entity (STA). Access to management objects within the WIS is accomplished by means of a set of registers within the MDIO register space as defined in 45.2.2, which are implemented by the Link Management function depicted in Figure 50–2.

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50.3.11.1 Management registers

The WIS management interface function shall utilize the following dedicated management registers:

a) WIS Control 1 register (Register 0)
b) WIS status 1 register (Register 1)
c) WIS Control 2 register (Register 7)
d) WIS status 2 register (Register 8)
e) WIS test-pattern error counter register (Register 9)
f) WIS Status 3 register (Register 33)
g) WIS J0 transmit register (Registers 64, 65, 66, 67, 68, 69, 70, 71)
h) WIS J0 receive register (Registers 72, 73, 74, 75, 76, 77, 78, 79)
i) WIS Far End Path Block Error Count register (Register 37)
j) WIS J1 transmit register (Registers 39, 40, 41, 42, 43, 44, 45, 46)
k) WIS J1 receive register (Registers 47, 48, 49, 50, 51, 52, 53, 54)
l) WIS Far End Line BIP Errors register pair (Registers 55 and 56)
m) WIS Line BIP Errors register pair (Register 57 and 58)
n) WIS Path Block Error Count register (Register 59)
o) WIS Section BIP Error Count register (Register 60)

These registers are implemented within the Device address space assigned to the WIS. The details of the register bit allocations and general usage are given in Clause 45. Note that Clause 45 also specifies several registers and register bits that are generic to every Device (e.g., Speed Ability and Identifier registers), and these are not covered by this clause.

NOTE—Clause 45 provides for additional vendor-specific registers within the address space assigned to the WIS. The presence, format, and function of these registers are implementation specific.

If the optional MDIO interface and associated register set are not implemented for the WIS, then equivalent capabilities are required to be provided.

50.3.11.2 WIS managed object class

The WIS Managed Object Class is defined in 30.8.1.

50.3.11.3 Management support objects

The following counters shall be provided to facilitate support of the WIS managed object class. If an MDIO interface is provided for the WIS, these counters are accessed via the WIS Far End Line BIP Errors and WIS Line BIP Errors registers, as described in 45.2.2.14 and 45.2.2.15 respectively. If no MDIO interface is implemented, these counters are to be accessible by equivalent means.

Far End Line BIP Errors
: A 32-bit counter that is incremented by the number of Line BIP errors detected by the far-end WIS and reported via the M1 octet present in each received WIS frame (see 50.3.2.5). This counter has a maximum increment rate of 2 040 000 counts per second. The counter is cleared to zero when the WIS is reset, and wraps around to zero when it is incremented beyond the maximum count value. The contents of this counter are reflected in the WIS Far End Line BIP Errors register pair.

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Line BIP Errors

A 32-bit counter that is incremented by the number of Line BIP errors detected by the Receive process while processing each received WIS frame (see 50.3.2.5). This counter has a maximum increment rate of 12 288 000 counts per second. The counter is cleared to zero when the WIS is reset, and wraps around to zero when it is incremented beyond the maximum count value. The contents of this counter are reflected in the WIS Line BIP Errors register pair.

50.4 Synchronization state diagram

The WIS Synchronization process shall implement the state diagrams specified in this subclause and meet the corresponding state diagram interface requirements, also specified here. Additional requirements to this state diagrams are made in 50.3.4. In the case of any ambiguity between the text and the state diagrams, the state diagrams shall take precedence.

The notation used in the state diagrams is described in 21.5, and the conventions for state diagram timers in 14.2.3.2. The notation ++ after a counter or integer variable indicates that its value is to be incremented by 1.

50.4.1 State diagram variables

Variables of the form name<x:0> indicate arrays or vectors of bits; for such variables, "<x>" indexes an element or set of elements in the array or vector, where "x" may be as follows:

— Any integer or set of integers.
— Any variable that takes on integer values.

In the variable and function descriptions in 50.4.1.2 and 50.4.1.3, the parameters *f*, *i*, *j*, *k*, *m*, and *n* are implementation-specific. Maximum and minimum values for these parameters are specified in 50.4.3.

50.4.1.1 Constants

A1

An octet value (bits 1:8) of 11110110 as assigned to the A1 framing character within the SONET Section Overhead, as specified in Table 1 of Section 4.2 of ATIS-0600416.1999(R2010). Used to obtain octet and WIS frame alignment.

A2

An octet value (bits 1:8) of 00101000 as assigned to the A2 framing character within the SONET Section Overhead, as specified in Table 1 of Section 4.2 of ATIS-0600416.1999(R2010). Used to obtain octet and WIS frame alignment.

Hunt_Pattern

A sequence of *i* consecutive A1 octets.

Presync_Pattern

A sequence of *j* consecutive A1 octets, immediately followed by a sequence of *k* consecutive A2 octets.

Sync_Pattern

A sequence of *f* consecutive A1 octets immediately followed by a sequence of *f* consecutive A2 octets.

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50.4.1.2 Variables

power_on

A condition that is true until such time as the power supply to the device containing the WIS has reached the operating region.

Values: FALSE; The device is completely powered and ready to operate.
TRUE; The device has not been completely powered.

reset

A Boolean variable that is true when a hardware reset has been applied to the WIS, and false otherwise.

Values: TRUE; A hardware reset is being applied.
FALSE; A hardware reset is not being applied.

signal_fail

A condition that is true whenever the underlying PMA sublayer indicates by means of the PMA_SIGNAL.indication primitive that valid data are not being supplied to the WIS. Once set to TRUE, signal_fail remains set until the PMA sublayer explicitly indicates that valid data are being recovered and supplied to the WIS, after which it is set to FALSE.

Values: FALSE; A PMA_SIGNAL.indication(SIGNAL_OK) primitive was received with SIGNAL_OK set to OK, indicating that the PMA has begun to provide valid data to the WIS Receive process.
TRUE; A PMA_SIGNAL.indication(SIGNAL_OK) primitive was received with SIGNAL_OK set to FAIL, indicating that the PMA is unable to provide valid data to the WIS Receive process.

in_HUNT

Boolean variable, set by the Primary Synchronization state diagram to indicate to the Interval Pattern Search state diagram to indicate that it has entered, or returned to, the HUNT state.

Values: TRUE; The Primary Synchronization state diagram is presently in the HUNT state.
FALSE; The Primary Synchronization state diagram is not in the HUNT state.

sync_start

Boolean variable, set by the Primary Synchronization state diagram to trigger the operation of the Interval Pattern Search state diagram.

Values: TRUE; The Interval Pattern Search state diagram should begin scanning for framing sequences.
FALSE; The Interval Pattern Search state diagram should not begin scanning.

50.4.1.3 Functions

found_Hunt

For each bit input to the Synchronization process, this function indicates whether the Hunt_Pattern pattern has been detected in the bit string formed by concatenating the current bit with the (i * 8 – 1) consecutive previously input bits. If the number of bits previously input is less than (i * 8 – 1), this function outputs a FALSE value. Note that this function inspects its input on a bit-by-bit basis.

Values: TRUE; The (i * 8) bits examined so far, consisting of the current bit plus previously input bits, matches Hunt_Pattern.
FALSE; The pattern is not matched, or less than (i * 8) bits have been input so far.

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found_Presync

For the last ($j + k$) sets of 8 bits (1 octet) input to the Synchronization process, this function indicates whether the Presync_Pattern pattern has been matched. If the number of octets previously input is less than ($j + k$), or the string match is still proceeding, this function outputs a WAIT value. Note that this function inspects its input on an octet-by-octet basis.

Values: TRUE; The octets examined so far, consisting of the current octet plus previously input bits, matches Presync_Pattern.
FALSE; The pattern is not matched.
WAIT; Insufficient data has been received so far to complete the match or declare failure.

found_Sync

For the last 2f sets of 8 bits (1 octet) input to the Synchronization process, this function indicates whether the Sync_Pattern pattern has been matched. If the number of octets previously input is less than 2f, the function outputs a FALSE value. Note that this function inspects its input on an octet-by-octet basis.

Values: TRUE; The octets examined so far, consisting of the current octet plus previously input octets, matches Sync_Pattern.
FALSE; The pattern is not matched, or insufficient octets have been received so far.

50.4.1.4 Counters

good_sync_cnt

Count of the number of consecutive candidate Sync_Pattern pattern locations that contain a valid Sync_Pattern pattern. This counter is controlled by the Interval Pattern Search state diagram, and used to report the number of valid framing locations to the Primary Synchronization state diagram.

bad_sync_cnt

Count of the number of consecutive candidate Sync_Pattern pattern locations that have failed to contain a valid Sync_Pattern pattern. This counter is controlled by the Interval Pattern Search state diagram, and used to report the number of mismatched framing locations to the Primary Synchronization state diagram.

octet_cnt

Count of octets input to the Synchronization process; always increments for every octet input. This counter is forced to zero in specific states of the Interval Pattern Search state diagram, but for all other states it increments by 1 for each octet received. It is used to force the state diagram to wait in a given state until a required number of octets have been received.

50.4.2 State diagram

The Primary Synchronization state diagram is depicted in Figure 50–15, and the Interval Pattern Search state diagram in Figure 50–16. The WIS shall implement the Synchronization process according to these state diagrams, including compliance with the associated state variables as specified in 50.4.1. The Synchronization process is responsible for detecting octet and WIS frame boundaries and also for determining whether the underlying receive channel is ready for operation. Failure to achieve synchronization, as indicated by the Synchronization state diagram not being in the SYNC state, shall cause the WIS Receive process to suspend normal operation and propagate the error to the PCS as described in 50.3.5.

The function of the Primary Synchronization state diagram is to track the four phases through which the Synchronization process must progress in order to achieve and maintain lock to the incoming frame stream. In the first phase, the state diagram performs a bit-by-bit hunt over the input data for a string of A1 octets.

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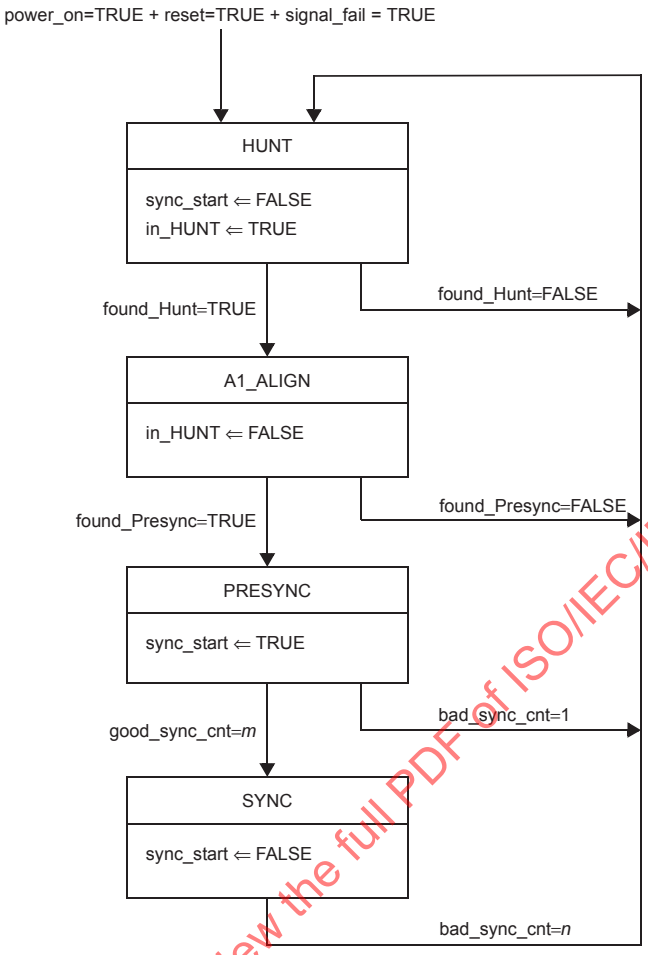

Figure 50–15—Primary Synchronization state diagram

Successful location of several A1 octets indicates both a candidate octet and a candidate frame boundary; this is validated by scanning for additional A1 octets followed immediately by another string of A2 octets, which corresponds to the framing pattern present at the start of every WIS frame. The candidate frame boundary is now confirmed by searching for several consecutive such patterns, each separated by a frame size; if successful, frame lock is deemed to have been achieved. The state diagram then remains in the frame lock state until a number of consecutive candidate pattern locations have failed to match the A1/A2 pattern. This behavior implements the necessary hysteresis required to reject transient bit errors.

The Interval Pattern Search state diagram is activated when the Synchronization process has successfully located the first occurrence of the framing pattern, and performs the actual function of searching for subsequent framing patterns that are located 155 520 octets apart, and counting failed and successful matches.

The functions fount_Hunt, found_Presync, and found_Sync implement bit and octet scanners that search through the incoming data stream for the respective data patterns that must be matched.

NOTE—Implementations may choose any conforming means of realizing the state diagram described herein, provided that the external behavior of the Synchronization process is unchanged.

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50.4.3 Parameter values

Table 50–5 identifies the minimum and maximum values permissible for the parameters *f*, *i*, *j*, *k*, *m*, and *n* that are used in the preceding state diagram descriptions. Implementations shall set these parameters to values within the limits specified in the table.

Table 50–5—Minimum and maximum parameter values

Parameters	Minimum values	Maximum values	Purpose
f	2	192	Controls width of Sync_Pattern pattern
i	1	192	Controls width of Hunt_Pattern pattern
j	16	190	Controls width of Presync_Pattern pattern
k	16	192	Controls width of Presync_Pattern pattern
m	4	8	Controls hysteresis for SYNC state entry
n	1	8	Controls hysteresis for SYNC state exit

NOTE—The ranges for the parameters stipulated in Table 50–5 are intended to provide the implementer with latitude in creating implementations of the Synchronization process. However, adherence to the stipulated minimum values for the parameters will result in an implementation that provides the minimum time-to-frame (5 WIS frame periods) and required bit error tolerance at the normal BER (10^{-12}).

50.5 Environmental specifications

All equipment subject to this clause shall conform to the requirements of 14.7 and applicable sections of ISO/IEC 11801:1995.

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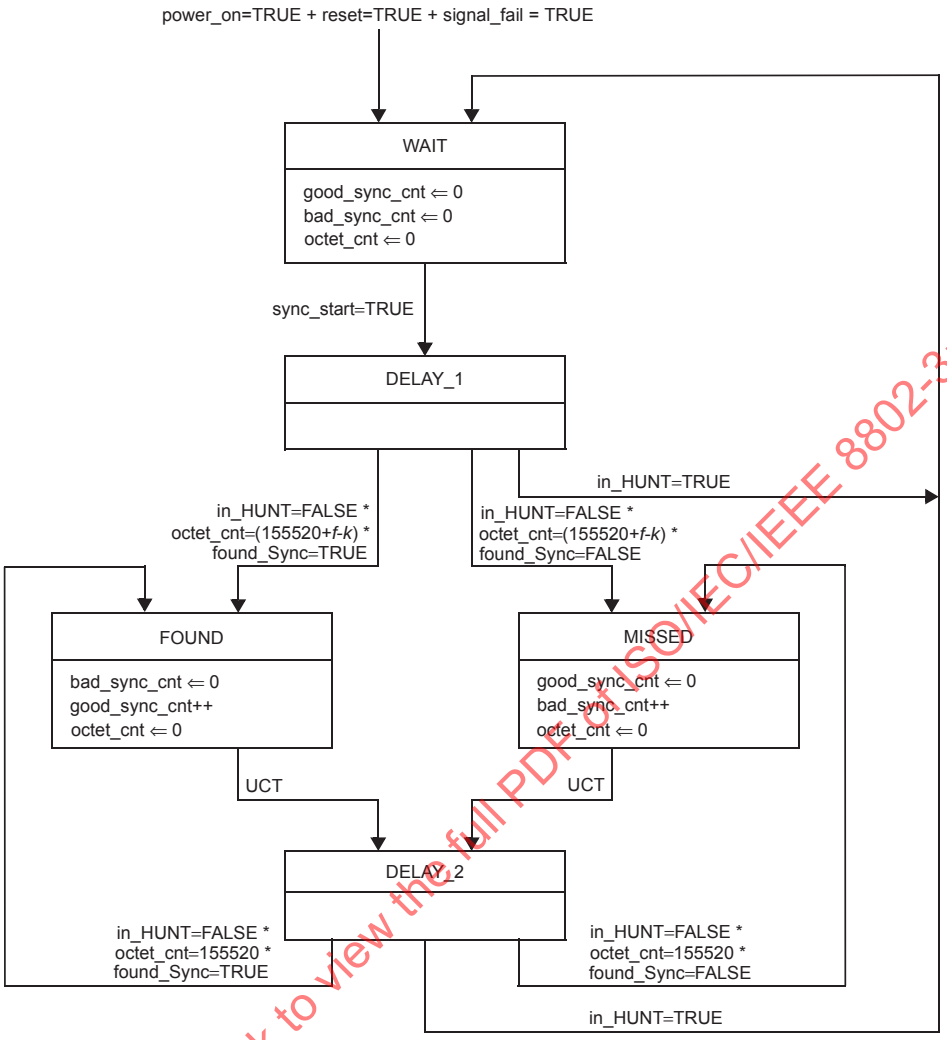

Figure 50–16—Interval Pattern Search state diagram

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50.6 Protocol implementation conformance statement (PICS) proforma for Clause 50, WAN Interface Sublayer (WIS), type 10GBASE-W[11]

50.6.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 50, WAN Interface Sublayer, type 10GBASE-W, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the same, can be found in Clause 21.

50.6.2 Identification

50.6.2.1 Implementation identification

Supplier[1]	
Contact point for inquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1,3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

50.6.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, WAN Interface Sublayer (WIS), type 10GBASE-W
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	

Date of Statement	

[11] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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50.6.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
XSBI	XSBI compatibility interface	51, 50.3.6	Compatibility interface supported	O	Yes [ ] No [ ]
*MD	MDIO	50.3.11.1	Registers and interface supported	O	Yes [ ] No [ ]
*PRBS	PRBS31 Test-pattern mode	50.3.8.2	Registers and functionality supported	O	Yes [ ] No [ ]

50.6.4 PICS proforma tables for the WAN Interface Sublayer (WIS), type 10GBASE-W

50.6.4.1 Compatibility considerations

Item	Feature	Subclause	Value/Comment	Status	Support
CC1	Meets requirements of ATIS-0600416.1999(R2010)	50.1.1	Except as specifically excluded	M	
CC2	Precedence of ATIS-0600416.1999(R2010) and ANSI T1.269-2000 in case of discrepancies	50.3.2, 50.3.2.1, 50.3.2.3, 50.3.3	Unless specifically overridden by Clause 50	M	
CC3	Environmental specifications	50.5		M	Yes [ ]

50.6.4.2 WIS transmit functions

Item	Feature	Subclause	Value/Comment	Status	Support
WT1	Bit significance of data-unit vector from 10GBASE-R PCS	50.2.1.1	Data-unit<0> is interpreted as the least-significant bit	M	Yes [ ]
WT2	Payload mapping of octets from data-units to SPE by Transmit process	50.3.1.1	Tx_data-unit<7:0> mapped to lower-numbered (even) octet and tx_data-unit<15:8> to next higher-numbered (odd) octet	M	Yes [ ]
WT3	Bit relabeling during transmit mapping	50.3.1.1	Ethernet FCS error detection properties to be maintained	M	Yes [ ]
WT4	Path Overhead generation	50.3.2.1		M	Yes [ ]
WT5	J1 octet in Path Overhead	50.3.2.1	Transports a 16-octet repeating Path Trace Message	M	Yes [ ]
WT6	Default Path Trace Message	50.3.2.1	Consists of 15 octets of zeros and a header octet	M	Yes [ ]
WT7	Line Overhead generation	50.3.2.2		M	Yes [ ]
WT8	Unspecified Line Overhead octets	50.3.2.2	Set to 00000000 binary if not specifically listed	M	Yes [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
WT9	H1 and H2 octets in Line Overhead	50.3.2.2	Set to 522 decimal and also indicates concatenated payload	M	Yes [ ]
WT10	K1 octet in Line Overhead	50.3.2.2	Set to 00000000 binary	M	Yes [ ]
WT11	Bits 1 to 5 of K2 octet in Line Overhead	50.3.2.2	Set to 00000 binary	M	Yes [ ]
WT12	Bits 6 to 8 of K2 octet in Line Overhead	50.3.2.2	Set to either an RDI-L encoding, or 000 binary	M	Yes [ ]
WT13	Section Overhead generation	50.3.2.3		M	Yes [ ]
WT14	Unspecified Section Overhead octets	50.3.2.3	Set to 00000000 binary if not specifically listed	M	Yes [ ]
WT15	J0 octet in Section Overhead	50.3.2.3	Transports a 16-octet repeating Section Trace Message	M	Yes [ ]
WT16	Default Section Trace Message	50.3.2.3	Consists of 15 octets of zeros and a header octet	M	Yes [ ]
WT17	Frame scrambler	50.3.3		M	Yes [ ]
WT18	Octet ordering to PMA	50.3.6	First data-group transmitted contains the first two A1 octets	M	Yes [ ]
WT19	Bit ordering to PMA	50.3.6	Ethernet FCS error detection properties to be maintained	M	Yes [ ]
WT20	Data-group ordering to PMA	50.3.6		M	Yes [ ]
WT21	Transmit data delay constraint	50.3.7	Sum of transmit and receive data delays not to exceed 14336 BT	M	Yes [ ]

50.6.4.3 WIS receive functions

Item	Feature	Subclause	Value/Comment	Status	Support
WR1	Bit significance of data-unit vector to 10GBASE-R PCS	50.2.2.1	Data-unit<0> is interpreted as the least-significant bit	M	Yes [ ]
WR2	Payload mapping of octets from SPE to data-units	50.3.1.2	Rx_data-unit<7:0> mapped from lower-numbered (even) octet and rx_data-unit<15:8> from next higher-numbered (odd) octet	M	Yes [ ]
WR3	Bit relabeling during receive mapping	50.3.1.2	Ethernet FCS error detection properties to be maintained	M	Yes [ ]
WR4	Section, Line, and Path Overhead extraction and processing	50.3.2.4		M	Yes [ ]
WR5	Unsupported overhead octets	50.3.2.4	Ignored if marked as unsupported in Tables 50–1, 50–2, and 50–3	M	Yes [ ]
WR6	Unlisted overhead octets	50.3.2.4	Ignored if not listed in Table 1 of ATIS-0600416.1999(R2010)	M	Yes [ ]
WR7	Interpretation of J1 octet in Path Overhead	50.3.2.4	Interpreted as carrying a 16-byte repeating Path Trace Message	M	Yes [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
WR8	Extraction of valid Path Trace Message data	50.3.2.4	After receiver accomplishes synchronization	M	Yes [ ]
WR9	Interpretation of bits 6 through 8 of K2 octet in Line Overhead	50.3.2.4	Interpreted as carrying AIS-L or RDI-L	M	Yes [ ]
WR10	Unsupported encodings of bits 6 through 8 of K2 octet in Line Overhead	50.3.2.4	Ignored by receiver	M	Yes [ ]
WR11	Interpretation of J0 octet in Path Overhead	50.3.2.4	Interpreted as carrying a 16-byte repeating Section Trace Message	M	Yes [ ]
WR12	Extraction of valid Section Trace Message data	50.3.2.4	After receiver accomplishes synchronization	M	Yes [ ]
WR13	Detection of Section, Line and Path Defects and Anomalies	50.3.2.5	Only Defects and Anomalies listed in Table 50–4 processed	M	Yes [ ]
WR14	Support for PLM-P and LCD-P defects	50.3.2.5		M	Yes [ ]
WR15	Detection of LOS defect	50.3.2.5	No services provided by the PMA or PMD are used	M	Yes [ ]
WR16	LOS defect detection parameters	50.3.2.5	Parameters *T* and *T'* between 2.3 and 100 microseconds	M	Yes [ ]
WR17	Frame descrambler	50.3.3		M	Yes [ ]
WR18	Bit, octet and data-group ordering from PMA	50.3.6	Ethernet FCS error detection properties to be maintained	M	Yes [ ]
WR19	Delineation of octet and WIS frame boundaries	50.3.4	According to Synchronization process	M	Yes [ ]
WR20	Reporting of errors on synchronization failure	50.3.4	SEF or LOF defects reported on synchronization failure	M	Yes [ ]
WR21	Receive data delay constraint	50.3.7	Sum of transmit and receive data delays not to exceed 14336 BT	M	Yes [ ]

50.6.4.4 State diagrams

Item	Feature	Subclause	Value/Comment	Status	Support
SD1	Synchronization state diagram	50.4	Meets the requirements of Figures 50–15 and 50–16	M	Yes [ ]
SD2	Synchronization process	50.4.2		M	Yes [ ]
SD3	Receive process suspended upon failure to achieve synchronization	50.4.2		M	Yes [ ]
SD4	Synchronization parameters	50.4.3	Meets the requirements of Table 50–5	M	Yes [ ]

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50.6.4.5 Error notification

Item	Feature	Subclause	Value/Comment	Status	Support
EN1	Notification of fault presence to PCS	50.3.5	WIS_SIGNAL.indication SIGNAL_OK set to FAIL	M	Yes [ ]
EN2	Removal of fault notification to PCS in the absence of faults	50.3.5	WIS_SIGNAL.indication SIGNAL_OK set to OK	M	Yes [ ]
EN3	Faults notified to PCS	50.3.5.1	Detects and reports the following errors: Synchronization process not in SYNC state, PLM-P defect, AIS-P defect, and LOP-P defect	M	Yes [ ]
EN4	PCS fault notification timing	50.3.5.2	Error propagation terminates, and valid data transferred, within 125 microseconds after error conditions removed	M	Yes [ ]
EN5	Presence of Loss of Code-group Delineation condition	50.3.5.3	When indicated by the 10GBASE-R PCS	M	Yes [ ]
EN6	Reporting of Loss of Code-group Delineation presence	50.3.5.3	Reported only if condition persists for more than 3 ms	M	Yes [ ]
EN7	Reporting with respect to WIS re-initialization	50.3.5.3	Report Loss of Code-group Delineation on re-initialization	M	Yes [ ]
EN8	Absence of Loss of Code-group Delineation condition	50.3.5.3	When indicated by the 10GBASE-R PCS	M	Yes [ ]
EN9	Reporting of Loss of Code-group Delineation absence	50.3.5.3	Reported only if condition is absent for more than 1 ms	M	Yes [ ]

50.6.4.6 Management registers and functions

Item	Feature	Subclause	Value/Comment	Status	Support
MR1	Management registers	50.3.11.1	If management registers are not physically implemented, equivalent capabilities must be provided	MD:M	Yes [ ]
MR2	Management support objects	50.3.11.3	If management interface is not physically implemented, equivalent capabilities must be provided	MD:M	Yes [ ]
MR3	Loopback function	50.3.9	Data accepted on the transmit path from the 10GBASE-R PCS returned via the receive path	M	Yes [ ]
MR4	Data transmitted to PMA during loopback	50.3.9	The 16-bit pattern 00-FF hexadecimal must be transmitted	M	Yes [ ]
MR5	Data received from PMA during loopback	50.3.9	All data received from PMA during loopback must be ignored	M	Yes [ ]
MR6	WIS link status function	50.3.10	Set to up or down as defined	M	Yes [ ]

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50.6.4.7 WIS test-pattern generator and checker

Item	Feature	Subclause	Value/Comment	Status	Support
TP1	Test-pattern generator and checker	50.3.8	Separate generator and checker functionality for transmit and receive	M	Yes [ ]
TP2	Data pattern used in square-wave test-pattern mode	50.3.8.1	Data pattern as specified in 52.9.1	M	Yes [ ]
TP3	PRBS31 generator functionality	50.3.8.2		PRBS:M	Yes [ ]
TP4	PRBS31 checker functionality	50.3.8.2		PRBS:M	Yes [ ]
TP5	Bit error detection and reporting by PRBS31 checker	50.3.8.2	If management interface is not physically implemented, equivalent reporting capabilities must be provided	PRBS:M	Yes [ ]
TP6	Bit error detection in received mixed-frequency test pattern	50.3.8.3	Detection by Section, Line and Path BIP checking facilities	M	Yes [ ]
TP7	Functionality of WIS Transmit, Receive and Synchronization processed in mixed-frequency test-pattern mode	50.3.8.3	With the exceptions that fault processing and error propagation are not carried out, the Z0 octets are overwritten with CID pattern, and a PRBS used in place of the PCS data	M	Yes [ ]
TP8	Format of TSS	50.3.8.3.1		M	Yes [ ]
TP9	PRBS generator reset in TSS	50.3.8.3.1	Reset to all-ones prior to start of SPE	M	Yes [ ]
TP10	PRBS generator invert in TSS	50.3.8.3.1	Invert PRBS pattern in second SPE	M	Yes [ ]
TP11	Overhead octets in TSS	50.3.8.3.1	Set to defaults except for J1	M	Yes [ ]
TP12	Default value for J1 in TSS	50.3.8.3.1	Set to 89 hexadecimal if not used for providing stress	M	Yes [ ]
TP13	CID pattern used in TSS	50.3.8.3.2	72 bits of ones and 72 bits of zeros	M	Yes [ ]
TP14	Alternating value for CID pattern	50.3.8.3.2	72 bits of zeros in first frame and 72 bits of ones in second	M	Yes [ ]

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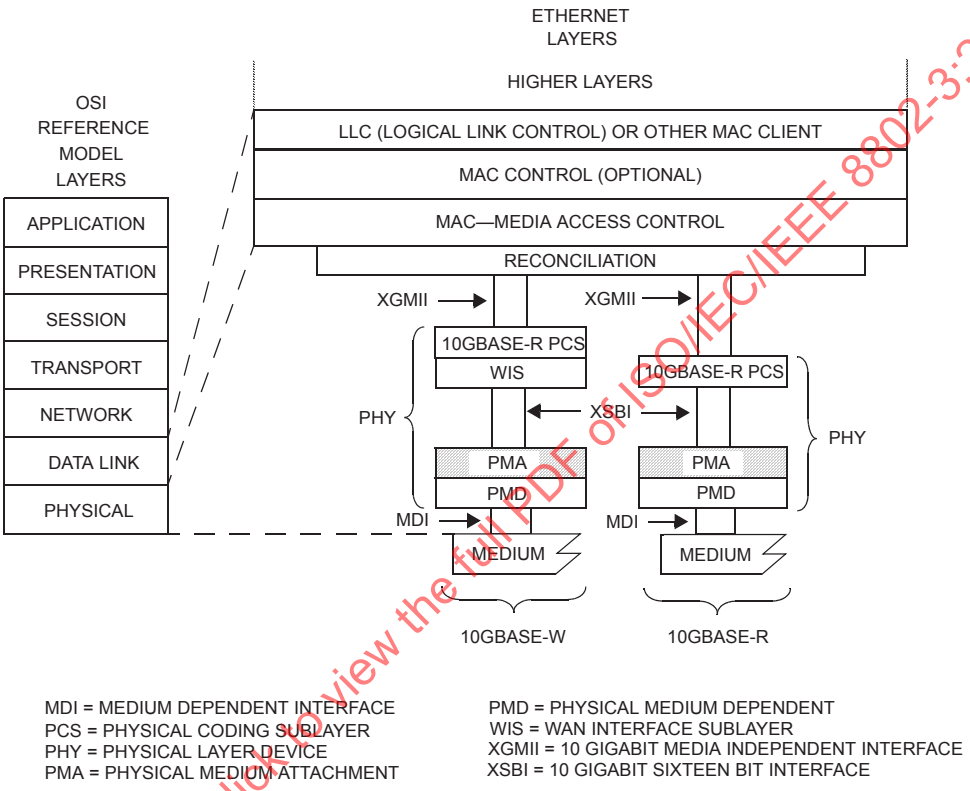
51. Physical Medium Attachment (PMA) sublayer, type Serial

51.1 Overview

This clause defines the functional characteristics for the Physical Media Attachment (PMA) used in 10GBASE-R and 10GBASE-W. Figure 51–1 depicts the relationships of the serial PMA (shown shaded) with other sublayers and the ISO/IEC Open System Interconnection (OSI) reference model.



MDI = MEDIUM DEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT
WIS = WAN INTERFACE SUBLAYER
XGMII = 10 GIGABIT MEDIA INDEPENDENT INTERFACE
XSBI = 10 GIGABIT SIXTEEN BIT INTERFACE

Figure 51–1—Relationship of serial PMA to PCS, WIS, and PMD

The purpose of the serial PMA is to attach the PMD of choice to its client, i.e., the PCS or WIS sublayer.

51.1.1 Scope

This clause specifies the functions, features, and services of the serial PMA sublayer, including electrical and timing specifications for the 10 Gigabit sixteen bit interface (XSBI). Specifications for the serial input and output of the PMA are left to the implementer with conformance and consideration of the serial PMD type. The serial PMA is used between the PMD and the PMA client as shown in Figure 51–1.

51.1.2 Summary of functions

The following is a summary of the principal functions implemented by the PMA.

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In the transmit direction (i.e., transmitting data from the PMA client to the PMD), the PMA performs the following functions:

a) Provide transmit source clock to PMA client.
b) Serialization of 16-bit data to serial bit stream.
c) Transmission of serial data to PMD.

In the receive direction (i.e., serial data from PMD to the PMA client), the PMA performs the following functions:

a1) Bit clock recovery of serial data from PMD.
b1) Provide receive clock to PMA client.
c1) Deserialization of serial data to16-bit parallel data.
d1) Transmission of parallel data to PMA client.
e1) Provide link status information.

51.2 PMA Service Interface

The Serial PMA provides a Service Interface to the 10G BASE-R PCS or WIS sublayer, i.e., the PMA client. These services are described in an abstract manner and do not imply any particular implementation. The PMA Service Interface shall support the exchange of data-groups between the PMA and the PMA client. The PMA converts data-groups into bits and passes these to the PMD, and vice versa. It also generates an additional status indication for use by its client.

The following primitives are defined:

PMA_UNITDATA.request(tx_data-group<15:0>)

PMA_UNITDATA.indication(rx_data-group<15:0>)

PMA_SIGNAL.indication(SIGNAL_OK)

PMA_RXMODE.request(rx_mode)

PMA_TXMODE.request(tx_mode)

PMA_ENERGY.indication(energy_detect)

51.2.1 PMA_UNITDATA.request

This primitive defines the transfer of data (in the form of data-groups) from the PMA client to the PMA. PMA_UNITDATA.request is generated by the PMA client's transmit process.

51.2.1.1 Semantics of the service primitive

PMA_UNITDATA.request(tx_data-group<15:0>)

The data conveyed by PMA_UNITDATA.request is a 16 bit vector representing a single data-unit which has been prepared for transmission by the PMA client.

51.2.1.2 When generated

The PMA client continuously sends tx_data-group<15:0> to the PMA at a nominal clock rate of 644.53125 MHz and 622.08 MHz in 10GBASE-R and 10GBASE-W operations, respectively.

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51.2.1.3 Effect of receipt

Upon receipt of this primitive, the PMA generates a series of sixteen PMD_UNITDATA.request primitives, requesting transmission of the indicated tx_data-group bit to the PMD.

51.2.2 PMA_UNITDATA.indication

This primitive defines the transfer of data (in the form of data-groups) from the PMA to its client. PMA_UNITDATA.indication is used by the client's synchronization process.

51.2.2.1 Semantics of the service primitive

PMA_UNITDATA.indication(rx_data-group<15:0>)

The data conveyed by PMA_UNITDATA.indication is a 16 bit vector representing a single data-unit which has been prepared for transmission by the PMA receive process to the PMA client.

51.2.2.2 When generated

The PMA continuously sends one rx_data-group<15:0> to the PMA client corresponding to the receipt of each data-group of sixteen PMD_UNITDATA.indication primitives received from the PMD. The PMA sends the rx_data-group<15:0> at a nominal rate derived from the recovered bit clock.

51.2.2.3 Effect of receipt

The effect of receipt of this primitive by the client is unspecified by the PMA sublayer.

51.2.3 PMA_SIGNAL.indication

This primitive is sent by the PMA to its client to indicate the status of the receive process. PMA_SIGNAL.indication is generated by the PMA receive process to propagate the detection of severe error conditions (e.g. no valid signal being received from the PMD sublayer) to the PMA client.

51.2.3.1 Semantics of the service primitive

PMA_SIGNAL.indication (SIGNAL_OK)

The SIGNAL_OK can take one of two values: OK or FAIL. A value of FAIL denotes that invalid data is being presented to the PMA client. A value of OK does not guarantee valid data is being presented to the PMA client.

51.2.3.2 When generated

The PMA generates a PMA_SIGNAL.indication primitive to the PMA client whenever there is change in the value of the SIGNAL_OK parameter.

51.2.3.3 Effect of receipt

The effect of receipt of this primitive by the client is unspecified by the PMA sublayer.

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51.2.4 PMA_RXMODE.request

This primitive is generated by the PCS Receive Process for EEE capability (see 78.3) to indicate when the PMA and PMD receive functions may go into a low power mode, see 49.3.6.6. Without EEE capability, the primitive is never invoked and the PMA behaves as if rx_mode = DATA.

51.2.4.1 Semantics of the service primitive

PMA_RXMODE.request(rx_mode)

The rx_mode parameter takes on one of two values: QUIET or DATA.

51.2.4.2 When generated

The PCS generates this primitive to indicate the low power mode of the receive path.

51.2.4.3 Effect of receipt

When received the PMA receive is configured appropriately for the indicated state and the value is propagated to PMD_RX_MODE.request(rx_mode). When rx_mode is DATA, the PMA operates normally. When rx_mode is QUIET, the PMA may go into a low power mode.

51.2.5 PMA_TXMODE.request

This primitive is generated by the PCS Transmit Process for EEE capability to invoke the appropriate PMA and PMD transmit EEE states, see 49.2.13.3.1. Without EEE capability, the primitive is never invoked and the PMA behaves as if tx_mode = DATA.

51.2.5.1 Semantics of the service primitive

PMA_TXMODE.request(tx_mode)

The tx_mode parameter takes on one of three values: QUIET, ALERT, or DATA.

51.2.5.2 When generated

The PCS generates this primitive to indicate the low power mode of the transmit path.

51.2.5.3 Effect of receipt

When received the PMA transmit is configured appropriately for the indicated state and the value is propagated to PMD_TX_MODE.request(tx_mode). When tx_mode is DATA, the PMA operates normally. When tx_mode is QUIET, the PMA may go into a low power mode. When tx_mode is ALERT, the PMA operation is not defined.

51.2.6 PMA_ENERGY.indication

This primitive is sent by the PMA to its client to indicate the status of the receive process for EEE capability. PMA_ENERGY.indication is generated by the PMA receive process to propagate the energy detection indication from the PMD to the PMA client.

51.2.6.1 Semantics of the service primitive

PMA_ENERGY.indication(energy_detect)

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The energy_detect parameter is Boolean and reflects the state of the PMD_SIGNAL.-indication(SIGNAL_OK) received from the PMD.

51.2.6.2 When generated

The PMA generates this primitive whenever there is a change in the value of the SIGNAL_OK parameter.

51.2.6.3 Effect of receipt

The effect of receipt of this primitive by the client is unspecified by the PMA sublayer.

51.3 Functions within the PMA

The PMA comprises the PMA Transmit and PMA Receive processes for 10GBASE-W and 10GBASE-R. The PMA Transmit process serializes the tx_data-groups and passes them to the PMD for transmission on the underlying medium. Similarly, the PMA Receive process deserializes received data from the PMD and presents the data as rx_data-groups to the PMA client. The PMA receiver continuously conveys sixteen-bit data-groups to the PMA client, independent of data-group alignment.

NOTE—Strict adherence to manufacturer-supplied guidelines for the operation and use of PMA serializer components is required to meet the jitter specifications of the respective PMD clause. The supplied guidelines should address the quality of power supply filtering associated with the transmit clock generator, and also the purity of reference clock fed to the transmit clock generator.

51.3.1 PMA transmit function

The PMA Transmit function passes data unaltered (except for serializing) from the PMA client directly to the PMD. Upon receipt of a PMA_UNITDATA.request primitive, the PMA Transmit function shall serialize the sixteen bits of the tx_data-group<15:0> parameter and transmit them to the PMD in the form of sixteen successive PMD_UNITDATA.request primitives.

51.3.2 PMA receive function

The PMA Receive function passes data unaltered from the PMD directly to the PMA client. Upon receipt of sixteen successive PMD_UNITDATA.indication primitives, the PMA shall assemble the sixteen received bits into a single sixteen-bit value and pass that value to the PMA client as the rx_data-group<15:0> parameter of the primitive PMA_UNITDATA.indication. The PMA receive function does not align rx_data-group<15:0> to the original tx_data-group<15:0> from the remote end of the link.

51.3.3 Delay Constraints

The PMA receives a one bit data stream from the PMD and presents a sixteen bit wide data unit to the PMA client. Received bits from the PMD are buffered to facilitate proper deserialization of the rx_data-group<15:0> to the PMA client. These functions necessitate an internal PMA delay of at least sixteen unit intervals. In practice, this serial to parallel conversion may necessitate even longer delays of the incoming data stream.

Predictable operation of the MAC Control PAUSE operation (Clause 31, Annex 31B) demands that there be an upper bound on the propagation delays through the network. This implies that MAC, MAC Control sublayer, and PHY implementers will conform to certain delay maxima, and that network planners and administrators conform to constraints regarding the cable topology and concatenation of devices. The sum of transmit and receive delay constraints for the serial PMA/PMD sublayer shall meet the requirements as specified in the respective PMD clause. The serial PMA/PMD sublayer includes the serial PMA, the serial PMD, and 2 m of fiber.

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51.4 Sixteen-Bit Interface (XSBI)

A physical instantiation of the sixteen-bit PMA service interface (XSBI) is defined to provide compatibility among devices designed by different manufacturers for the operation of PHY implementations in either the 10GBASE-R family or the 10GBASE-W family. There is no requirement for an integrated compliant device to implement or expose the XSBI. A XSBI implementation is described in 51.4 through 51.9. Though the XSBI is an optional interface, it is used extensively in this standard as a basis for specification. The PMA is specified to the XSBI interface, so if the XSBI is not physically implemented, a conforming implementation shall behave as if the XSBI functions were implemented.

Table 51–1 defines terms used within the description of the XSBI interface and the rest of this clause. For the XSBI instantiation of the PMA service interface, the mapping of bits between the PMA service interface and the XSBI physical interface is defined for transmit in Table 51–2 and for receive in Table 51–3. Figure 51–2 depicts the relationship between the XSBI physical instantiation and the service interface provided by the PMA to its client.

NOTE—Document OIF SFI-4-01.0, an implementer's agreement, was used as a basis for the development of the XSBI instantiation.

Table 51–1—Terms and definitions

Term	Definition
10GBASE-R nominal baud rate	10.3125 GBd
10GBASE-W nominal baud rate	9.95328 GBd
Data signals, data-group, clock signal	Operating rate is 1/16 of nominal baud rate
Differential signal name used without <P,N> (e.g., PMA_TX_CLK)	= signal<P> minus signal <N> (e.g., = PMA_TX_CLK<P-N>)

Table 51–2—Transmit bit mapping

	Name	Bit numbers															
PMA service interface	tx_data-group	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
XSBI physical interface	xsbi_tx	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Table 51–3—Receive bit mapping

	Name	Bit numbers															
PMA service interface	rx_data-group	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
XSBI physical interface	xsbi_rx	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

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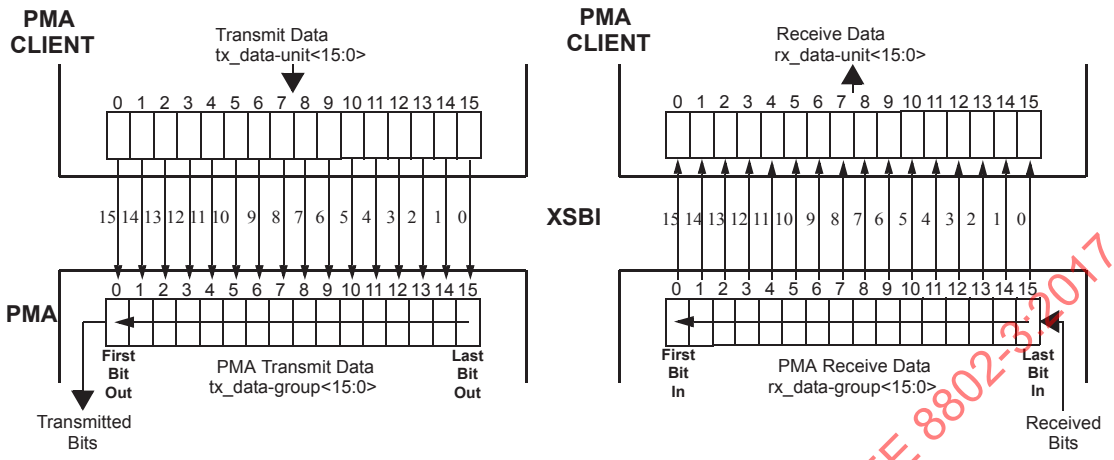

Figure 51–2—XSBI physical interface mapping into PMA service interface

As depicted in Figure 51–3, the XSBI connects the PMA to its client, the PCS or WIS sublayer. It is equipped for full duplex transmission of data-groups with associated data-group clock signals. The PMA client provides data-groups on xsbi_tx<15:0> to the XSBI transmit function which latches the data on the rising edge of the PMA_TX_CLK. See section 51.6.1.2 for details. The PMA_TX_CLK signal is derived from PMA_TXCLK_SRC as provided by the PMA. An internal Transmit Clock Generation Unit (TXCGU) uses REFCLK to generate the internal bit clock that is used to serialize the latched data out of the PMA outputs.

The PMA Receive function accepts serial data from the PMD and extracts a bit clock and recovered data from the serial inputs in the Receive Clock Recovery Unit (RXCRU). The recovered data is deserialized and conveyed to the PMA client on xsbi_rx<15:0>. The rising edge of the recovered clock, PMA_RX_CLK, which is at 1/16 the bit rate, is used by the PMA to send the received 16-bit data-groups to the PMA client.

The PMA_SIGNAL.indication is a function of PMD_SIGNAL.indication, the Sync_Err signal and the optional PMA loopback signal. These signals can be seen in context in Figure 44A–7 and Figure 51–3. In the case of PMA loopback being inactive, the PMA_SIGNAL will indicate a FAIL whenever the PMD_SIGNAL.indication indicates a FAIL. The PMA_SIGNAL will also indicate a FAIL when Sync_Err is valid, i.e., PMA unable to recover clock from the incoming data stream. If the PMA loopback function is implemented and activated, the PMA_SIGNAL.indication will ignore the PMD_SIGNAL.indication and behave as if PMD_SIGNAL.indication is valid.

PMA_RX_CLK is derived from the serial input data whenever possible. When there is no valid input signal or the optional Synchronization Error (Sync_Err) asserted or other conditions where the PMA cannot derive the clock from the serial input data, a valid PMA_RX_CLK is provided as described in 51.7.2.

51.4.1 Required signals

In the event this XSBI is made accessible, the signals listed in Table 51–4 are provided, with the meanings described elsewhere in this subclause.

xsbi_tx<15:0>
: The 16-bit parallel low-voltage differential signaling (LVDS) data presented to the XSBI for serialization and transmission onto the media. Bit xsbi_tx<15> shall be transmitted first, followed by xsbi_tx<14> through xsbi_tx<0>.

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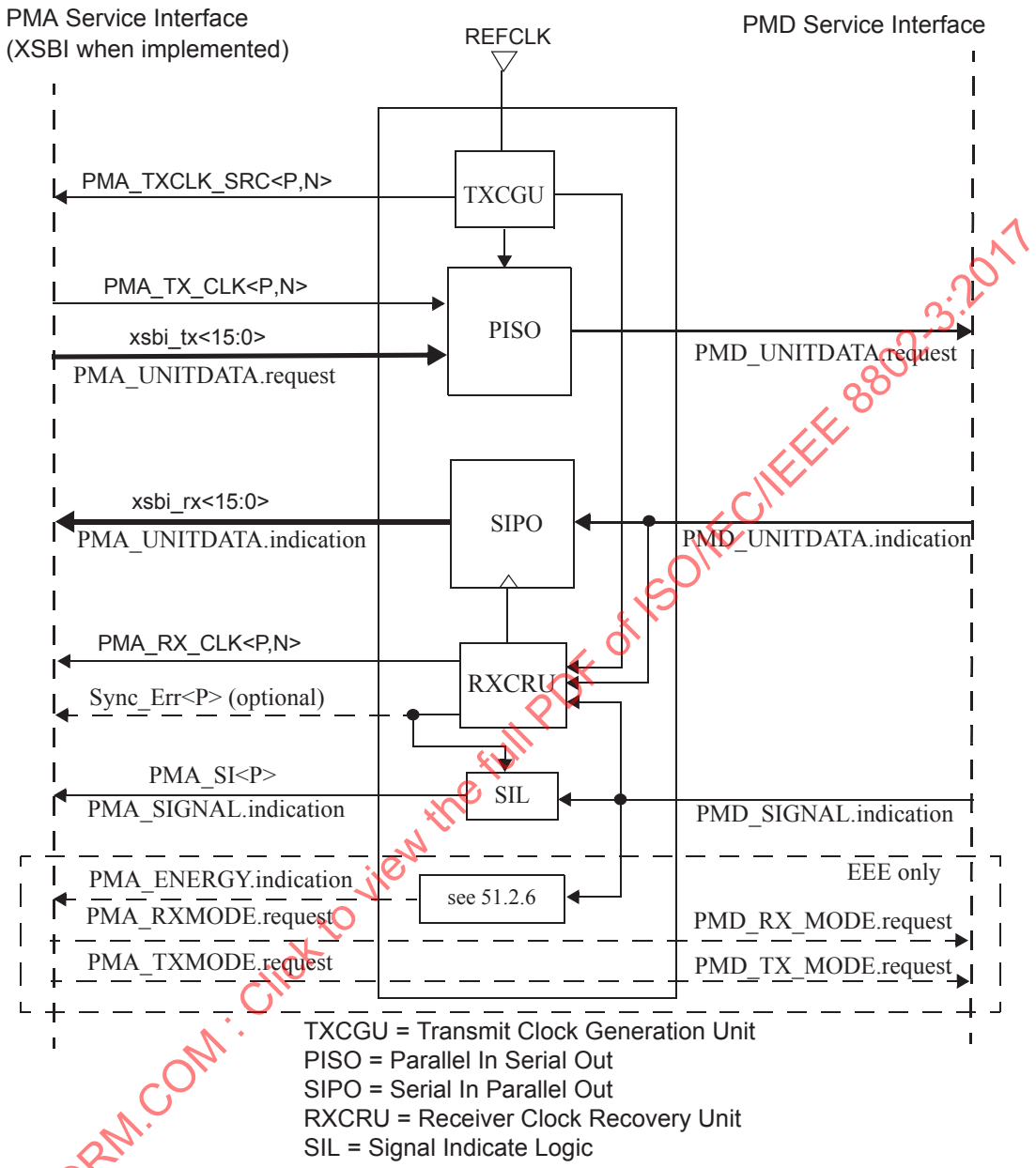

Figure 51–3—XSBI reference diagram

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PMA_TX_CLK<P,N>

The LVDS transmit data-group clock. This data-group clock is used to latch data into the PMA for transmission. The PMA_TX_CLK<P,N> shall be derived from PMA_TXCLK_SRC<P,N>. The rising edge of PMA_TX_CLK is used to latch data into the PMA for transmission. Refer to 51.6.1.2 for details.

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Table 51–4—XSBI required signals

Symbol	Signal name	Signal type	Active level
xsbi_tx<15:0>	Transmit Data	Input	H
PMA_TX_CLK<P,N>	Transmit Clock	Input	↑
PMA_TXCLK_SRC<P,N>	Transmit Clock Source	Output	either edge
xsbi_rx<15:0>	Receive Data	Output	H
PMA_RX_CLK<P,N>	Receive Clock	Output	↑
PMA_SI<P>	PMA Signal Indicate	Output	H

PMA_TXCLK_SRC<P,N>
: The LVDS transmit data-group clock source. The PMA derives the PMA_TXCLK_SRC<P,N> from the local REFCLK. The PMA_TXCLK_SRC<P,N> is used by the PMA client to derive PMA_TX_CLK<P,N>.

xsbi_rx<15:0>
: The 16-bit parallel LVDS data transmitted by the PMA and presented to the PMA client for further processing. The PMA deserializes the incoming data to 16-bit wide data groups, xsbi_rx<15:0>. Bit xsbi_rx<15> shall be received first, followed by xsbi_rx<14> through xsbi_rx<0>. Data alignment is NOT performed by the PMA.

PMA_RX_CLK<P,N>
: The LVDS receive data-group clock. The PMA derives the PMA_RX_CLK<P,N> from the line rate when the serial data from the PMD is present, or the REFCLK when the serial data from the PMD is absent, e.g. PMD_SI invalid or Sync_Err asserted. The xsbi_rx<15:0> data groups are presented to the PMA client on the rising edge of PMA_RX_CLK<P,N>.

PMA_SI<P>
: A logic 0 on PMA Signal Indicate (PMA_SI) indicates that the receiver is unable to properly recover the receive data. The indicator is a function of the PMD_SIGNAL.indication status, the Sync_Err function and the optional PMA loopback signal. This signal is the physical instantiation of the SIGNAL_OK parameter as described in the PMA_SIGNAL.indication primitive. This signal shall be compliant with the EIA/JESD8-B Interface Standards for Nominal 3V/3.3V Supply Digital Integrated Circuits.

51.4.2 Optional Signals

Sync_Err<P>
: This signal is used to indicate the inability of the PMA to recover the clock from the serial data stream. A logic high indicates that there is a synchronization error. A logic low does not guarantee synchronization. This signal shall be compliant with the EIA/JESD8-B Interface Standards for Nominal 3V/3.3V Supply Digital Integrated Circuits.

energy_detect
: If the optional Energy-Efficient Ethernet (EEE) function is supported (see Clause 78) then the XSBI interface includes energy_detect as described in 51.2.

rx_quiet
: If the optional EEE function is supported (see Clause 78) then the XSBI interface includes rx_quiet as described in 51.2.

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tx_quiet

If the optional EEE function is supported (see Clause 78) then the XSBI interface includes tx_quiet as described in 51.2.

51.5 General electrical characteristics of the XSBI

In the event this XSBI is made accessible, this subclause specifies the general electrical characteristics of the XSBI.

NOTE—All LVDS AC and DC parameters shall conform to the TIA/EIA-644 LVDS specification with the exception of those parameters specified by the tables of this clause.

51.5.1 DC characteristics

Table 51–5 documents the required DC parametric attributes of all inputs and outputs of the XSBI. The signal specification is based on low voltage differential signals (LVDS) as described in ANSI/TIA-644 LVDS specifications. Unless otherwise stated, all terms and test conditions related to electrical parameters (AC or DC) are as specified in the TIA/EIA-644 LVDS document.

Table 51–5—Electrical specifications

Symbol	Parameter	Conditions	Min	Max	Units	Note
$\|V_{OD}\|$	Output differential voltage	Differential load, R_{load} = 100Ω ± 1%	250	400	mV	
V_{OS}	Output offset voltage	Differential load, R_{load} = 100Ω ± 1%	1125	1375	mV	
R_O	Output impedance, single ended		40	140	Ω	[a]
ΔR_O	R_O mismatch			10	%	*
$\|\Delta V_{OD}\|$	Change in VOD between “0” and “1”	Differential load, R_{load} = 100Ω ±1%		50	mV	
$\|\Delta V_{OS}\|$	Change in VOS between “0” and “1”	Differential load, R_{load} = 100Ω ±1%		50	mV	
V_I	Input voltage range	|Vgpd| < 50mV	900	1600	mV	[b]
V_{ID}	Input differential voltage	|Vgpd| < 50mV	100	600	mV	
R_{IN}	Receiver differential input impedance		70	130	Ω	*
t_R, t_F	20%-80% rise and fall times		100	400	ps	*

[a]Modified from or not specified in TIA/EIA-644 document.
[b]$|V_{gpd}|$ is the ground potential differential between PMA client and PMA.

51.5.2 Valid signal levels

All AC measurements are made from the cross-over level of the clock to the valid input or output data levels as shown in Figure 51–4. The CLK and DATA is defined to be the differential signal, i.e., <P-N>, of a clock or data signal.

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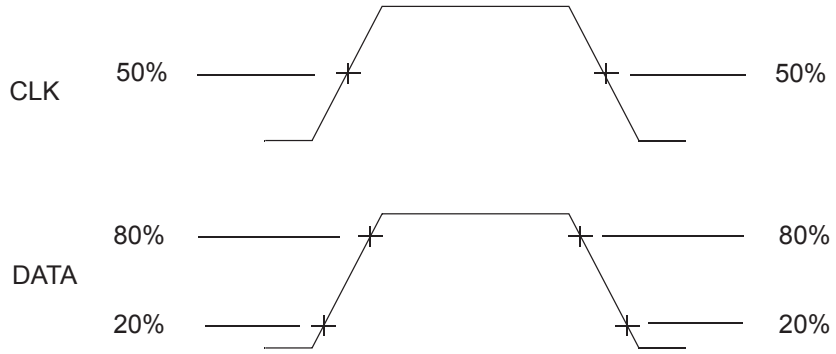

Figure 51–4—Input/output valid level for AC measurements

51.5.3 Rise and fall time definition

The rise and fall time definition for PMA_TX_CLK, PMA_TXCLK_SRC, PMA_RX_CLK, and DATA is shown below in Figure 51–5. All signals are measured differentially.

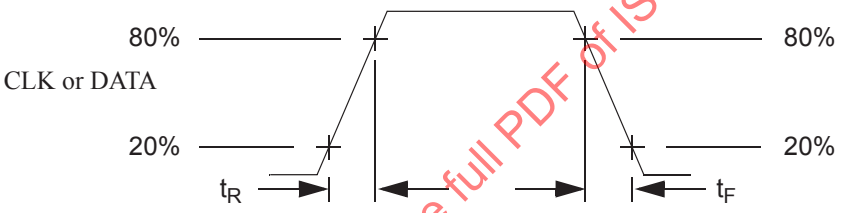

Figure 51–5—Rise and fall time definition

51.5.4 Output load

All AC measurements are assumed to have a differential output load of 100 Ω ± 1%.

51.6 XSBI transmit interface electrical characteristics

In the event this XSBI is made accessible, the electrical characteristics of the XSBI transmit interface are specified in this subclause. A XSBI receiver shall meet the specifications in sections 51.6.1 through 51.6.2.

NOTE—The following approach is taken for positioning clocks relative to the data. For both the PMA and PMA client drivers, the <P-N> clock edges are aligned to the data edges, to allow simplification of macro design. For both the PMA and PMA client receivers, the <P-N> clock edges are centered on the data bit, to allow simplification of macro design. The implementation to meet these requirements may be achieved on the system board. This can be done with either a delay of the clocks or by exchanging the positive and negative signals of the differential clock outputs.

51.6.1 XSBI transmit interface timing

The XSBI transmit interface timing specification consists of two separate specifications. The timing specifications at the PMA client output and the PMA input are described in 51.6.1.1 and 51.6.1.2, respectively. Data is latched into the PMA using rising edge of PMA_TX_CLK. The relationship between

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PMA_TX_CLK and PMA_TXCLK_SRC are described in 51.6.2. All transitions in Figure 51–6 and Figure 51–7 are specified from the PMA_TX_CLK reference level, to valid input signal levels (refer to 51.5.2).

51.6.1.1 PMA client output timing

Figure 51–6 and Table 51–6 detail the XSBI timing requirements for transmit data relative to PMA_TX_CLK at the PMA client outputs.

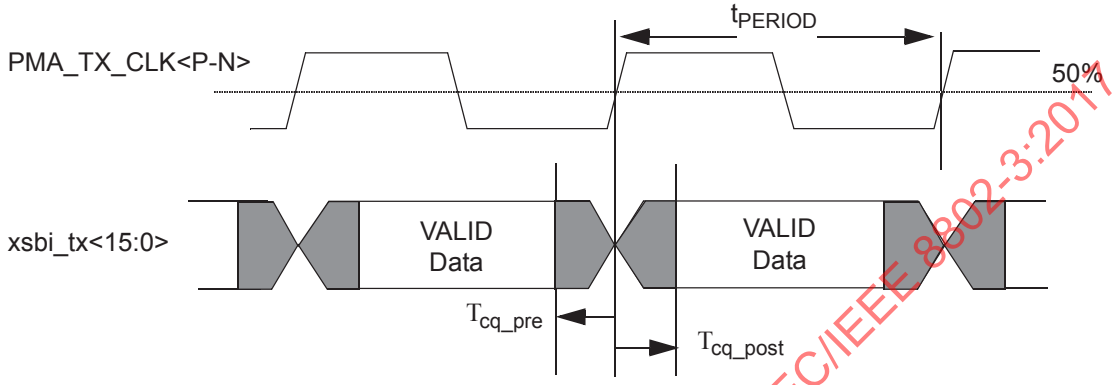

Figure 51–6—PMA client output timing

Table 51–6—PMA client output timing specifications

Parameter	Description	Min	Typ	Max	Units
t_{PERIOD}	PMA_TX_CLK Period 10GBASE-R 10GBASE-W		 1.55151 1.60751		ns[a]
T_{cq_pre}	data invalid window before ↑ PMA_TX_CLK<N-P>			200	ps
T_{cq_post}	data invalid window after ↑ PMA_TX_CLK<N-P>			200	ps
t_{DUTY}	PMA_TX_CLK Duty Cycle	40		60	%

[a]Period time value = 1/644.53125 MHz for 10GBASE-R, similarly = 1/622.08 MHz for 10GBASE-W.

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51.6.1.2 PMA input timing

Figure 51–7 and Table 51–7 detail the XSBI timing requirements for transmit data relative to the PMA_TX_CLK at the PMA inputs.

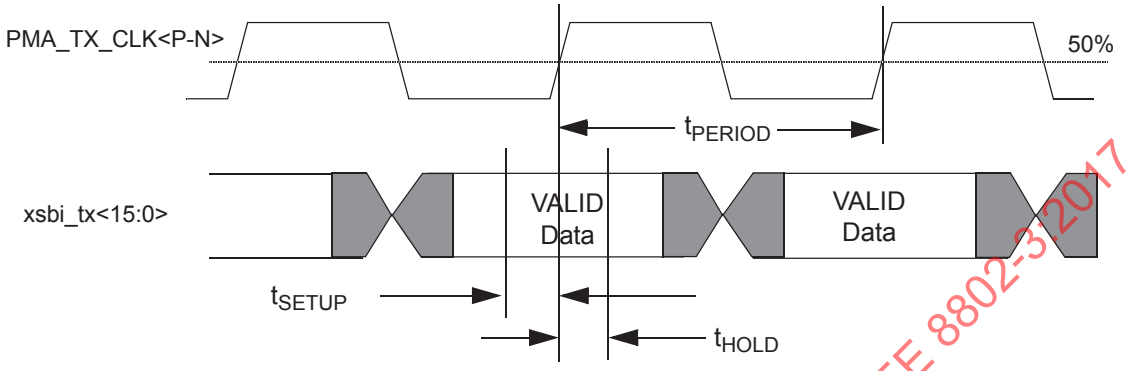

Figure 51–7—PMA input timing

Table 51–7—PMA input timing specifications

Parameter	Description	Min	Typ	Max	Units
t_{PERIOD}	PMA_TX_CLK period 10GBASE-R 10GBASE-W		 1.55151 1.60751		ns
t_{SETUP}	Data Setup to ↑ PMA_TX_CLK	300			ps
t_{HOLD}	Data Hold from ↑ PMA_TX_CLK	300			ps
t_{DUTY}	PMA_TX_CLK duty cycle	40		60	%

51.6.2 XSBI PMA_TX_CLK and PMA_TXCLK_SRC Specification

Table 51–8 specifies the XSBI interface transmit frequency. The frequency of xsbi_tx<15:0> and PMA_TX_CLK are derived from the frequency of PMA_TXCLK_SRC.

Table 51–9 specifies the phase variation between PMA_TX_CLK and PMA_TXCLK_SRC and the jitter requirements between PMA_TX_CLK and PMA_TXCLK_SRC. This specification describes the maximum delay variation through the PMA client (PMA_TXCLK_SRC to PMA_TX_CLK and xsbi_tx<15:0>). The absolute value of the delay is not specified, as it is not relevant to the operation of the interface.

Table 51–8—Transmit source clock specification

Parameter	Description	Value
$f_{PMA_TXCLK_SRC}$	PMA_TXCLK_SRC frequency 10GBASE-W 10GBASE-R	 622.08 MHz ± 20 ppm 644.53125 MHz ± 100 ppm

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Table 51–9—Transmitter clocks specification

Parameter	Description	Condition	Value(max)
TD	Variation of PMA_TXCLK_SRC to PMA_TX_CLK delay	frequency < 10 kHz	2ns(p-p)
CJ	Jitter between PMA_TXCLK_SRC and PMA_TX_CLK	frequency >10 kHz	175ps(p-p)

NOTE—The ± 20 ppm clock tolerance is not intended to interoperate directly with interfaces that comply with SONET of SDH standards, or other synchronous networks. Operation over electrically multiplexed payloads of a transmission network is outside the scope of this standard.

The TD parameter is defined to be the peak-to-peak variation of the phase offset measured in time between an arbitrary clock edge of the PMA_TXCLK_SRC clock and a selected clock edge on the PMA_TX_CLK. Letting "X" be the offset parameter, then TD = $X_{max} - X_{min}$.

51.7 XSBI receive interface electrical characteristics

In the event this XSBI is made accessible, the electrical characteristics of the XSBI receive interface are specified in this subclause. A XSBI receiver shall meet the specifications in 51.7.1 through 51.7.2.

NOTE—The following approach is taken for positioning clocks relative to the data. For both the PMA and PMA client drivers, the <P-N> clock edges are aligned to the data edges, to allow simplification of macro design. For both the PMA and PMA client receivers, the <P-N> clock edges are centered on the data bit, to allow simplification of macro design. The implementation to meet these requirements may be achieved on the system board. This can be done with either a delay of the clocks or by exchanging the positive and negative signals of the differential clock outputs.

51.7.1 XSBI receive interface timing

The XSBI receive interface timing specification consists of two separate specifications. The timing specifications at the PMA output and the PMA client input are described in 51.7.1.1 and 51.7.1.2, respectively. Data is latched into the PMA client using the rising edge of PMA_RX_CLK. All transitions in Figure 51–8 and Figure 51–9 are specified from the PMA_RX_CLK reference level, to valid output signal levels (refer to 51.5.2).

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51.7.1.1 PMA output timing

Figure 51–8 and Table 51–10 detail the XSBI timing requirements for receive data relative to the PMA_RX_CLK at the PMA outputs.

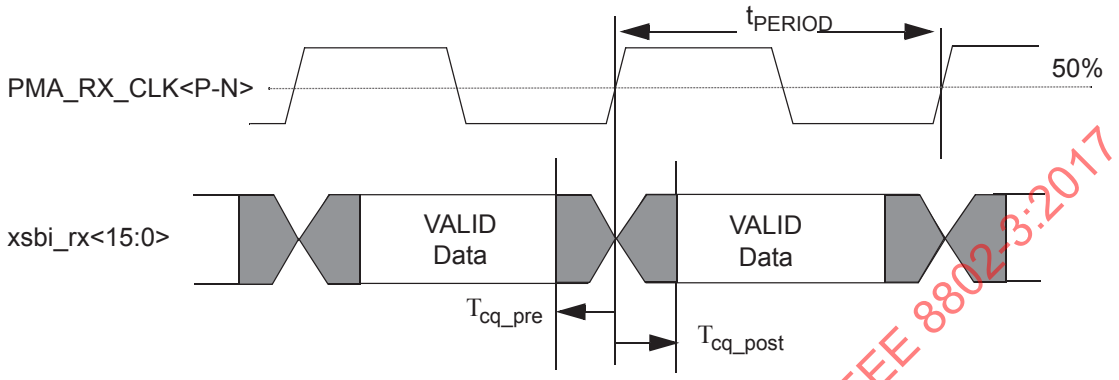

Figure 51–8—PMA output timing

Table 51–10—PMA output timing specifications

Parameter	Description	Min	Typical	Max	Units
t_{PERIOD}	PMA_RX_CLK period 10GBASE-R 10GBASE-W	—	 1.55151 1.60751	—	ns
T_{cq_pre}	data invalid window before ↑ PMA_RX_CLK<N-P>	—	—	200	ps
T_{cq_post}	data invalid window after ↑ PMA_RX_CLK<N-P>	—	—	200	ps
t_{DUTY}	PMA_RX_CLK duty cycle	45	—	55	%

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51.7.1.2 PMA client input timing

Figure 51–9 and Table 51–11 detail the XSBI timing requirements for receive data relative to the PMA_RX_CLK at the PMA client inputs.

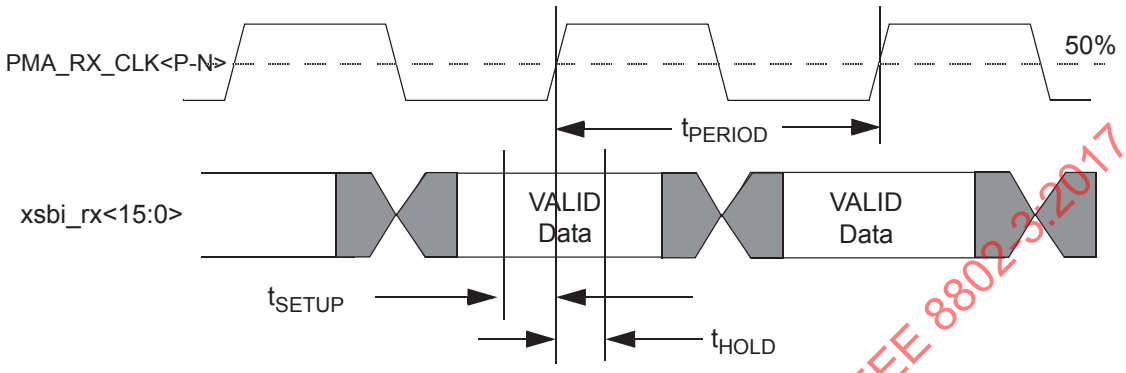

Figure 51–9—PMA client input timing

Table 51–11—PMA client input timing specifications

Parameter	Description	Min	Typical	Max	Units
t_{DUTY}	PMA_RX_CLK duty cycle	45	—	55	%
t_{SETUP}	Data Setup before ↑PMA_RX_CLK	300	—	—	ps
t_{HOLD}	Data Hold after ↑PMA_RX_CLK	300	—	—	ps

51.7.2 XSBI PMA_RX_CLK specification

Table 51–12 defines the PMA_RX_CLK frequency variation during PMA_SI valid and invalid conditions. PMA_RX_CLK is derived from the serial input data whenever possible. Under a loss-of-signal (LOS) or the optional Synchronization Error (Sync_Err) or other conditions where the PMA cannot derive the clock from the serial input data, a valid PMA_RX_CLK shall be provided with frequency characteristics as defined in Table 51–12. During the transitions from nominal clock to recovered clock or from recovered clock to nominal clock, the period and duty cycle requirements do not apply. However, the minimum pulse width should not change during the transitions between clock sources. During the transitions, the PMA_RX_CLK pulse width shall not be less than the minimum that is calculated by the period times the duty cycle as defined in Table 51–10 and Table 51–12.

51.8 PMA loopback mode (optional)

PMA loopback is optional. If PMA loopback is implemented it shall conform to the requirements of this subclause, i.e., 51.8.

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Table 51–12—Receiver clock specification

PMA_SI	Parameter	Description	Value
valid	$f_{PMA_RX_CLK}$	PMA_RX_CLK frequency 10GBASE-W 10GBASE-R	 622.08 MHz ± 20 ppm 644.53125 MHz ± 100 ppm
invalid	$f_{PMA_RX_CLK}$	PMA_RX_CLK frequency 10GBASE-W 10GBASE-R	 622.08 MHz ± 2500 ppm 644.53125 MHz ± 2500 ppm

If a Clause 45 MDIO is supported, then this function maps to the PMA loopback function as specified in 45.2.1.1.5. A device is placed in Loopback mode when the loopback bit in the PMA/PMD Control register 1 is set to a logic one. A device is removed from Loopback mode when this bit is set to a logic zero.

When loopback mode is selected, transmission requests passed to the transmitter are shunted directly to the receiver, overriding any signal detected by the receiver on its attached link. A device is explicitly placed in loopback mode (i.e., loopback mode is not the normal mode of operation of a device). The method of implementing loopback mode is not defined by this standard.

NOTE—Loopback mode may be implemented either in the parallel or the serial circuitry of a device.

51.9 Environmental specifications

All equipment subject to this clause shall conform to the requirements of 14.7 and applicable sections of ISO/IEC 11801:1995.

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51.10 Protocol implementation conformance statement (PICS) proforma for Clause 51, Physical Medium Attachment (PMA) sublayer, type Serial[12]

51.10.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 51, PMA Interface Sublayer, type Serial, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the same, can be found in Clause 21.

51.10.2 Identification

51.10.2.1 Implementation identification

Supplier[1]	
Contact point for inquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1,3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

51.10.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 51, PMA Interface Sublayer (PMA), type Serial
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	

Date of Statement	

[12]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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51.10.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
LPI	Implementation of LPI	51.2		O	Yes [ ] No [ ]
*XSBI	XSBI interface	51.4	Physical instantiation of PMA service interface	O	Yes [ ] No [ ]
M1	XSBI functionality	51.4	Behave functionally as if the XSBI is implemented	M	Yes [ ]
M2	PMA Service Interface	51.2	Supports data group transfer between PMA and PMA client	M	Yes [ ]
M3	PMA_SI	51.4.1	EIA/JESD8-B compliance	M	Yes [ ]
M4	Sync_Err	51.4.2	Local PMA synchronization indicator and EIA/ JESD8-B compliance	O	Yes [ ] No [ ]
M5	Local PMA loopback	51.8		O	Yes [ ] No [ ]
MD	MDIO interface	51.8	Registers and interface supported	O	Yes [ ] No [ ]

51.10.4 PICS proforma tables for the PMA Interface Sublayer, type Serial

51.10.4.1 Compatibility considerations

Item	Feature	Subclause	Value/Comment	Status	Support
CC1	Environmental specifications	51.9		M	Yes [ ]

51.10.4.2 PMA transmit functions

Item	Feature	Subclause	Value/Comment	Status	Support
PT1	Serialization and transmission of datagroup	51.3.1		M	Yes [ ]
PT2	Order of transmission	51.4.1	Bit xsbi_tx<15> shall be transmitted first	M	Yes [ ]
PT3	PMA_TX_CLK	51.4.1	PMA_TX_CLK derived from PMA_TXCLK_SRC	XSBI:M	Yes [ ] N/A[ ]
PT4	LVDS electrical compliance	51.5	Conformance to TIA/EIA644 LVDS specifications and to Table 51–5	XSBI:M	Yes [ ] N/A[ ]
PT5	Transmit electrical specifications	51.6	Electrical and timing specifications	XSBI:M	Yes [ ] N/A[ ]

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51.10.4.3 PMA receive functions

Item	Feature	Subclause	Value/Comment	Status	Support
PR1	Deserialization and transmissions of datagroup to PMA client	51.3.2		M	Yes [ ]
PR2	Order of reception	51.4.1	Bit xsbi_rx<15> shall be received first	M	Yes [ ]
PR3	LVDS electrical compliance	51.5	conformance to TIA/EIA644 LVDS specifications and to Table 51–5	XSBI:M	Yes [ ] N/A:[ ]
PR4	Transmit electrical specifications	51.7	Electrical and timing specifications	XSBI:M	Yes [ ] N/A[ ]
PR5	Valid PMA_RX_CLK	51.7.2	A valid clock is provided as defined in Table 51–12	XSBI:M	Yes [ ] N/A[ ]
PR6	PMA_RX_CLK pulse width during valid and invalid transitions	51.7.2	Clock pulse width is greater than or equal to the period times the duty cycle	XSBI:M	Yes [ ] N/A[ ]

51.10.4.4 PMA delay constraints

Item	Feature	Subclause	Value/Comment	Status	Support
PD1	Maximum delay for PMA/ PMD functions	51.3.3	Meets the requirements of the respective PMD clause	M	Yes [ ]

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52. Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-S (short wavelength serial), 10GBASE-L (long wavelength serial), and 10GBASE-E (extra long wavelength serial)

52.1 Overview

This clause specifies the PMDs and baseband media, including both single and multimode optical fiber, for the following 10GBASE serial PHYs, shown in Table 52–1.

Table 52–1—10GBASE serial PHYs

Name	Description
10GBASE-SR	850 nm serial LAN PHY
10GBASE-LR	1310 nm serial LAN PHY
10GBASE-ER	1550 nm serial LAN PHY
10GBASE-SW	850 nm serial WAN PHY
10GBASE-LW	1310 nm serial WAN PHY
10GBASE-EW	1550 nm serial WAN PHY

In order to form a complete Physical Layer, each PMD is combined with the appropriate physical sublayers indicated in Table 52–2 and optionally with the management functions that may be accessible through the management interface defined in Clause 45.

Table 52–2—PMD type and associated clauses

Associated clause	10GBASE-R	10GBASE-W
46—RS	Required	Required
46—XGMII	Optional	Optional
47—XGXS and XAUI	Optional	Optional
49—Type R PCS	Required	Required
50—WIS	N/A	Required
51—Serial PMA	Required	Required

Figure 52–1 depicts the relationships of the serial PMD (shown shaded) with other sublayers and the ISO/IEC Open System Interconnection (OSI) reference model.

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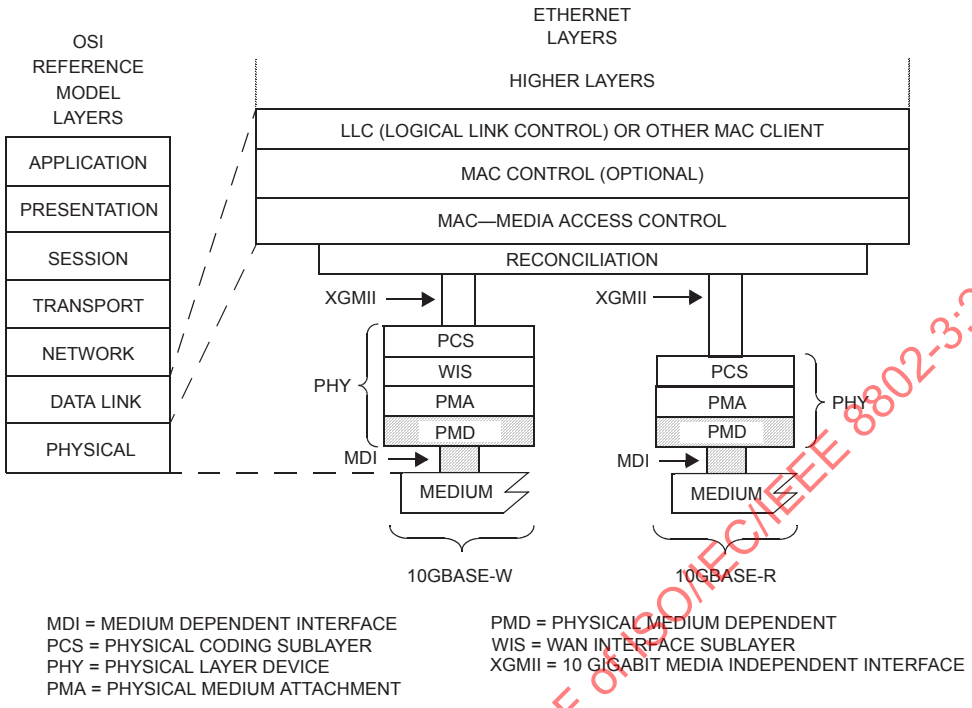

Figure 52–1—10GBASE-S, -L, and -E PMDs relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

52.1.1 Physical Medium Dependent (PMD) sublayer service interface

The following specifies the services provided by the 10GBASE-R and 10GBASE-W PMDs. These PMD sublayer service interfaces are described in an abstract manner and do not imply any particular implementation.

The PMD Service Interface supports the exchange of encoded and scrambled 64B/66B blocks between the PMA and PMD entities. In the case of the 10GBASE-W PMD types, these blocks are framed and scrambled by the WIS as described in Clause 50. The PMD translates the serialized data of the PMA to and from signals suitable for the specified medium.

The following primitives are defined:

PMD_UNITDATA.request

PMD_UNITDATA.indication

PMD_SIGNAL.indication

NOTE—Primitives are described in 1.2.2.

52.1.1.1 PMD_UNITDATA.request

This primitive defines the transfer of a serial data stream from the PMA to the PMD.

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52.1.1.1.1 Semantics of the service primitive

PMD_UNITDATA.request(tx_bit)

The data conveyed by PMD_UNITDATA.request is a continuous stream of bits. The tx_bit parameter can take one of two values: ONE or ZERO.

52.1.1.1.2 When generated

The PMA continuously sends the appropriate stream of bits to the PMD for transmission on the medium, at a nominal 10.3125 GBd signaling speed for 10GBASE-R PMD types and 9.95328 GBd signaling speed for 10GBASE-W PMDs.

52.1.1.1.3 Effect of receipt

Upon receipt of this primitive, the PMD converts the specified stream of bits into the appropriate signals on the MDI.

52.1.1.2 PMD_UNITDATA.indication

This primitive defines the transfer of data (in the form of serialized data) from the PMD to the PMA.

52.1.1.2.1 Semantics of the service primitive

PMD_UNITDATA.indication(rx_bit)

The data conveyed by PMD_UNITDATA.indication is a continuous stream of bits. The rx_bit parameter can take one of two values: ONE or ZERO.

52.1.1.2.2 When generated

The PMD continuously sends stream of bits to the PMA corresponding to the signals received from the MDI.

52.1.1.2.3 Effect of receipt

The effect of receipt of this primitive by the client is unspecified by the PMD sublayer.

52.1.1.3 PMD_SIGNAL.indication

This primitive is generated by the PMD to indicate the status of the signal being received from the MDI.

52.1.1.3.1 Semantics of the service primitive

PMD_SIGNAL.indication(SIGNAL_DETECT)

The SIGNAL_DETECT parameter can take on one of two values: OK or FAIL, indicating whether the PMD is detecting light at the receiver (OK) or not (FAIL). When SIGNAL_DETECT = FAIL, PMD_UNITDATA.indication(rx_bit) is undefined.

NOTE—SIGNAL_DETECT = OK does not guarantee that PMD_UNITDATA.indication(rx_bit) is known good. It is possible for a poor quality link to provide sufficient light for a SIGNAL_DETECT = OK indication and still not meet the 10^{-12} BER objective.

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52.1.1.3.2 When generated

The PMD generates this primitive to indicate a change in the value of SIGNAL_DETECT. If the MDIO interface is implemented, then PMD_global_signal_detect shall be continuously set to the value of SIGNAL_DETECT.

52.1.1.3.3 Effect of receipt

The effect of receipt of this primitive by the client is unspecified by the PMD sublayer.

52.2 Delay constraints

An upper bound to the delay through the PMA and PMD is required for predictable operation of the MAC Control PAUSE operation. The PMA and PMD shall incur a round-trip delay (transmit and receive) of not more than 512 bit-times, or 1 pause_quantum, including 2 m of fiber. A description of overall system delay constraints and the definitions for bit-times and pause_quanta can be found in 44.3.

52.3 PMD MDIO function mapping

The optional MDIO capability described in Clause 45 defines several variables that provide control and status information for and about the PMD. If MDIO is implemented, it shall map MDIO control variables to PMD control variables as shown in Table 52–3, and MDIO status variables to PMD status variables as shown in Table 52–4.

Table 52–3—MDIO/PMD control variable mapping

MDIO control variable	PMA/PMD register name	Register/ bit number	PMD control variable
Reset	Control register 1	1.0.15	PMD_reset
Global Transmit Disable	Transmit disable register	1.9.0	PMD_global_transmit_disable

Table 52–4—MDIO/PMD status variable mapping

MDIO status variable	PMA/PMD register name	Register/ bit number	PMD status variable
Fault	Status register 1	1.1.7	PMD_fault
Transmit fault	Status register 2	1.8.11	PMD_transmit_fault
Receive fault	Status register 2	1.8.10	PMD_receive_fault
Global PMD Receive signal detect	Receive signal detect register	1.10.0	PMD_global_signal_detect

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52.4 PMD functional specifications

The 10GBASE-R and 10GBASE-W PMDs perform the Transmit and Receive functions that convey data between the PMD service interface and the MDI.

52.4.1 PMD block diagram

For purposes of system conformance, the PMD sublayer is standardized at test points TP2 and TP3 as shown in Figure 52–2. The optical transmit signal is defined at the output end of a patch cord (TP2), between 2 and 5 m in length, of a type consistent with the link type connected to the transmitter. Unless specified otherwise, all transmitter measurements and tests defined in 52.9 are made at TP2. The optical receive signal is defined at the output of the fiber optic cabling (TP3) connected to the receiver. Unless specified otherwise, all receiver measurements and tests defined in 52.9 are made at TP3.

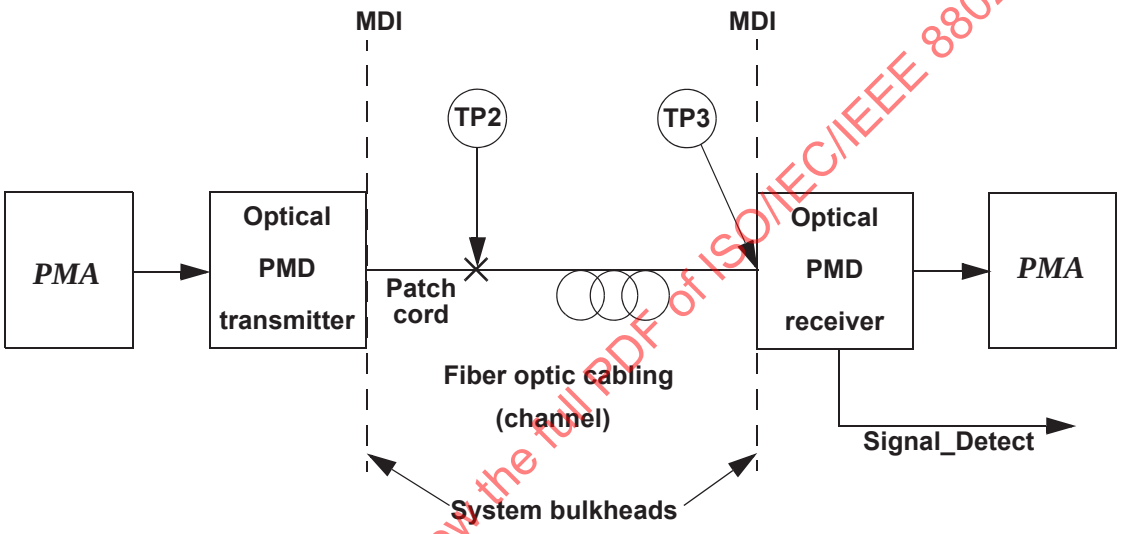

Figure 52–2—Block diagram

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52.4.2 PMD Transmit function

The PMD Transmit function shall convey the bits requested by the PMD service interface message PMD_UNITDATA.request(tx_bit) to the MDI according to the optical specifications in this clause. The higher optical power level shall correspond to tx_bit = ONE.

52.4.3 PMD Receive function

The PMD Receive function shall convey the bits received from the MDI according to the optical specifications in this clause to the PMD service interface using the message PMD_UNITDATA.indication(rx_bit). The higher optical power level shall correspond to rx_bit = ONE.

52.4.4 PMD Signal Detect function

The PMD Signal Detect function shall report to the PMD service interface, using the message PMD_SIGNAL.indication(SIGNAL_DETECT) which is signaled continuously. PMD_SIGNAL.indication is intended to be an indicator of optical signal presence. If the MDIO interface is implemented, then

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PMD_global_signal_detect (1.10.0) shall be continuously set to the value of SIGNAL_DETECT as described in 45.2.1.9.7.

The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 52–5. The PMD receiver is not required to verify whether a compliant 10GBASE-R or 10GBASE-W signal is being received. This standard imposes no response time requirements on the generation of the SIGNAL_DETECT parameter.

As an unavoidable consequence of the requirements for the setting of the SIGNAL_DETECT parameter, implementations must provide adequate margin between the input optical power level at which the SIGNAL_DETECT parameter is set to OK, and the inherent noise level of the PMD due to cross talk, power supply noise, etc.

Table 52–5—SIGNAL_DETECT value definition

Receive conditions	Signal Detect value
Input_optical_power ≤ -30 dBm average power	FAIL
Input_optical_power ≥ Receiver sensitivity (max) in OMA in Table 52–9, Table 52–13, or Table 52–17 AND compliant 10GBASE-R or 10GBASE-W signal input	OK
All other conditions	Unspecified

Various implementations of the Signal Detect function are permitted by this standard, including implementations that generate the SIGNAL_DETECT parameter values in response to the amplitude of the modulation of the optical signal and implementations that respond to the average optical power of the modulated optical signal.

52.4.5 PMD_reset function

If the MDIO interface is implemented, and if PMD_reset is asserted, the PMD shall be reset as defined in 45.2.1.1.1.

52.4.6 PMD_fault function

If the MDIO is implemented, PMD_fault is the logical OR of PMD_receive_fault, PMD_transmit_fault and any other implementation specific fault.

52.4.7 PMD_global_transmit_disable function

The PMD_global_transmit_disable function is optional. When asserted, this function shall turn off the optical transmitter so that it meets the requirements of the average launch power of OFF Transmitter in Table 52–7, Table 52–12, or Table 52–16.

If a PMD_transmit_fault (optional) is detected, then the PMD_global_transmit_disable function should also be asserted.

If the MDIO interface is implemented, then this function shall map to the PMD_global_transmit_disable bit as specified in 45.2.1.8.7.

NOTE—PMD Transmit Disable 0 is not used for serial PMDs.

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52.4.8 PMD_transmit_fault function

The PMD_transmit_fault function is optional. The faults detected by this function are implementation specific, but should not include the assertion of the PMD_global_transmit_disable function.

If a PMD_transmit_fault (optional) is detected, then the PMD_global_transmit_disable function should also be asserted.

If the MDIO interface is implemented, then this function shall be mapped to the PMD_transmit_fault bit as specified in 45.2.1.7.4.

52.4.9 PMD_receive_fault function

The PMD_receive_fault function is optional. PMD_receive_fault is the logical OR of NOT SIGNAL_DETECT and any implementation specific fault.

If the MDIO interface is implemented, then this function shall contribute to PMA/PMD receive fault bit as specified in 45.2.1.7.5.

52.5 PMD to MDI optical specifications for 10GBASE-S

The operating ranges for 10GBASE-S are defined in Table 52–6. A 10GBASE-S compliant PMD supports multimode fiber media types listed in Table 52–6 according to the specifications defined in 52.14. A PMD that exceeds the operational range requirement while meeting all other optical specifications is considered compliant (e.g., a 400 MHz km 50 µm solution operating at 80 m meets the operating range requirement of 2 m to 66 m).

Table 52–6—10GBASE-S operating range for each optical fiber type

Fiber type	Minimum modal bandwidth @ 850 nm (MHz•km)	Operating range (m)
62.5 µm MMF	160	2 to 26
	200	2 to 33
50 µm MMF	400	2 to 66
	500	2 to 82
	2000	2 to 300
	4700	2 to 400

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52.5.1 10GBASE-S transmitter optical specifications

The 10GBASE-S transmitter shall meet the specifications defined in Table 52–7 per measurement techniques defined in 52.9. It shall also meet the center wavelength, maximum spectral width and minimum optical modulation amplitude as defined in Table 52–8.

Table 52–7—10GBASE-S transmit characteristics

Description	10GBASE-SW	10GBASE-SR	Unit
Signaling speed (nominal)	9.95328	10.3125	GBd
Signaling speed variation from nominal (max)	± 20	± 100	ppm
Center wavelength (range)	840 to 860		nm
RMS spectral width[a] (max)	See footnote[b]		
Average launch power (max)	See footnote[c]		
Average launch power[d] (min)	–7.3		dBm
Launch power (min) in OMA	See footnote[b]		
Average launch power of OFF transmitter[e] (max)	–30		dBm
Extinction ratio (min)	3		dB
$RIN_{12}OMA$ (max)	–128		dB/Hz
Optical Return Loss Tolerance (max)	12		dB
Encircled flux	See footnote[f]		
Transmitter eye mask definition[g] A {X1, X2, X3, Y1, Y2, Y3}	{0.25, 0.40, 0.45, 0.25, 0.28, 0.40}		
Transmitter eye mask definition[g] B {X1, X2, X3, Y1, Y2, Y3} Hit ratio 5×10^{-5} per sample	{0.235, 0.395, 0.45, 0.235, 0.265, 0.4}		
Transmitter and dispersion penalty[h] (max)	3.9 dB		dB

[a]RMS spectral width is the standard deviation of the spectrum.
[b]Trade-offs are available between spectral width, center wavelength and minimum optical modulation amplitude. See Figure 52–3 and Table 52–8.
[c]The 10GBASE-S launch power shall be the lesser of the Hazard Level 1 safety limit as defined by 52.10.2 or the average receive power (max) defined by Table 52–9.
[d]Average launch power (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.
[e]Examples of an OFF transmitter are: no power supplied to the PMD, laser shutdown for safety conditions, activation of a PMD_global_transmit_disable or other optional transmitter shut down conditions.
[f]The encircled flux at 19 µm shall be greater than or equal to 86% and the encircled flux at 4.5 µm shall be less than or equal to 30% when measured into Type A1a (50/125 µm multimode) fiber per ANSI/TIA/EIA-455-203-2001.
[g]Either transmitter eye mask definition A or B may be used. A transmitter is not required to comply with both definitions.
[h]TDP(max) and OMA(min) are at the respective wavelength and spectral width as specified in Table 52–8.

The tradeoffs between center wavelength, maximum RMS spectral width and minimum optical modulation amplitude are defined in Table 52–8 and are shown graphically in the informative Figure 52–3. In Table 52–8 the minimum optical modulation amplitude (dBm) allowed by this standard is given for the various ranges of center wavelength and spectral width.

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Table 52–8—Minimum 10GBASE-S optical modulation amplitude (dBm) as a function of center wavelength and spectral width

Center wavelength (nm)	RMS Spectral width (nm)								
	Up to 0.05	0.05 to 0.1	0.1 to 0.15	0.15 to 0.2	0.2 to 0.25	0.25 to 0.3	0.3 to 0.35	0.35 to 0.4	0.4 to 0.45
840 to 842	–4.2	–4.2	–4.1	–4.1	–3.9	–3.8	–3.5	–3.2	–2.8
842 to 844	–4.2	–4.2	–4.2	–4.1	–3.9	–3.8	–3.6	–3.3	–2.9
844 to 846	–4.2	–4.2	–4.2	–4.1	–4.0	–3.8	–3.6	–3.3	–2.9
846 to 848	–4.3	–4.2	–4.2	–4.1	–4.0	–3.8	–3.6	–3.3	–2.9
848 to 850	–4.3	–4.2	–4.2	–4.1	–4.0	–3.8	–3.6	–3.3	–3.0
850 to 852	–4.3	–4.2	–4.2	–4.1	–4.0	–3.8	–3.6	–3.4	–3.0
852 to 854	–4.3	–4.2	–4.2	–4.1	–4.0	–3.9	–3.7	–3.4	–3.1
854 to 856	–4.3	–4.3	–4.2	–4.1	–4.0	–3.9	–3.7	–3.4	–3.1
856 to 858	–4.3	–4.3	–4.2	–4.1	–4.0	–3.9	–3.7	–3.5	–3.1
858 to 860	–4.3	–4.3	–4.2	–4.2	–4.1	–3.9	–3.7	–3.5	–3.2

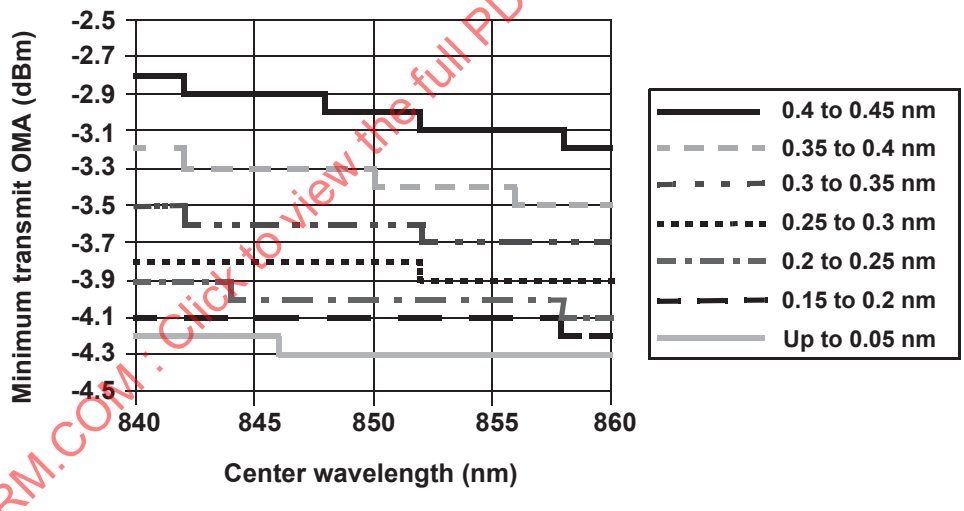

Figure 52–3—Triple tradeoff curve for 10GBASE-S (informative)

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52.5.2 10GBASE-S receive optical specifications

The 10GBASE-S receiver shall meet the specifications defined in Table 52–9 per measurement techniques defined in 52.9.

Table 52–9—10GBASE-S receive characteristics

Description	10GBASE-SW	10GBASE-SR	Unit
Signaling speed (nominal)	9.95328	10.3125	GBd
Signaling speed variation from nominal (max)	± 20	± 100	ppm
Center wavelength (range)	840 to 860		nm
Average receive power[a] (max)	–1.0		dBm
Average receive power[b] (min)	–9.9		dBm
Receiver sensitivity (max) in OMA[c]	0.077 (–11.1)		mW (dBm)
Receiver Reflectance (max)	–12		dB
Stressed receiver sensitivity in OMA[d] [e](max)	0.18 (–7.5)		mW (dBm)
Vertical eye closure penalty[f] (min)	3.5		dB
Stressed eye jitter[g] (min)	0.3		UI pk-pk
Receive electrical 3 dB upper cutoff frequency (max)	12.3		GHz

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having a power level equal to the average receive power (max) plus at least 1 dB.
[b]Average receive power (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.
[c]Receiver sensitivity is informative.
[d]Measured with conformance test signal at TP3 (see 52.9.9.3) for BER = 10^{-12}.
[e]The stressed sensitivity values in the table are for system level BER measurements which include the effects of CDR circuits. It is recommended that at least 0.4 dB additional margin be allocated if component level measurements are made without the effect of CDR circuits
[f]Vertical eye closure penalty is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.
[g]Stressed eye jitter is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.

52.5.3 10GBASE-S link power budgets (informative)

Example power budgets and penalties for a 10GBASE-S channel are shown in Table 52–10.

52.6 PMD to MDI optical specifications for 10GBASE-L

The operating range for 10GBASE-L PMDs is defined in Table 52–11. A 10GBASE-L compliant PMD supports Types B1.1 and B1.3 single-mode fibers according to the specifications defined in 52.14. A PMD that exceeds the operational range requirement while meeting all other optical specifications is considered compliant (e.g., operating at 12.5 km meets the minimum range requirement of 2 m to 10 km).

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Table 52–10—10GBASE-S link power budgets[a,b]

Parameter	62.5 μm MMF		50 μm MMF				Unit
Modal bandwidth as measured at 850 nm	160	200	400	500	2000	4700	MHz•km
Power budget	7.3	7.3	7.3	7.3	7.3	7.3	dB
Operating distance	26	33	66	82	300	400	m
Channel insertion loss[c, d]	1.6	1.6	1.7	1.8	2.6	2.9	dB
Allocation for penalties	4.7	4.8	5.1	5.0	4.7	4.4	dB
Additional insertion loss allowed[e]	1.0	0.8	0.5	0.5	0.0	0.0	dB

[a]Budget numbers are rounded to nearest 0.1 dB.
[b]Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.
[c]Operating distances used to calculate the channel insertion loss are the maximum values specified in Table 52–6.
[d]The specifications for a wavelength of 840 nm and a spectral width of 0.29 nm in Table 52–8 is used to calculate channel insertion loss, allocation for penalties, and additional insertion loss allowed.
[e]This portion of the link budget is permitted to be used to overcome insertion loss higher than the "Channel insertion loss" value and in some cases may be less than the value shown.

Table 52–11—10GBASE-L operating range

PMD Type	Nominal Wavelength (nm)	Minimum range
10GBASE-L	1310	2 m to 10 km

52.6.1 10GBASE-L transmitter optical specifications

The 10GBASE-L transmitter shall meet the specifications defined in Table 52–12 per measurement techniques defined in 52.9.

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Table 52–12—10GBASE-L transmit characteristics

Description	10GBASE-LW	10GBASE-LR	Unit
Signaling speed (nominal)	9.95328	10.3125	GBd
Signaling speed variation from nominal (max)	± 20	± 100	ppm
Center wavelength (range)	1260 to 1355		nm
Side Mode Suppression Ratio (min)	30		dB
Average launch power (max)	0.5		dBm
Average launch power[a] (min)	–8.2		dBm
Launch power (min) in OMA minus TDP[b]	–6.2		dBm
Optical Modulation Amplitude[c] (min)	–5.2		dBm
Transmitter and dispersion penalty (max)	3.2		dB
Average launch power of OFF transmitter[d] (max)	–30		dBm
Extinction ratio (min)	3.5		dB
$RIN_{12}OMA$ (max)	–128		dB/Hz
Optical Return Loss Tolerance (max)	12		dB
Transmitter Reflectance[e] (max)	–12		dB
Transmitter eye mask definition[f] A {X1, X2, X3, Y1, Y2, Y3}	{0.25, 0.40, 0.45, 0.25, 0.28, 0.40}		
Transmitter eye mask definition[f] B {X1, X2, X3, Y1, Y2, Y3} Hit ratio 5×10^{-5} per sample	{0.235, 0.395, 0.45, 0.235, 0.265, 0.4}		

[a]Average launch power (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.
[b]TDP is transmitter and dispersion penalty.
[c]Even if the TDP < 1 dB, the OMA(min) must exceed this value.
[d]Examples of an OFF transmitter are: no power supplied to the PMD, laser shutdown for safety conditions, activation of a PMD_global_transmit_disable or other optional transmitter shut down conditions.
[e]Transmitter reflectance is defined looking into the transmitter.
[f]Either transmitter eye mask definition A or B may be used. A transmitter is not required to comply with both definitions.

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52.6.2 10GBASE-L receive optical specifications

The 10GBASE-L receiver shall meet the specifications defined in Table 52–13 per measurement techniques defined in 52.9.

Table 52–13—10GBASE-L receive characteristics

Description	10GBASE-LW	10BGASE-LR	Unit
Signaling speed (nominal)	9.95328	10.3125	GBd
Signaling speed variation from nominal (max)	± 20	± 100	ppm
Center wavelength (range)	1260 to 1355		nm
Average receive power[a] (max)	0.5		dBm
Average receive power[b] (min)	–14.4		dBm
Receiver sensitivity (max) in OMA[c]	0.055 (–12.6)		mW (dBm)
Receiver Reflectance (max)	–12		dB
Stressed receiver sensitivity (max) in OMA[d, e]	0.093 (–10.3)		mW (dBm)
Vertical eye closure penalty[f] (min)	2.2		dB
Stressed eye jitter[g] (min)	0.3		UI pk-pk
Receive electrical 3 dB upper cutoff frequency (max)	12.3		GHz

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having a power level equal to the average receive power (max) plus at least 1 dB.
[b]Average receive power (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.
[c]Receiver sensitivity is informative.
[d]Measured with conformance test signal at TP3 (see 52.9.9.3) for BER = 10^{-12}.
[e]The stressed sensitivity values in the table are for system level BER measurements, which include the effects of CDR circuits. It is recommended that at least 0.4 dB additional margin be allocated if component level measurements are made without the effect of CDR circuits.
[f]Vertical eye closure penalty is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.
[g]Stressed eye jitter is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.

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52.6.3 10GBASE-L link power budgets (informative)

An example power budget and penalties for a 10GBASE-L channel are shown in Table 52–14.

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Table 52–14—10GBASE-L link power budget[a,b]

Parameter	10GBASE-L	Unit
Power budget	9.4	dB
Operating distance	10	km
Channel insertion loss[c, d]	6.2	dB
Allocation for penalties	3.2	dB
Additional insertion loss allowed	0.0	dB

[a]Budget numbers are rounded to nearest 0.1 dB.
[b]Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.
[c]The channel insertion loss is calculated using the maximum distance specified in Table 52–11 and cabled optical fiber attenuation of 0.4 dB/km at 1310 nm plus an allocation for connection and splice loss given in 52.14.2.1.
[d]A transmitter wavelength of 1260 nm with a TDP of 3 dB is used to calculate channel insertion loss and allocation for penalties in this table.

52.7 PMD to MDI optical specifications for 10GBASE-E

The operating range for 10GBASE-E PMDs is defined in Table 52–15. A 10GBASE-E compliant PMD supports Types B1.1 and B1.3 single-mode fibers according to the specifications defined in 52.14. A PMD which exceeds the operational range requirement while meeting all other optical specifications is considered compliant (e.g., operating at 42.5 km meets the minimum range requirement of 2 m to 30 km).

Table 52–15—10GBASE-E operating range

PMD Type	Nominal Wavelength (nm)	Minimum Range
10GBASE-E	1550	2 m to 30 km
		2 m to 40 km[a]

[a]Links longer than 30 km for the same link power budget are considered engineered links. Attenuation for such links needs to be less than the minimum specified for B1.1 or B1.3 single-mode fiber.

Link attenuation requirements are specified in 52.14.3.

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52.7.1 10GBASE-E transmitter optical specifications

The 10GBASE-E transmitter shall meet the specifications defined in Table 52–16 per measurement techniques defined in 52.9.

Table 52–16—10GBASE-E transmit characteristics

Description	10GBASE-EW	10GBASE-ER	Unit
Signaling speed (nominal)	9.95328	10.3125	GBd
Signaling speed variation from nominal (max)	± 20	± 100	ppm
Center wavelength (range)	1530 to 1565		nm
Side Mode Suppression Ratio (min)	30		dB
Average launch power (max)	4.0		dBm
Average launch power[a] (min)	–4.7		dBm
Launch power (min) in OMA minus TDP[b]	–2.1		dBm
Average launch power of OFF transmitter[c] (max)	–30		dBm
Optical Modulation Amplitude[d] (min)	–1.7		dBm
Transmitter and dispersion penalty (max)	3.0		dB
Extinction ratio (min)	3		dB
$RIN_{21}OMA$[e] (max)	–128		dB/Hz
Optical Return Loss Tolerance (max)	21		dB
Transmitter eye mask definition[f] A {X1, X2, X3, Y1, Y2, Y3}	{0.25, 0.40, 0.45, 0.25, 0.28, 0.40}		
Transmitter eye mask definition[f] B{X1, X2, X3, Y1, Y2, Y3} Hit ratio 5×10^{-5} per sample	{0.235, 0.395, 0.45, 0.235, 0.265, 0.4}		

[a]Average launch power (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.
[b]TDP is transmitter and dispersion penalty.
[c]Examples of an OFF transmitter are: no power supplied to the PMD, laser shutdown for safety conditions, activation of a PMD_global_transmit_disable or other optional transmitter shut-down conditions.
[d]Even if the TDP < 0.4 dB, the OMA(min) must exceed this value.
[e]RIN measurement is made with a return loss at 21 dB.
[f]Either transmitter eye mask definition A or B may be used. A transmitter is not required to comply with both definitions.

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52.7.2 10GBASE-E receive optical specifications

The 10GBASE-E receiver shall meet the specifications defined in Table 52–17 per measurement techniques defined in 52.9.

Table 52–17—10GBASE-E receive characteristics

Description	10GBASE-EW	10GBASE-ER	Unit
Signaling speed (nominal)	9.95328	10.3125	GBd
Signaling speed variation from nominal (max)	± 20	± 100	ppm
Center wavelength (range)	1530 to 1565		nm
Average receive power (max)	–1.0		dBm
Average receive power[a] (min)	–15.8		dBm
Maximum receive power (for damage)	4.0		dBm
Receiver sensitivity (max) in OMA[b]	0.039 (–14.1)		mW (dBm)
Receiver Reflectance (max)	–26		dB
Stressed receiver sensitivity (max) in OMA[c,d]	0.074 (-11.3)		mW (dBm)
Vertical eye closure penalty[e] (min)	2.7		dB
Stressed eye jitter (min)[f]	0.3		UI pk-pk
Receive electrical 3 dB upper cutoff frequency (max)	12.3		GHz

[a]Average receive power (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.
[b]Receiver sensitivity is informative.
[c]Measured with conformance test signal at TP3 (see 52.9.9.3) for BER = 10^{-12}.
[d]The stressed sensitivity values in the table are for system level BER measurements which include the effects of CDR circuits. It is recommended that at least 0.4 dB additional margin be allocated if component level measurements are made without the effects of CDR circuits.
[e]Vertical eye closure penalty is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.
[f]Stressed eye jitter is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.

52.7.3 10GBASE-E link power budgets (informative)

Example power budgets and penalties for a 10GBASE-E channel are shown in Table 52–18.

52.8 Jitter specifications for 10GBASE-R and 10GBASE-W

Acceptable transmitted jitter is achieved by compliance with 52.9.7, transmitter optical waveform, and 52.9.10, transmitter and dispersion penalty. Tolerance to received jitter is achieved by compliance to 52.9.9, stressed receiver conformance, which includes sinusoidal jitter as in the following subclause. There is no jitter transfer specification.

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Table 52–18—10GBASE-E link power budgets[a,b]

Parameter	10GBASE-E		Unit
Power budget	15.0		dB
Operating distance	30	40[c]	km
Channel insertion loss[d, e]	10.9	10.9	dB
Maximum Discrete Reflectance (max)	–26		dB
Allocation for penalties	3.6	4.1	dB
Additional insertion loss allowed	0.5	0.0	dB

[a]Budget numbers are rounded to nearest 0.1 dB.
[b]Link penalties are built into the transmitter specifications by testing the PMD with a maximum dispersion fiber.
[c]Links longer than 30 km are considered engineered links. Attenuation for such links needs to be less than that guaranteed by B1.1 or B1.3 single-mode fiber.
[d]Operating distances used to calculate the channel insertion loss are the maximum values specified in Table 52–15
[e]A wavelength of 1565 nm and 3dB transmitter and dispersion penalty (TDP) is used to calculate channel insertion loss, and allocation for penalties.

52.8.1 Sinusoidal jitter for receiver conformance test

The sinusoidal jitter is used to test receiver jitter tolerance. Sinusoidal jitter may vary over a magnitude range as required to accurately calibrate a stressed eye per 52.9.9. The range is limited by the constraints of Table 52–19.

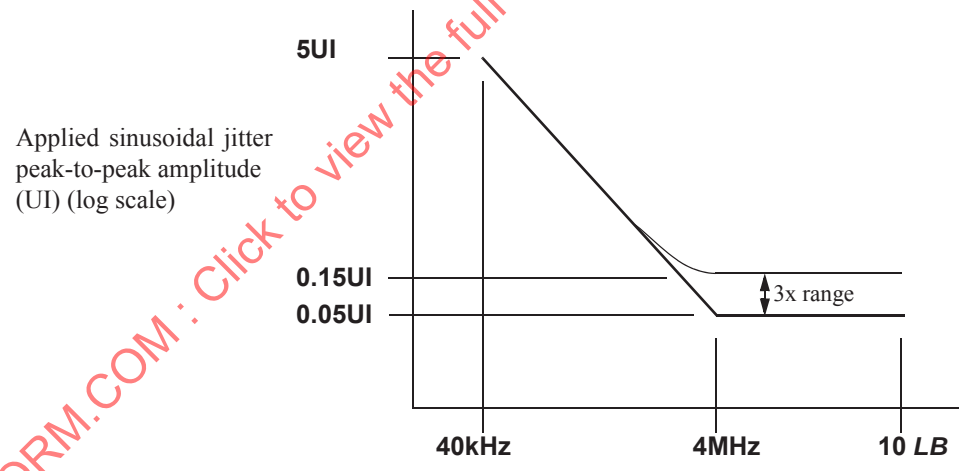

Figure 52–4—Mask of the sinusoidal component of jitter tolerance (informative)

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Table 52–19—Applied sinusoidal jitter

Frequency range	Sinusoidal jitter ($UI_{pk\ to\ pk}$)
$f < 40$kHz	NA
40 kHz $< f \leq$ 4MHz	$2 \times 10^5 / f + S - 0.05$[a]
4 MHz $< f <$ 10 LB[b]	$0.05 \leq S \leq 0.15$ [a]

[a]S is the magnitude of sine jitter actually used in the calibration of the stressed eye per the methods of 52.9.9.3.
[b]LB = Loop Bandwidth; Upper frequency bound for added sine jitter should be at least 10 times the loop bandwidth of the receiver being tested.

52.9 Optical measurement requirements

All optical measurements shall be made through a short patch cable, between 2 m and 5 m in length, unless otherwise specified.

52.9.1 Test patterns

Compliance is to be achieved in normal operation. Two types of test pattern are used, square wave (52.9.1.2) and other (52.9.1.1). Test patterns are as in Table 52–22 for 10GBASE-R and in 50.3.8 for 10GBASE-W unless specified otherwise.

NOTE—Test patterns for specific optical tests are designed to emulate system operation, which would entail passing valid 10GBASE-R or 10GBASE-W data.

52.9.1.1 Test-pattern definition

Patterns 1, 2, and 3 are defined in Table 52–21. Pattern 3 is optional.

For 10GBASE-R, two test pattern segments are specified, in two variants, “normal” (n) and “inverted” (i). Both are 8448 bits long. They may be generated dynamically by the 58 bit scrambler and “control block” sync header generation defined in 49.2.6, and using the scrambler starting seeds specified in Table 52–20 and the method of generation in 49.2.8. The segments are assembled into patterns, each containing four segments, as described in Table 52–21. Each may be held as a static pattern in test equipment, or generated or detected dynamically using the methods of 49.2.8 and 49.2.12 respectively, or otherwise.

Each segment contains a sync header transition every 66 bits.

Table 52–20—Pattern segments

Segments	Seed[57:0][a]
A_n	0x3C8B44DCAB6804F
B_n	0x34906BB85A38884

[a]The “invert” segments A_i and B_i are generated using the inverted seeds for A_n and B_n, respectively.

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Table 52–21—Test patterns

Pattern	Pattern for 10GBASE-R	Pattern for 10GBASE-W
1	$B_n B_i B_n B_i$	Mixed[a]
2	$A_n A_i A_n A_i$	
3	PRBS31[b]	PRBS31[c]

[a]The patterns for 10GBASE-W are defined in 50.3.8.
[b]This is the test-pattern checker defined in 49.2.12.
[c]This is the test-pattern checker defined in 50.3.8.2.

The test pattern 1 is generated with the data input mode programmed to select LF data input. The test pattern 2 is generated with the data input mode programmed to select all zero data input.

Pattern 1 represents typical scrambled data while pattern 2 represents a less typical pattern that could happen by chance and is thought to be more demanding of the transmission process including the clock recovery subsystem. Both patterns are balanced over their length of 33 792 bits.

NOTE—While other test methods and patterns could be used it is the implementer's responsibility to ensure that measurements carried out with the specified patterns achieve the requirements specified.

Table 52–22—Test-pattern definitions and related subclauses

Test	Pattern	Related subclause
Average optical power	1 or 3	52.9.3
OMA (modulated optical power)	Square	52.9.5
Extinction ratio	1 or 3	52.9.4
Transmit eye	1 or 3	52.9.7
Receive upper cutoff frequency	1 or 3	52.9.11
$RIN_x OMA$	Square	52.9.6
Wavelength, spectral width	1 or 3	52.9.2
Side mode suppression ratio	1 or 3	—
Vertical eye closure penalty calibration	2 or 3	52.9.9
Receiver sensitivity	1 or 3	52.9.9
Receiver overload	1 or 3	—
Stressed receive conformance	2 or 3	52.9.9
Transmitter and dispersion penalty	2 or 3	52.9.10

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52.9.1.2 Square wave pattern definition

A pattern consisting of four to eleven consecutive ones followed by an equal run of zeros may be used as a square wave. These patterns have fundamental frequencies between approximately 452 MHz (10GBASE-W) and 1289 MHz (10GBASE-R).

52.9.2 Center wavelength and spectral width measurements

The center wavelength and spectral width (RMS) shall be measured using an optical spectrum analyzer per TIA-455-127-A under modulated conditions using an appropriate PRBS or a valid 10GBASE-R or 10GBASE-W signal, OC-192 signal, STM-64 signal, or another representative test pattern.

52.9.3 Average optical power measurements

Average optical power shall be measured using the methods specified in TIA/EIA-455-95. This measurement may be made with the node transmitting test pattern 1 or 3 or a valid 10GBASE-R or 10GBASE-W signal, OC-192 signal, STM-64 signal, or another representative test pattern.

52.9.4 Extinction ratio measurements

Extinction ratio shall be measured using the methods specified in IEC 61280-2-2. This parameter is to be assured during system operation. However, measurements with an appropriate PRBS ($2^{23} – 1$ or $2^{31} – 1$) or a valid 10GBASE-R or 10GBASE-W or OC-192c or STM-64 signal will give equivalent results.

52.9.5 Optical modulation amplitude (OMA) test procedure

OMA is the difference in optical power for the nominal "1" and "0" levels of the optical signal, OMA in Figure 52–6, using waveform averaging or histogram means. OMA should be measured for a node transmitting the square wave pattern defined in 52.9.1.

The recommended technique for measuring optical modulation amplitude is illustrated in Figure 52–5. Optionally, a fourth-order Bessel-Thomson filter as specified in 52.9.7 can be used after the O/E converter. The measurement system consisting of the O/E converter, the optional filter and the oscilloscope has the following requirements:

a) The bandwidth of the measurement system shall be at least 3/T where T is the time at high or low (00001111 giving approximately T = 400 ps and 7.5 GHz as an example); and
b) The measurement system is calibrated at the appropriate wavelength for the transmitter under test.

With the device under test transmitting the square wave described above, use the following procedure to measure optical modulation amplitude:

c) Configure the test equipment as illustrated in Figure 52–5.
d) Measure the mean optical power P_1 of the logic "1" as defined over the center 20% of the time interval where the signal is in the high state. (See Figure 52–6.)
e) Measure the mean optical power P_0 of the logic "0" as defined over the center 20% of the time interval where the signal is in the low state. (See Figure 52–6.)
f) OMA = $P_1 – P_0$.

A method of approximating OMA is shown in Figure 52–11.

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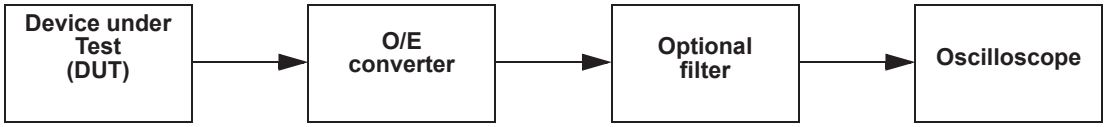

Figure 52–5—Recommended test equipment for measurement of optical modulation amplitude

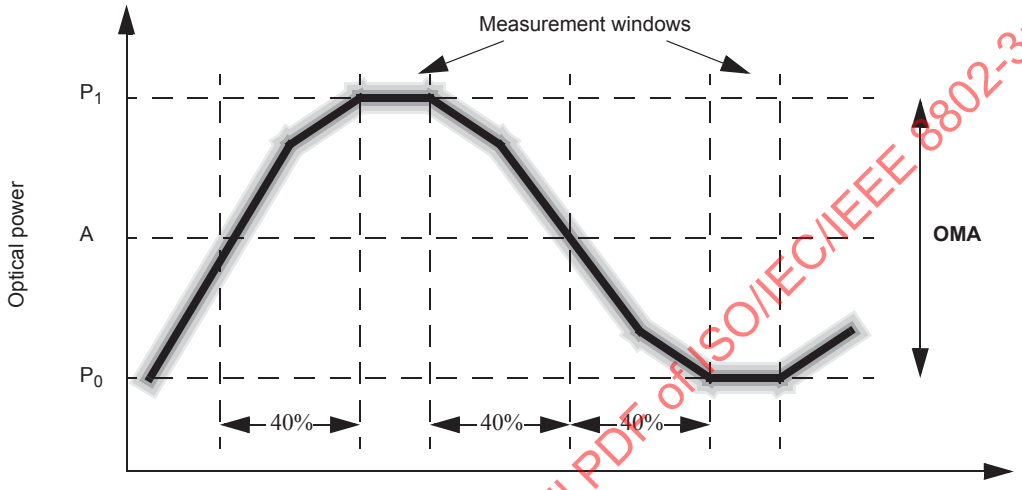

Figure 52–6—Optical modulation amplitude waveform measurement

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52.9.6 Relative intensity noise optical modulation amplitude (RIN_xOMA) measuring procedure

This procedure describes a component test that may not be appropriate for a system level test depending on the implementation. If used, the procedure shall be performed as described in 52.9.6.1, 52.9.6.2, and 52.9.6.3.

52.9.6.1 General test description

The test arrangement is shown in Figure 52–7. The optical path between the device under test (DUT) and the detector has a single discrete reflection with the specified optical return loss as seen by the DUT.

Both the OMA power and noise power are measured by AC-coupling the O/E converter into the high-frequency electrical power meter. If needed, an amplifier may be used to boost the signal to the power meter. A low-pass filter is used between the photodetector and the power meter to limit the noise measured to the passband appropriate to the data rate of interest. In order to measure the noise, the modulation to the DUT is turned off.

52.9.6.2 Component descriptions

Optical path: The optical path and detector combination must be configured for a single dominant reflection with an optical return loss specified in Table 52–7 for 10GBASE-S, Table 52–12 for 10GBASE-L, and Table 52–16 for 10GBASE-E. (The optical return loss may be determined by the method of FOTP-107.) The length of the test cable is not critical but should be in excess of 2 m.

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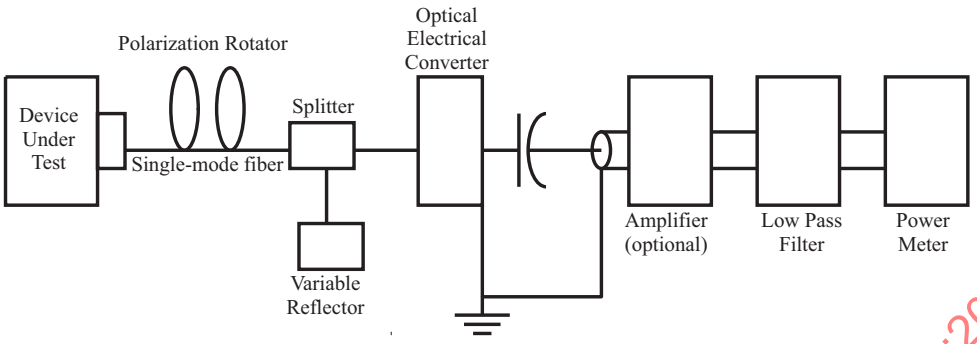

Figure 52–7—RIN$_x$OMA measurement setup

Polarization rotator: The polarization rotator is required to be capable of transforming an arbitrary orientation elliptically polarized wave into a fixed orientation linearly polarized wave.

O/E converter (and amplifier): If necessary, the noise may be amplified to a level consistent with accurate measurement by the power meter.

Filter: The upper –3 dB limit of the measurement apparatus is to be approximately equal to the bit rate (i.e., 10 GHz). The total filter bandwidth used in the RIN calculation is required to take the low-frequency cutoff of the DC-blocking capacitor into consideration. The low-frequency cutoff is recommended to be less than 1 MHz.

The filter should be placed in the circuit as the last component before the power meter so that any high-frequency noise components generated by the detector/amplifier are eliminated. If the power meter used has a very wide bandwidth, care should be taken to ensure that the filter does not lose its rejection at extremely high frequencies.

Power meter: The RMS electrical power meter should be capable of being zeroed in the absence of input optical power to remove any residual noise.

52.9.6.3 Test Procedure

Use the following procedure to test relative intensity noise optical modulation amplitude:

a) With the DUT disconnected, zero the power meter;
b) Connect the DUT, turn on the laser, and ensure that the laser is not modulated;
c) Operate the polarization rotator while observing the power meter output to maximize the noise read by the power meter. Note the maximum power, P_N;
d) Turn on the modulation to the laser using the square wave pattern of 52.9.1 and note the power measurement, P_M. It may be necessary to change or remove the effective reflection to obtain an accurate reading;
e) Calculate RIN from the observed electrical signal power and noise power by use of Equation (52–1).

$$RIN_xOMA = 10\log\frac{P_N}{BW \times P_M} \text{ (dB/Hz)} \qquad (52\text{–}1)$$

where:

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RIN_xOMA= Relative Intensity Noise referred to optical modulation amplitude measured with x dB reflection,

P_N = Electrical noise power in watts with modulation off,

P_M = Electrical power in watts with modulation on,

BW = Low-pass bandwidth of filter – high-pass bandwidth of DC-blocking capacitor [noise bandwidth of the measuring system (Hz)].

For testing multimode components or systems, the polarization rotator is removed from the setup and the single-mode fiber replaced with a multimode fiber. Step c) of the test procedure is eliminated.

52.9.7 Transmitter optical waveform

The required transmitter pulse shape characteristics are specified in the form of a mask of the transmitter eye diagram as shown in Figure 52–8. Compliance is to be assured during system operation. However, measurements with pattern 3 or 1 defined in 52.9.1, or other patterns such as a 2^{23}– 1 PRBS or a valid 10GBASE-R, or 10GBASE-W, or OC-192c, or STM-64 signal are likely to give very similar results. Measurements should be made as defined by IEC 61280-2-2 with the eye mask definition A coordinates, or as defined by 86.8.3.2 with the eye mask definition B coordinates. The two sets of coordinates (A and B) are given in Table 52–7, Table 52–12 or Table 52–16 as appropriate. A transmitter is not required to comply with both definitions. Measurement at 10.3125 GBd shall qualify for 10GBASE-W and 10GBASE-R use, measurement at 9.95328 GBd shall qualify for 10GBASE-W use only.

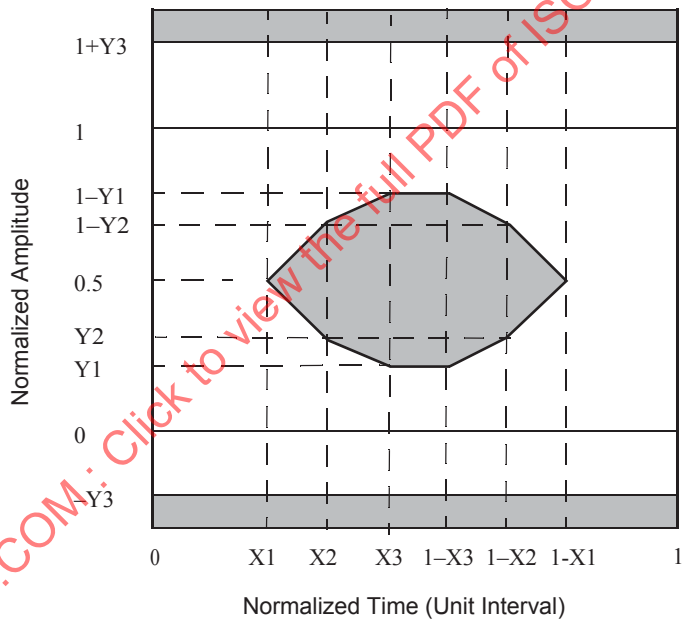

Figure 52–8—Transmitter eye mask definition

Normalized amplitudes of 0.0 and 1.0 represent the amplitudes of logic ZERO and ONE respectively. Normalized times of 0 and 1 on the unit interval scale are to be determined by the eye crossing means measured at the average value of the optical eye pattern.

A clock recovery unit (CRU) should be used to trigger the scope for mask measurements as shown in Figure 52–9. It should have a high-frequency corner bandwidth of less than or equal to 4 MHz and a slope of –20 dB/decade.

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The eye shall be measured with respect to the mask of the eye using a receiver with a fourth-order Bessel-Thomson response having a transfer function given by Equation (52–2) and Equation (52–3):

$$H(y) = \frac{105}{105 + 105y + 45y^2 + 10y^3 + y^4} \quad (52–2)$$

where:

$$y = 2.114p\ ; \quad p = \frac{j\omega}{\omega_r}\ ; \quad \omega_r = 2\pi f_r\ ; \quad f_r = 7.5\text{GHz} \quad (52–3)$$

and where the filter response vs. frequency range for this fourth-order Bessel-Thomson receiver is defined in ITU-T G.691, along with the allowed tolerances (STM-64 values) for its physical implementation.

This Bessel-Thomson receiver is not intended to represent the noise filter used within a compliant optical receiver, but is intended to provide uniform measurement conditions at the transmitter.

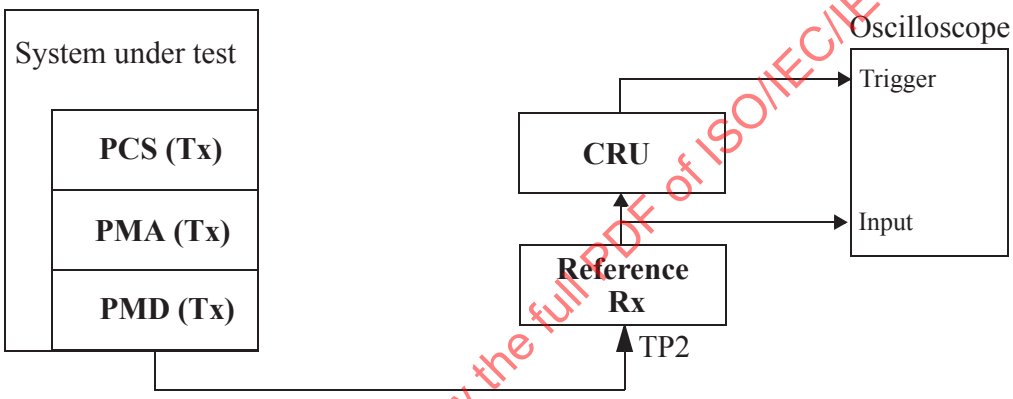

Figure 52–9—Transmitter optical waveform test block diagram

The fourth-order Bessel-Thomson filter is reactive. In order to suppress reflections, a 6 dB attenuator may be required at the filter input and/or output.

52.9.8 Receiver sensitivity measurements

Receiver sensitivity, which is defined for an ideal input signal, is informative and testing is not required. If measured, the test signal should have negligible impairments such as intersymbol interference (ISI), rise/fall times, jitter and RIN. Instead, the normative requirement for receivers is stressed receiver sensitivity. Stressed sensitivity is measured with a conditioned input signal where both vertical eye closure and jitter have been added according to 52.9.9.

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52.9.9 Stressed receiver conformance test

Stressed receiver tolerance testing shall be performed in accordance with the requirements of 52.9.9.1, 52.9.9.2, 52.9.9.3, and 52.9.9.4.

Receivers must operate with BER less than 10^{-12} when tested with a conditioned input signal that combines vertical eye closure and jitter according to this clause.

The measurements in this subclause are performed with asynchronous data flowing out of the optical transmitter of the system under test. The output data pattern from the transmitter of the system under test is to be the same pattern defined for this measurement in 52.9.1.

52.9.9.1 Stressed receiver conformance test block diagram

A block diagram for the receiver conformance test is shown in Figure 52–10. A suitable pattern generator is used to continuously generate a signal or test pattern according to 52.9.1. The optical test signal is conditioned (stressed) using the methodology, as defined in 52.9.9.3, while applying sinusoidal jitter, as defined in 52.8.1. The receiver of the system under test is tested for conformance by enabling the error counter on the receiving side. As defined in section 49.2.12 and 50.3.8, the PCS or WIS is capable of detecting the data pattern and reporting any errors received. The optical power penalty for the stressed eye is intended to be similar to its vertical eye closure penalty. This is not necessarily the same as the highest TDP anticipated in service, but represents a standardized test condition for the receiver.

A suitable test set is needed to characterize and verify that the signal used to test the receiver has the appropriate characteristics. The test fiber called out for LW/LR and EW/ER and the transversal filter called out for SW/SR are not needed to characterize the receiver input signal; nor are they used during testing.

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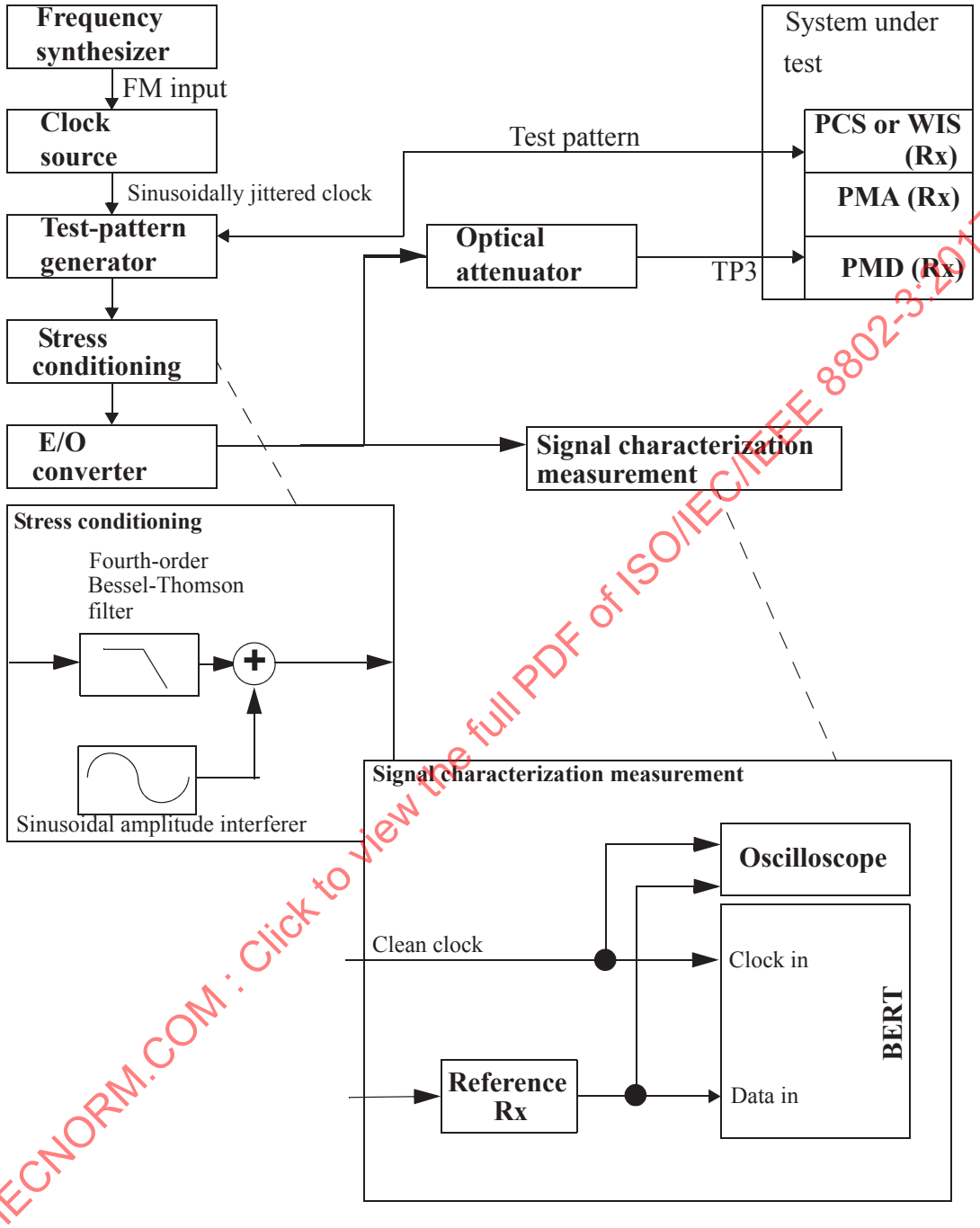

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Figure 52–10—Stressed receiver conformance test block diagram

The fourth-order Bessel-Thomson filter is used to create ISI-induced vertical eye closure penalty (VECP). The sinusoidal amplitude interferer causes additional eye closure, but in conjunction with the slowed edge rates from the filter, also causes jitter. The nature of the jitter is intended to emulate instantaneous bit shrinkage that can occur with DDJ. This type of jitter cannot be created by simple phase modulation. The sinusoidal phase modulation represents other forms of jitter and also verifies that the receiver under test can

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track low-frequency jitter. The frequency of the sinusoidal interference may be set at any frequency between 100 MHz and 2 GHz, although be careful to avoid a harmonic relationship between the sinusoidal interference, the sinusoidal jitter, the data rate and the pattern repetition rate.

For improved visibility for calibration, it is imperative that the Bessel-Thomson filter and all other elements in the signal path (cables, DC blocks, E/O converter, etc.) have wide and smooth frequency response and linear phase response throughout the spectrum of interest. Baseline wander and overshoot and undershoot should be minimized. If this is achieved, then data dependent effects should be minimal, and short data patterns can be used for calibration with the benefit of providing much improved trace visibility on sampling oscilloscopes. Actual patterns for testing the receiver shall be as specified in Table 52–22.

To further improve visibility for calibration, random noise effects, such as RIN and random clock jitter, should also be minimized. A small amount of residual noise and jitter from all sources is unavoidable, but should be less than 0.25 UI peak-peak of jitter at the 10^{-12} points.

The Bessel-Thomson filter and the E/O converter should have the appropriate frequency response to result in the appropriate level of initial ISI eye closure before the sinusoidal terms are added. The E/O converter should be fast and linear such that the waveshape and edge rates are predominantly controlled or limited by the electrical circuitry. Electrical summing requires high linearity of all elements including the E/O converter. Summing with an optical coupler after the E/O converter is an option that eases linearity requirements, but requires a second source for the interfering signal, will complicate settings of extinction ratio, and will add more RIN.

The vertical and horizontal eye closures to be used for receiver conformance testing are verified using an optical reference receiver with a 7.5 GHz fourth order ideal Bessel-Thomson response. Use of G.691 tolerance filters may significantly degrade this calibration. Care should be taken to ensure that all the light from the fiber is collected by the fast photodetector and that there is negligible mode selective loss, especially in the optical attenuator and the optical coupler, if used.

The clock output from the clock source in Figure 52–10 will be modulated with the sinusoidal jitter. To use an oscilloscope to calibrate the final stressed eye jitter that includes the sinusoidal jitter component, a separate clock source (clean clock of Figure 52–11) is required that is synchronized to the source clock, but not modulated with the jitter source.

52.9.9.2 Parameter definitions

The primary parameters of the conformance test signal are vertical eye closure penalty (VECP) and stressed eye jitter, J. Vertical eye closure penalty is measured at the time center of the eye (halfway between 0 and 1 on the unit interval scale as defined in 52.9.7) and is calculated relative to the measured OMA value. J is defined from the 0.5th to the 99.5th percentile of the jitter histogram. J is measured at the average optical power, which can be obtained with AC-coupling. The values of these components are defined by their histogram results.

The vertical eye closure penalty is given by Equation (52–4).

$$\text{Vertical eye closure penalty [dB, optical]} = 10 \times \log \frac{OMA}{A_O} \tag{52–4}$$

where:

A_O is the amplitude of the eye opening from the 99.95th percentile of the lower histogram to the 0.05th percentile of the upper histogram, and

OMA is the normal amplitude without ISI, as shown in Figure 52–11.

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52.9.9.3 Stressed receiver conformance test signal characteristics and calibration

The conformance test signal is used to validate that the PMD receiver meets BER requirements with near worst case waveforms including pulse width shrinkage, power, simulated channel penalties, and a swept frequency sinusoidal jitter contribution applied at TP3.

Signal characteristics are described below along with a suggested approach for calibration.

The test signal includes vertical eye closure and high-probability jitter components. For this test, these two components are defined by peak values that include all but 0.1% for VECP and all but 1% for jitter of their histograms. Histograms should include at least 10 000 hits, and should be about 1%-width in the direction not being measured. Residual low-probability noise and jitter should be minimized—that is, the outer slopes of the final histograms should be as steep as possible down to very low probabilities.

The following steps describe a suggested method for calibrating a stressed eye generator:

1) Set the signaling speed of the test-pattern generator to satisfy the requirements of 52.5.2, 52.6.2, or 52.7.2.
2) Turn on the calibration pattern. A short pattern may be used for calibration if the conditions described in 52.9.9.1 are met, but this increases the risk that the longer test pattern used during testing will overstress the device under test. In any case, a pattern shorter than PRBS10 is not recommended.
3) Set the extinction ratio to approximately the Extinction Ratio (min) value given in 52.5.1, 52.6.1, or 52.7.1. Sinusoidal interference and jitter signals should be turned off at this point. If optical summing is used, ER may need to be adjusted after the sinusoidal interference signal is added below.
4) Measure the OMA of the test signal (without attenuation). OMA is measured per the method in 52.9.5 using the square wave pattern.
5) The requirements for vertical eye closure and jitter of the stressed eye test signal are given by the Vertical eye closure penalty (VECP) and Stressed eye jitter (J) values given in Table 52–9 for 10GBASE-S, Table 52–13 for 10GBASE-L, or Table 52–17 for 10GBASE-E.

   There are three components involved in calibration for vertical closure and J. These are a linear phase filter, sinusoidal interference, and sinusoidal jitter.

   Without sinusoidal jitter or sinusoidal interference, greater than two thirds of the vertical eye closure penalty value should be created by use of a linear phase, low jitter filter (such as Bessel-Thomson). The filter should be tested with the prescribed test patterns to verify that residual jitter and baseline wander are small, not to exceed 0.25 UI peak-peak. If not, the stress may be more than desired, leading to conservative results. However, compensation is not allowed. Once done, revert to the calibration pattern, if different than the final test pattern specified in Table 52–22.

   Any remaining vertical eye closure required must be created with sinusoidal interference or sinusoidal jitter.

   Sinusoidal jitter (phase modulation) must be added per the template of Table 52–19. For calibration purposes, sinusoidal jitter frequencies must be well within the flat portion of the template greater than 4 MHz.

   Iterate the settings for sinusoidal interference and/or jitter until all constraints are met, including jitter (J), vertical closure (VECP), and that sinusoidal jitter above 4 MHz is as specified in Table 52–19.

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Verify that the optical power penalty for the stressed eye (relative to the reference transmitter per 52.9.10) is greater than or equal to VECP.

To emulate the effects of DCD or data-dependent jitter, at least 5 ps peak-peak of pulse shrinkage jitter should have been achieved.

6) Decrease the amplitude with the optical attenuator until the OMA complies with the OMA values given in Table 52–9 for 10GBASE-S, Table 52–13 for 10GBASE-L, Table 52–17 for 10GBASE-E. If high linearity exists, then the sinusoidal interference should not change the OMA value. OMA can be approximated with histograms as suggested in Figure 52–11. However, the normative definition for OMA is as given in 52.9.5.

7) For testing, turn on the actual required test pattern(s) per 52.9.1.

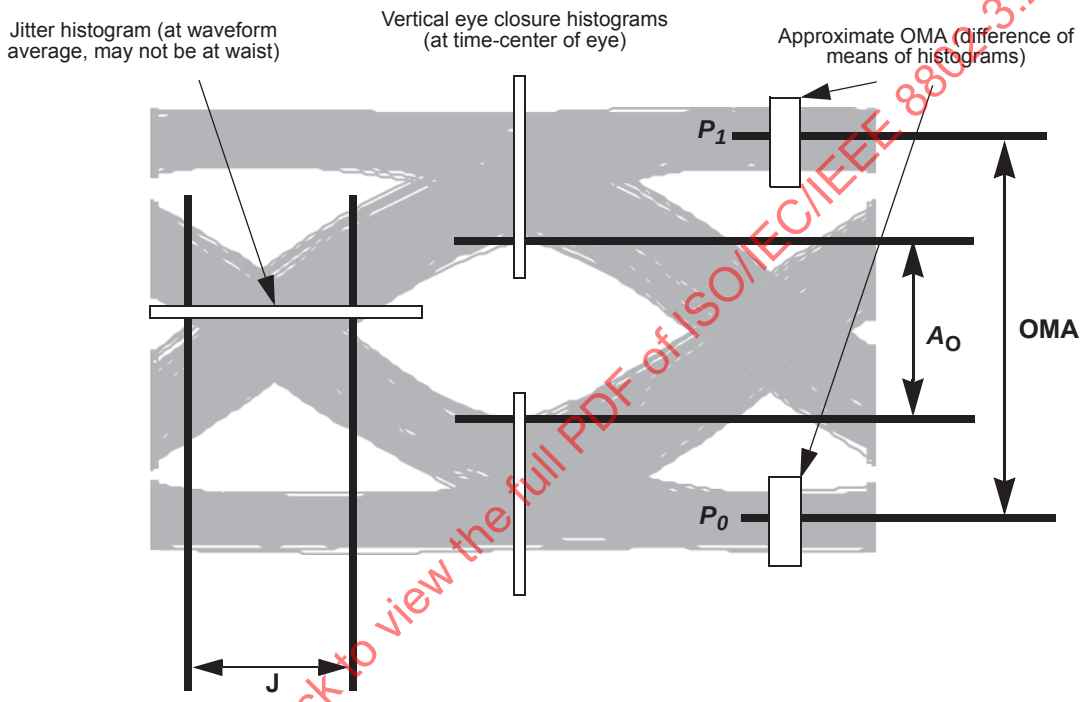

Figure 52–11—Required characteristics of the conformance test signal at TP3

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Care should be taken when characterizing the signal used to make receiver tolerance measurements. In the case of a transmit jitter measurement, excessive and/or uncalibrated noise/jitter in the test system makes it more difficult to meet the specification and may have a negative impact on yield but will not effect interoperability. Running the receiver tolerance test with a signal that is under-stressed may result in the deployment of non-compliant receivers. Care should be taken to minimize and/or correct for the noise/jitter introduced by the reference receiver, filters, oscilloscope, and BERT. While the details of measurement and test equipment are beyond the scope of this standard it is recommended that the implementer fully characterize the test equipment and apply appropriate guard bands to ensure that the receive input signal meets the specified requirements.

52.9.9.4 Stressed receiver conformance test procedure

The test apparatus is set up as described in 52.9.9.1, 52.9.9.2 and 52.9.9.3. The sinusoidal jitter is then stepped across the frequency and amplitude range specified in 52.8.1 while monitoring BER at the receiver. The BER is to be compliant for all jitter frequencies. This method does not result in values for jitter

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contributed by the receiver. It does, however, guarantee that a receiver meeting the requirements of this test will operate with the worst-case optical input.

52.9.10 Transmitter and dispersion penalty measurement

The transmitter and dispersion penalty (TDP) measurement tests for transmitter impairments with chromatic effects for a transmitter to be used with single-mode fiber, and for transmitter impairments with modal (not chromatic) dispersion effects for a transmitter to be used with multimode fiber.

The setup for measurement of transmitter and dispersion penalty is shown in Figure 52–12 and consists of a reference transmitter, the transmitter under test, a controlled optical reflection, an optical attenuator, a test fiber, a reference receiver, a transversal filter for 10GBASE-S, and a bit-error ratio tester. For 10GBASE-S, the polarization rotator shown in Figure 52–12 is removed from the setup and the single-mode fiber replaced with a multimode fiber. All BER and sensitivity measurements are made with the test patterns in 52.9.1.

52.9.10.1 Reference transmitter requirements

The reference transmitter is a high-quality instrument-grade device, which can be implemented by a CW laser modulated by a high-performance modulator. It should meet the following basic requirements:

a) The rise/fall times should be less than 30 ps at 20% to 80%.
b) The output optical eye is symmetric and passes the eye mask test of 52.9.7.
c) In the center 20% region of the eye, the worst case vertical eye closure penalty as defined in 52.9.9.3 is less than 0.5 dB.
d) Jitter less than 0.20 UI peak-peak.
e) RIN should be minimized to less than –136 dB/Hz

52.9.10.2 Channel requirements

The transmitter is tested using an optical channel that meets the requirements listed in Table 52–23.

Table 52–23—Transmitter compliance channel specifications

PMD Type	Dispersion[a] (ps/nm)		Insertion loss[b]	Optical return loss[c] (max)
	Minimum	Maximum		
10GBASE-S	N/A	N/A	Minimum	See ORLT in Table 52–7
10GBASE-L	$0.2325 \cdot \lambda \cdot [1 - (1324 / \lambda)^4]$	$0.2325 \cdot \lambda \cdot [1 - (1300 / \lambda)^4]$	Minimum	21 dB
10GBASE-E	0 (maximum)	$0.93 \cdot \lambda \cdot [1 - (1300 / \lambda)^4]$	Minimum	See ORLT in Table 52–16

[a]The dispersion is measured for the wavelength of the device under test. The coefficient assumes 10 km for 10GBASE-L and 40 km for 10GBASE-E.
[b]There is no intent to stress the sensitivity of the BERT's optical receiver.
[c]The optical return loss is applied at TP2.

A 10GBASE-L/E transmitter is to be compliant with a total dispersion at least as negative as the "minimum dispersion" and at least as positive as the "maximum dispersion" columns specified in Table 52–23 for the

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wavelength of the device under test. This may be achieved with channels consisting of fibers with lengths chosen to meet the dispersion requirements.

To verify that the fiber has the correct amount of dispersion, the measurement method defined in ANSI/TIA/EIA-455-175A-92 may be used. The measurement is made in the linear power regime of the fiber.

The channel for 10GBASE-S is a 2 m to 5 m patch cord meeting the requirements in Table 52–25.

The channel provides a maximum optical return loss specified in Table 52–23. The state of polarization of the back reflection is adjusted to create the greatest RIN. The methods of 52.9.6.2 and 52.9.6.3 may be used.

52.9.10.3 Reference receiver requirements

The reference receiver should have the bandwidth given in 52.9.7. The sensitivity of the reference receiver should be limited by Gaussian noise. The receiver should have minimal threshold offset, deadband, hysteresis, baseline wander, deterministic jitter or other distortions. Decision sampling should be instantaneous with minimal uncertainty and setup/hold properties.

The nominal sensitivity of the reference receiver, S, is measured in OMA using the set up of Figure 52–12 without the test fiber and with the transversal filter removed. The sensitivity S must be corrected for any significant reference transmitter impairments including any vertical eye closure. It should be measured while sampling at the eye center or corrected for off-center sampling. It is calibrated at the wavelength of the transmitter under test.

For all transmitter and dispersion penalty measurements, determination of the center of the eye is required. Center of the eye is defined as the time halfway between the left and right sampling points within the eye where the measured BER is greater than or equal to 1×10^{-3}.

For 10GBASE-S the reference receiver is followed by a transversal filter with two equal amplitude paths with a differential delay of 55 ps. For 10GBASE-L/E the transversal filter is not used.

The clock recovery unit (CRU) used in the TDP measurement has a corner frequency of less than or equal to 4 MHz and a slope of 20 dB/decade. When using a clock recovery unit as a clock for BER measurements, passing of low-frequency jitter from the data to the clock removes this low-frequency jitter from the measurement.

52.9.10.4 Test procedure

To measure the transmitter and dispersion penalty (TDP) the following procedure shall be used. The decision threshold amplitude is defined to occur at the average signal level. The sampling instant is displaced from the eye center by ± 0.05 UI. The following procedure is repeated for early and late decision and the larger TDP value is used:

a) Configure the test equipment as described above and illustrated in Figure 52–12.
b) Adjust the attenuation of the optical attenuator to obtain a BER of 1×10^{-12}.
c) Record the optical power in OMA at the input to the reference receiver, P_DUT, in dBm.
d) If P_DUT is larger than S, the transmitter and dispersion penalty (TDP) for the transmitter under test is the difference between P_DUT and S, TDP = P_DUT – S. Otherwise the transmitter and dispersion penalty is zero, TDP = 0.

It is to be ensured that the measurements are made in the linear power regime of the fiber.

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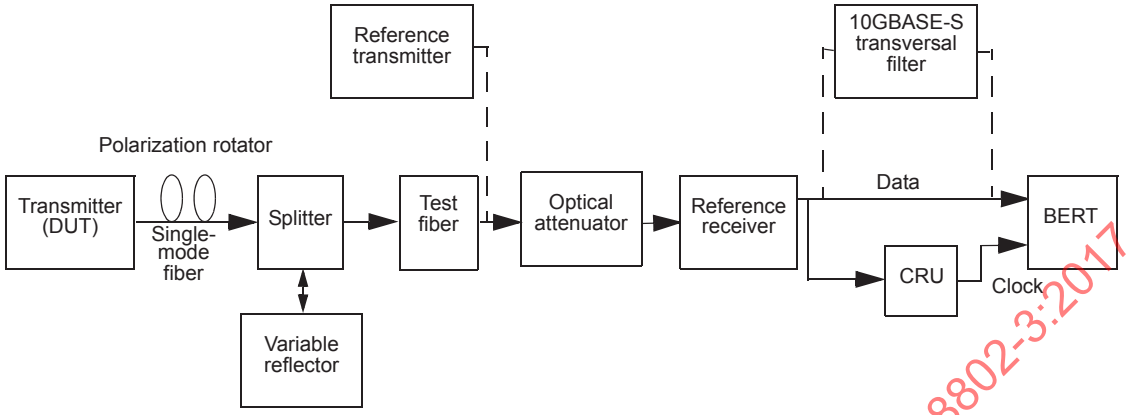

Figure 52–12—Test setup for measurement of transmitter and dispersion penalty

52.9.11 Measurement of the receiver 3 dB electrical upper cutoff frequency

The receiver 3 dB electrical upper cutoff frequency may be measured as described in Figure 52–13 and the list below. The test setup is shown in Figure 52–13. The test uses two optical sources and an optical combiner. One source is modulated by a digital data signal. The other, approximately linear, source is modulated with an analog signal. The analog and digital signals should be asynchronous. The recommended patterns are test patterns 1 or 3 of 52.9.1. An appropriate PRBS or a valid 10GBASE-R or 10GBASE-W signal, OC-192 signal, STM-64 signal, or another representative test pattern may be used.

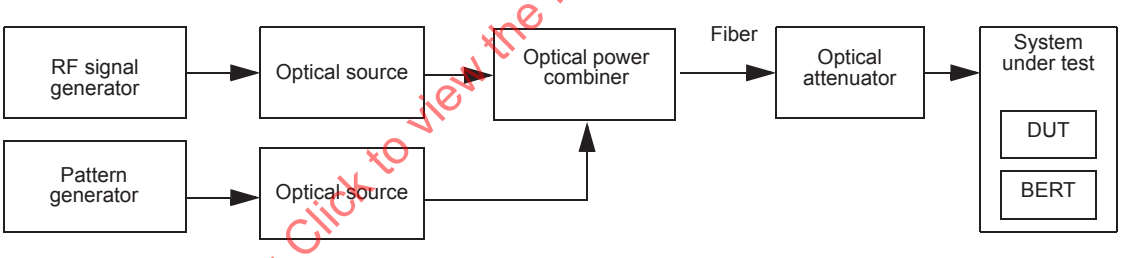

Figure 52–13—Test setup for receiver bandwidth measurement

The 3 dB upper cutoff frequency may be measured using the following steps:

a) Calibrate the frequency response characteristics of the test equipment including the analog radio frequency (RF) signal generator and laser sources. The digital optical source meets the requirements of this clause.

b) Configure the test equipment as shown in Figure 52–13. Take care to minimize changes to the signal path which could affect the system frequency response after the calibration in step a. With the RF modulation turned off, and both optical sources turned on, set the Optical Modulation Amplitude to a level that approximates the stressed receiver sensitivity level in Table 52–9 for 10GBASE-S, Table 52–13 for 10GBASE-L, and Table 52–17 for 10GBASE-E.

c) Turn on the RF modulation while maintaining the same average optical power and OMA established in step b).

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d) Measure the necessary RF modulation amplitude (in electrical dBm) required to achieve a constant BER (e.g., 10^{-8}) for a number of frequencies.

e) The receiver 3 dB electrical upper cutoff frequency is that frequency where the corrected RF modulation amplitude (the measured amplitude in "d" corrected with the calibration data in "a") increases by 3 dB (electrical).

52.10 Environmental specifications

52.10.1 General safety

All equipment meeting this standard shall conform to IEC-60950-1.

52.10.2 Laser safety

10GBASE-R and 10GBASE-W optical transceivers shall conform to Hazard Level 1 laser requirements as defined in IEC 60825-1 and IEC 60825-2, under any condition of operation. This includes single fault conditions whether coupled into a fiber or out of an open bore.

Conformance to additional laser safety standards may be required for operation within specific geographic regions.

Laser safety standards and regulations require that the manufacturer of a laser product provide information about the product's laser, safety features, labeling, use, maintenance, and service. This documentation is required to explicitly define requirements and usage restrictions on the host system necessary to meet these safety certifications.[13]

52.10.3 Installation

Sound installation practice, as defined by applicable local codes and regulations, shall be followed in every instance in which such practice is applicable.

52.11 Environment

Normative specifications in this clause shall be met by a system integrating a 10GBASE-R or 10GBASE-W over the life of the product while the product operates within the manufacturer's range of environmental, power, and other specifications.

It is recommended that manufacturers indicate in the literature associated with the PHY the operating environmental conditions to facilitate selection, installation, and maintenance.

It is recommended that manufacturers indicate, in the literature associated with the components of the optical link, the distance and operating environmental conditions over which the specifications of this clause will be met.

52.11.1 Electromagnetic emission

A system integrating a 10GBASE-R or 10GBASE-W PMD shall comply with applicable local and national codes for the limitation of electromagnetic interference.

[13] A host system that fails to meet the manufacturers requirements and/or usage restrictions may emit laser radiation in excess of the safety limits of one or more safety standards. In such a case, the host manufacturer is required to obtain its own laser safety certification.

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52.11.2 Temperature, humidity, and handling

The optical link is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

52.12 PMD labeling requirements

It is recommended that each PHY (and supporting documentation) be labeled in a manner visible to the user, with at least the applicable safety warnings and the applicable port type designation (e.g., 10GBASE-ER).

Labeling requirements for Hazard Level 1 lasers are given in the laser safety standards referenced in 52.10.2.

52.13 Fiber optic cabling model

The fiber optic cabling model is shown in Figure 52–14.

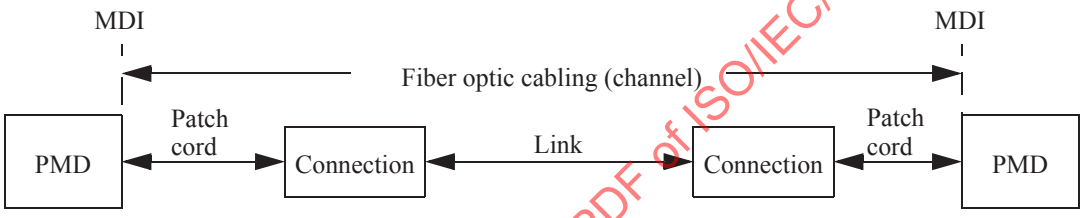

Figure 52–14—Fiber optic cabling model

The channel insertion loss is given in Table 52–24. A channel may contain additional connectors or other optical elements as long as the optical characteristics of the channel, such as attenuation, dispersion, reflections, polarization mode dispersion and modal bandwidth meet the specifications. Insertion loss measurements of installed fiber cables are made in accordance with ANSI/TIA/EIA-526-14A/method B, and ANSI/TIA/EIA-526-7/method A-1. The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment. The term channel is used here for consistency with generic cabling standards.

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Table 52–24—Fiber optic cabling (channel)

Description	62.5 μm MMF		50 μm MMF				Type B1.1, B1.3 SMF			Unit
Nominal wavelength	**850[a]**						**1310[b]**	**1550**		**nm**
Modal bandwidth (min)	**160**	**200**	**400**	**500**	**2000**	**4700**	**N/A**	**N/A**		**MHz•km**
Operating distance (max)	26 m	33 m	66 m	82 m	300 m	400 m	10 km	30 km	40 km	
Channel insertion loss (max) [c,d,e]	2.6	2.5	2.2	2.3	2.6	2.9	6.0	11.0[f]		dB
Channel insertion loss (min)	0	0	0	0	0	0	0	5		dB
Dispersion (max)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	546	728	ps/nm
DGD_max[g]	N/A	N/A	N/A	N/A	N/A	N/A	10	19		ps
Optical return loss	N/A	N/A	N/A	N/A	N/A	N/A	N/A	21		dB

[a]Channel insertion loss at 850 nm includes cable, connectors, and splices.
[b]Channel insertion loss at 1310 nm includes cable, connectors, and splices.
[c]These channel insertion loss numbers are based on the nominal wavelength.
[d]Operating distances used to calculate channel insertion loss are those listed in this table.
[e]Maximum attenuation given in Table 52–25.
[f]Channel insertion loss at 1550 nm includes cable, connectors and splices.
[g]Differential Group Delay (DGD) is the time difference between the fractions of a pulse that are transmitted in the two principal states of polarization of an optical signal. DGD_max is the maximum differential group delay that the system must tolerate.

52.14 Characteristics of the fiber optic cabling (channel)

The 10GBASE-R and 10GBASE-W fiber optic cabling shall meet the specifications defined in Table 52–24. The fiber optic cabling consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together.

52.14.1 Optical fiber and cable

The fiber optic cable shall meet the requirements of IEC 60793-2 or the requirements of Table 52–25 where they differ for fiber types A1a (50/125 μm multimode), A1b (62.5/125 μm multimode), B1.1 (dispersion un-shifted single mode), or B1.3 (low water peak single mode).

NOTE—It is believed that for 10GBASE-E, type B4 fiber with positive dispersion may be substituted for B1.1 or B1.3. A link using B4 fiber with negative dispersion should be validated for compliance at TP3.

52.14.2 Optical fiber connection

An optical fiber connection, as shown in Figure 52–14, consists of a mated pair of optical connectors.

52.14.2.1 Connection insertion loss

The insertion loss is specified for a connection, which consists of a mated pair of optical connectors.

The maximum link distances for multimode fiber are calculated based on an allocation of 1.5 dB total connection and splice loss. For example, this allocation supports three connections with an insertion loss equal to 0.5 dB (or less) per connection, or two connections (as shown in Figure 52–14) with an insertion

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Table 52–25—Optical fiber and cable characteristics

Description	62.5 μm MMF	50 μm MMF		Type B1.1, B1.3 SMF		Unit
Nominal fiber specification wavelength	**850**	**850**		**1310**	**1550**	**nm**
Cabled optical fiber attenuation (max)	3.5	3.5		0.4[a] or 0.5[b]	see footnote[c]	dB/km
Modal Bandwidth (min)	160[d] or 200[d]	400[d] or 500[d] or 2000[e]	4700[f]	N/A		MHz km
Zero dispersion wavelength (λ_0)	$1320 \le \lambda_0 \le 1365$	$1295 \le \lambda_0 \le 1320$[g]	$1295 \le \lambda_0 \le 1340$[f]	$1300 \le \lambda_0 \le 1324$		nm
Dispersion slope (max) (S_0)	0.11 for $1320 \le \lambda_0 \le 1348$ and $0.001(1458-\lambda_0)$ for $1348 \le \lambda_0 \le 1365$	0.11 for $1300 \le \lambda_0 \le 1320$ and $0.001(\lambda_0-1190)$ for $1295 \le \lambda_0 \le 1300$[g]	0.105 for $1295 \le \lambda_0 \le 1310$ and $0.000375(1590-\lambda_0)$ for $1310 \le \lambda_0 \le 1340$	0.093		ps / nm^2 km

[a]For the single-mode case, the 0.4 dB/km attenuation for optical fiber cables is defined in ITU-T G.652.
[b]For the single-mode case, the 0.5 dB/km attenuation is provided for Outside Plant cable as defined in ANSI/TIA 568-C.3. Using 0.5 dB/km may not support operation at 10 km.
[c]Attenuation for 1550 nm links is based on the fiber channel and is specified in 52.14.3.
[d]Overfilled launch bandwidth per IEC 60793-1-41 or ANSI/TIA/EIA 455-204-2000.
[e]Effective modal bandwidth for fiber meeting IEC 60793-2-10 Type A1a.2 when used with sources meeting the wavelength (range) and encircled flux specifications of Table 52–7.
[f]Effective modal bandwidth, zero dispersion wavelength and dispersion slope for OM4 fibers are specified in IEC 60793-2-10 Type A1a.3.
[g]Cabled optical fiber with 400 or 500 or 2000 MHz km minimum Modal Bandwidth may alternatively comply with the zero dispersion wavelength and dispersion slope specifications for 4700 MHz km minimum Modal Bandwidth fiber.

loss of 0.75 dB per connection. Connections with different loss characteristics may be used provided the requirements of Table 52–24 are met.

The maximum link distances for single-mode fiber are calculated based on an allocation of 2 dB total connection and splice loss at 1310 nm for 10GBASE-L, and 2 dB for 30 km total connection and splice loss at 1550 nm for 10GBASE-E.

52.14.2.2 Maximum discrete reflectance

The maximum discrete reflectance for 10GBASE-S shall be less than –20 dB.

The maximum discrete reflectance for 10GBASE-L and 10GBASE-E shall be less than –26 dB.

52.14.3 10GBASE-E attenuator management

The 10GBASE-E channel shall have an attenuation between 5 dB and 11 dB. If required, an attenuator can be added to comply with this specification. The ideal channel attenuation is 8 dB. Figure 52–15 graphically shows the compliant region.

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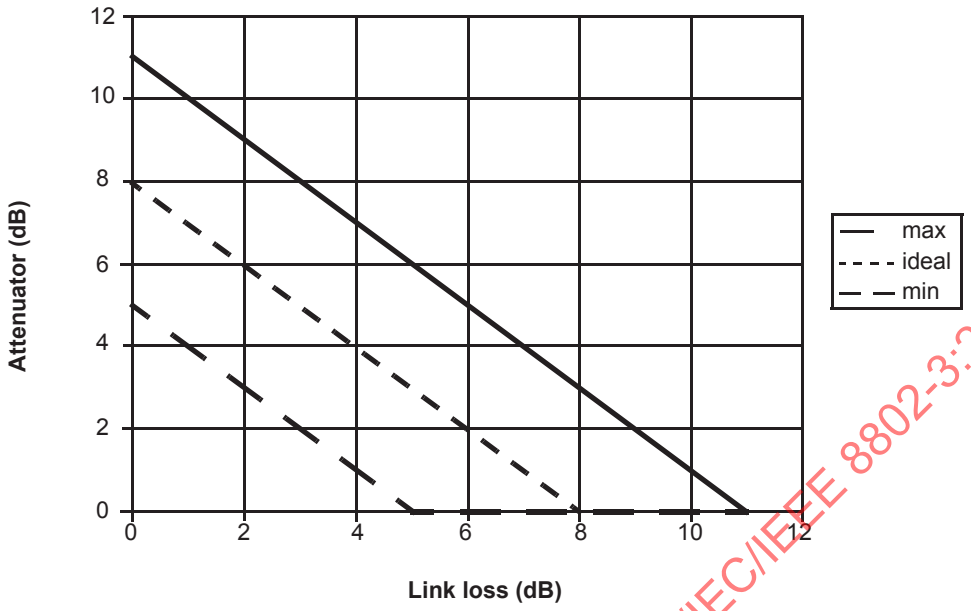

Figure 52–15—10GBASE-E attenuator management (informative)

52.14.4 Medium Dependent Interface (MDI) requirements

The 10GBASE-R and 10GBASE-W PMD is coupled to the fiber optic cabling at the MDI. The MDI is the interface between the PMD and the "fiber optic cabling" (as shown in Figure 52–14). Examples of an MDI include the following:

a) Connectorized fiber pigtail.
b) PMD receptacle.

When the MDI is a connector plug and receptacle connection, it shall meet the interface performance specifications of the following:

c) IEC 61753-1-1—Fibre optic interconnecting devices and passive component performance standard—Part 1-1: General and guidance—Interconnecting devices (connectors).
d) IEC 61753-021-2—Fibre optic passive components performance standard—Part 021-2: Fibre optic connectors terminated on single-mode fibre for Category C—Controlled environment, performance Class S.
e) IEC 61753-022-2—Fibre optic passive components performance standard—Part 022-2: Fibre optic connectors terminated on multimode fibre for Category C—Controlled environment, performance Class M.

NOTE—Compliance testing is performed at TP2 and TP3 as defined in 52.4.1, not at the MDI.

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52.15 Protocol implementation conformance statement (PICS) proforma for Clause 52, Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-S (short wavelength serial), 10GBASE-L (long wavelength serial), and 10GBASE-E (extra long wavelength serial)[14]

52.15.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 52, Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-R and 10GBASE-W, shall complete the following protocol implementation conformance statement (PICS) proforma. A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

52.15.2 Identification

52.15.2.1 Implementation identification

Supplier[1]	
Contact point for inquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1,3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

52.15.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 52, Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-R and 10GBASE-W
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	

Date of Statement	

[14]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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52.15.2.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*MD	MDIO capability	52.3	Registers and interface supported	O	Yes [ ] No [ ]
*SR	10GBASE-SR PMD	52.5	Device supports shortwave (850 nm) operation LAN PHY	O	Yes [ ] No [ ]
*LR	10GBASE-LR PMD	52.6	Device supports longwave (1310 nm) operation LAN PHY	O	Yes [ ] No [ ]
*ER	10GBASE-ER PMD	52.7	Device supports extra long wave (1550 nm) operation LAN PHY	O	Yes [ ] No [ ]
*SW	10GBASE-SW PMD	52.5	Device supports shortwave (850 nm) operation WAN PHY	O	Yes [ ] No [ ]
*LW	10GBASE-LW PMD	52.6	Device supports longwave (1310 nm) operation WAN PHY	O	Yes [ ] No [ ]
*EW	10GBASE-EW PMD	52.7	Device supports extra long wave (1550 nm) operation WAN PHY	O	Yes [ ] No [ ]
*INS	Installation / Cable	52.4.1	Items marked with INS include installation practices and cable specifications not applicable to a PHY manufacturer	O	Yes [ ] No [ ]
DLY	Delay constraints	52.2	Device conforms to delay constraints	M	Yes [ ]

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52.15.3 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and baseband medium, types 10GBASE-R and 10GBASE-W

52.15.3.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FS1	Transmit function	52.4.2	Conveys bits from PMD service interface to MDI	M	Yes [ ]
FS2	Transmitter optical signal	52.4.2	Higher optical power transmitted is a logic 1	M	Yes [ ]
FS3	Receive function	52.4.3	Conveys bits from MDI to PMD service interface	M	Yes [ ]
FS4	Receiver optical signal	52.4.3	Higher optical power received is a logic 1	M	Yes [ ]
FS5	Signal detect function	52.4.4	Mapping to PMD service interface	M	Yes [ ]
FS6	Signal detect parameter	52.4.4	Generated according to Table 52–5	M	Yes [ ]

52.15.3.2 Management functions

Item	Feature	Subclause	Value/Comment	Status	Support
MD1	Management register set	52.3	As defined in Table 52–3 and Table 52–4	MD:M	Yes [ ] N/A [ ]
MD2	PMD_reset bit	52.4.5	As defined in 45.2.1.1.1	MD:M	Yes [ ] N/A[ ]
MD3	PMD_global_transmit_disable bit	52.4.7	As defined in 45.2.1.8.7	MD:O	Yes [ ] No [ ] N/A [ ]
MD4	PMD_transmit_fault bit	52.4.8	As defined in 45.2.1.7.4	MD:O	Yes [ ] No [ ] N/A [ ]
MD5	PMA/PMD receive fault bit	52.4.9	Contributes to receive fault bit as defined in 45.2.1.7.5	MD:O	Yes [ ] No [ ] N/A [ ]
MD6	PMD_signal_detect bit	52.4.4	As defined in 45.2.1.9.7	MD:M	Yes [ ] N/A [ ]

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52.15.3.3 PMD to MDI optical specifications for 10GBASE-SR

Item	Feature	Subclause	Value/Comment	Status	Support
SR1	10GBASE-SR transmitter	52.5.1	Meets specifications in Table 52–8 and Table 52–7	SR:M	Yes [ ] N/A [ ]
SR2	10GBASE-SR receiver	52.5.2	Meets specifications in Table 52–9	SR:M	Yes [ ] N/A [ ]

52.15.3.4 PMD to MDI optical specifications for 10GBASE-SW

Item	Feature	Subclause	Value/Comment	Status	Support
SW1	10GBASE-SW transmitter	52.5.1	Meets specifications in Table 52–8 and Table 52–7	SW:M	Yes [ ] N/A [ ]
SW2	10GBASE-SW receiver	52.5.2	Meets specifications in Table 52–9	SW:M	Yes [ ] N/A [ ]

52.15.3.5 PMD to MDI optical specifications for 10GBASE-LR

Item	Feature	Subclause	Value/Comment	Status	Support
LR1	10GBASE-LR transmitter	52.6.1	Meets specifications in Table 52–12	LR:M	Yes [ ] N/A [ ]
LR2	10GBASE-LR receiver	52.6.2	Meets specifications in Table 52–13	LR:M	Yes [ ] N/A [ ]

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52.15.3.6 PMD to MDI optical specifications for 10GBASE-LW

Item	Feature	Subclause	Value/Comment	Status	Support
LW1	10GBASE-LW transmitter	52.6.1	Meets specifications in Table 52–12	LW:M	Yes [ ] N/A [ ]
LW2	10GBASE-LW receiver	52.6.2	Meets specifications in Table 52–13	LW:M	Yes [ ] N/A [ ]

52.15.3.7 PMD to MDI optical specifications for 10GBASE-ER

Item	Feature	Subclause	Value/Comment	Status	Support
ER1	10GBASE-ER transmitter	52.7.1	Meets specifications in Table 52–16	ER:M	Yes [ ] N/A [ ]
ER2	10GBASE-ER receiver	52.7.2	Meets specifications in Table 52–17	ER:M	Yes [ ] N/A [ ]

NOTE— Link attenuation requirements are specified in 52.14.3.

52.15.3.8 PMD to MDI optical specifications for 10GBASE-EW

Item	Feature	Subclause	Value/Comment	Status	Support
EW2	10GBASE-EW transmitter	52.7.1	Meets specifications in Table 52–16	EW:M	Yes [ ] N/A [ ]
EW2	10GBASE-EW receiver	52.7.2	Meets specifications in Table 52–17	EW:M	Yes [ ] N/A [ ]

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52.15.3.9 Optical measurement requirements

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	Measurement cable	52.9	2–5 m in length	M	Yes [ ]
OM2	Center wavelength and spectral width measurement	52.9.2	Measured using an optical spectrum analyzer per TIA-455-127-A under modulated conditions	M	Yes [ ]
OM3	Average optical power	52.9.3	Measured using the methods specified in TIA/EIA-455-95	M	Yes [ ]
OM4	Extinction ratio	52.9.4	Measured using the methods specified in IEC 61280-2-2	M	Yes [ ]
OM5	OMA measurement bandwidth	52.9.5	At least 3/T	M	Yes [ ]
OM6	RIN_xOMA measurement procedure	52.9.6	As described in 52.9.6.1, 52.9.6.2, and 52.9.6.3	M	Yes [ ]
OM7	Transmit eye	52.9.7	10.3125 GBd shall qualify for 10GBASE-W and 10GBASE-R use, measurement at 9.95328 GBd shall qualify for 10GBASE-W use only	M	Yes [ ]
OM8	Stressed receiver conformance test	52.9.9	Performed in accordance with the requirements of 52.9.9.1, 52.9.9.2, 52.9.9.3, and 52.9.9.4	M	Yes [ ]
OM9	Transmitter and dispersion penalty measurement	52.9.10.4		M	Yes [ ]

52.15.3.10 Characteristics of the fiber optic cabling and MDI

Item	Feature	Subclause	Value/Comment	Status	Support
FO1	Fiber optic cabling	52.14	Specified in Table 52–24	INS:M	Yes [ ] N/A [ ]
FO2	Optical fiber characteristics	52.14.1	Meet the requirements of IEC 60793-2 and the requirements of Table 52–25	INS:M	Yes [ ] N/A [ ]
FO3	Maximum discrete reflectance-multimode fiber	52.14.2.2	Less than –20 dB	INS:M	Yes [ ] N/A [ ]
FO4	Maximum discrete reflectance -single-mode fiber	52.14.2.2	Less than –26 dB	INS:M	Yes [ ] N/A [ ]
FO5	10GBASE-E attenuation management	52.14.3	An attenuation between 5 dB and 11 dB	INS:M	Yes [ ] N/A [ ]
FO6	MDI requirements	52.14.4	Meet the interface performance specifications listed	INS:M	Yes [ ] N/A [ ]

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52.15.3.11 Environmental specifications

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	General safety	52.10.1	Conforms to IEC-60950-1	M	Yes [ ]
ES2	Laser safety —IEC Hazard Level 1	52.10.2	Conform to Hazard Level 1 laser requirements defined in IEC 60825-1 and IEC 60825-2	M	Yes [ ]
ES3	Installation	52.10.3	Follow applicable local codes and regulations	M	Yes [ ]

52.15.3.12 Environment

Item	Feature	Subclause	Value/Comment	Status	Support
EC1	Electromagnetic interference	52.11.1	Comply with applicable local and national codes for the limitation of electromagnetic interference	M	Yes [ ]

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53. Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-LX4

53.1 Overview

This clause specifies the 10GBASE-LX4 PMD (including MDI) and the baseband medium for both multimode and single-mode optical fiber. When forming a complete PHY, a PMD shall be connected to the appropriate sublayers (see Table 53–1) and with the management functions that are accessible through the Management Interface defined in Clause 45, all of which are hereby incorporated by reference.

Table 53–1—LX4 PMD type and associated Physical Layer clauses

Associated clause	10GBASE-LX4
46—RS and	Required
XGMII[a]	Optional
47—XGXS and XAUI	Optional
48—10GBASE-X PCS/PMA	Required
49—10GBASE-R PCS	n/a
50—10GBASE-W WIS	n/a

[a]The XGMII is an optional interface. However, if the XGMII is not implemented, a conforming implementation must behave functionally as though the RS and XGMII were present.

Figure 53–1 shows the relationship of the PMD and MDI sublayers to the ISO/IEC (IEEE) OSI reference model.

53.1.1 Physical Medium Dependent (PMD) service interface

This subclause specifies the services provided by the 10GBASE-LX4 PMD. The service interface for this PMD is described in an abstract manner and do not imply any particular implementation. The PMD Service Interface supports the exchange of encoded data between peer PMA entities. The PMD translates the encoded data to and from signals suitable for the specified medium.

The following PMD service primitives are defined:

PMD_UNITDATA.request

PMD_UNITDATA.indication

PMD_SIGNAL.indication

53.1.2 PMD_UNITDATA.request

This primitive defines the transfer of data (in the form of encoded 8B/10B characters) from the PMA to the PMD.

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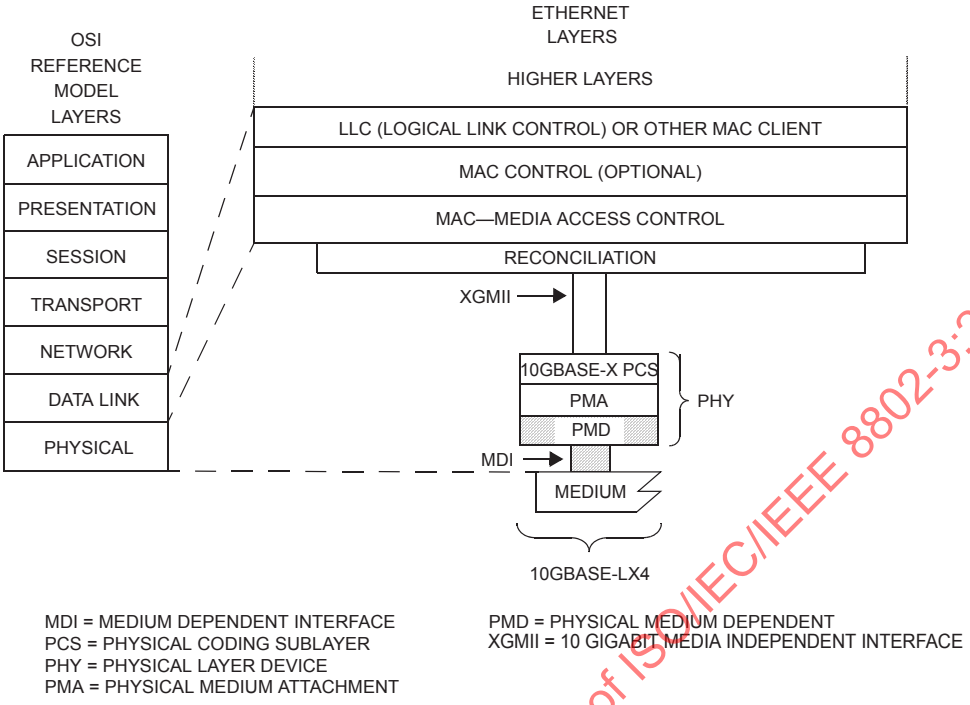

Figure 53–1—10GBASE-LX4 PMD relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

53.1.2.1 Semantics of the service primitive

PMD_UNITDATA.request (tx_bit <0:3>)

The data conveyed by PMD_UNITDATA.request is a continuous sequence of four parallel code-group streams, one stream for each lane. The tx_bit <0:3> correspond to the bits in the tx_lane<0:3> bit streams. Each bit in the tx_bit parameter can take one of two values: ONE or ZERO.

53.1.2.2 When generated

The PMA continuously sends four parallel code-group streams to the PMD at a nominal signaling speed of 3.125 GBd.

53.1.2.3 Effect of Receipt

Upon receipt of this primitive, the PMD converts the specified stream of bits into the appropriate signals on the MDI.

53.1.3 PMD_UNITDATA.indication

This primitive defines the transfer of data (in the form of encoded 8B/10B characters) from the PMD to the PMA.

53.1.3.1 Semantics of the service primitive

PMD_UNITDATA.indication (rx_bit <0:3>)

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The data conveyed by PMD_UNITDATA.indication is a continuous sequence of four parallel encoded bit streams. The rx_bit<0:3> correspond to the bits in the rx_lane<0:3> bit streams. Each bit in the rx_bit parameter can take one of two values: ONE or ZERO.

53.1.3.2 When generated

The PMD continuously sends stream of bits to the PMA corresponding to the signals received from the MDI.

53.1.3.3 Effect of receipt

The effect of receipt of this primitive by the client is unspecified by the PMD sublayer.

53.1.4 PMD_SIGNAL.indication

This primitive is generated by the PMD to indicate the status of the signals being received from the MDI.

53.1.4.1 Semantics of the service primitive

PMD_SIGNAL.indication (SIGNAL_DETECT)

The SIGNAL_DETECT parameter can take on one of two values: OK or FAIL. When SIGNAL_DETECT = FAIL, rx_bit is undefined, but consequent actions based on PMD_UNITDATA.indication, where necessary, interpret rx_bit as a logic ZERO.

NOTE—SIGNAL_DETECT = OK does not guarantee that rx_bit is known to be good. It is possible for a poor quality link to provide sufficient light for a SIGNAL_DETECT = OK indication and still not meet the 10^{-12} BER objective.

53.1.4.2 When generated

The PMD generates this primitive to indicate a change in the value of SIGNAL_DETECT.

53.1.4.3 Effect of receipt

The effect of receipt of this primitive by the client is unspecified by the PMD sublayer.

53.2 Delay constraints

Predictable operation of the MAC Control PAUSE operation (Clause 31, Annex 31B) demands that there be an upper bound on the propagation delays through the network. This implies that MAC, MAC Control sublayer, and PHY implementers must conform to certain delay maxima, and that network planners and administrators conform to constraints regarding the cable topology and concatenation of devices. The sum of transmit and receive delay contributed by the 10GBASE-LX4 PMD shall be no more than 512 BT (including 2 m of fiber).

53.3 PMD MDIO function mapping

The optional MDIO capability described in Clause 45 defines several variables that provide control and status information for and about the PMD. Mapping of MDIO control variables to PMD control variables is shown in Table 53–2. Mapping of MDIO status variables to PMD status variables is shown in Table 53–3.

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Table 53–2—MDIO/PMD control variable mapping

MDIO control variable	PMA/PMD register name	Register/ bit number	PMD control variable
Reset	Control register 1	1.0.15	PMD_reset
Global transmit disable	Transmit disable register	1.9.0	Global_PMD_transmit_disable
Transmit disable 3	Transmit disable register	1.9.4	PMD_transmit_disable_3
Transmit disable 2	Transmit disable register	1.9.3	PMD_transmit_disable_2
Transmit disable 1	Transmit disable register	1.9.2	PMD_transmit_disable_1
Transmit disable 0	Transmit disable register	1.9.1	PMD_transmit_disable_0

Table 53–3—MDIO/PMD status variable mapping

MDIO status variable	PMA/PMD register name	Register/ bit number	PMD status variable
Local fault	Status register 1	1.1.7	PMD_fault
Transmit fault	Status register 2	1.8.11	PMD_transmit_fault
Receive fault	Status register 2	1.8.10	PMD_receive_fault
Global PMD signal detect	Receive signal detect register	1.10.0	Global_PMD_signal_detect
PMD signal detect 3	Receive signal detect register	1.10.4	PMD_signal_detect_3
PMD signal detect 2	Receive signal detect register	1.10.3	PMD_signal_detect_2
PMD signal detect 1	Receive signal detect register	1.10.2	PMD_signal_detect_1
PMD signal detect 0	Receive signal detect register	1.10.1	PMD_signal_detect_0

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53.4 PMD functional specifications

The 10GBASE-LX4 PMD performs the Transmit and Receive functions which convey data between the PMD service interface and the MDI plus various management functions if the optional MDIO is implemented.

53.4.1 PMD block diagram

The PMD block diagram is shown in Figure 53–2. For purposes of system conformance, the PMD sublayer is standardized at the points described in this subclause. The optical transmit signal is defined at the output end of a patch cord (TP2), between 2 m and 5 m in length, of a type consistent with the link type connected

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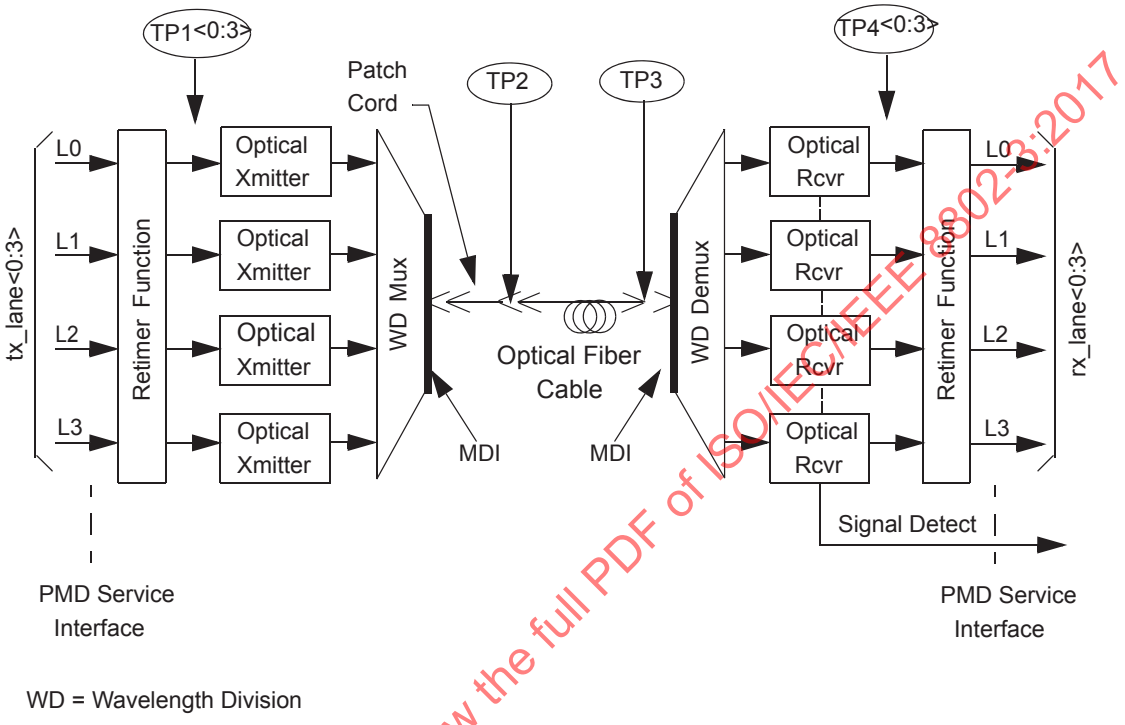
to the transmitter receptacle defined in 53.14.2. If a single-mode fiber offset-launch mode-conditioning patch cord is used, the optical transmit signal is defined at the end of this single-mode fiber offset-launch mode-conditioning patch cord at TP2. Unless specified otherwise, all transmitter measurements and tests defined in 53.9.1 through 53.9.8 are made at TP2. The optical receive signal is defined at the output of the fiber optic cabling (TP3) at the MDI (see 53.14.3). Unless specified otherwise, all receiver measurements and tests defined in 53.9.9 through 53.9.15 are made at TP3.



NOTE—Specification of the retimer function is beyond the scope of this standard; however, a retimer may be required to ensure compliance at test points TP2 and TP3.

Figure 53–2—Block diagram for LX4 PMD transmit/receive paths

TP1 <0:3> and TP4 <0:3> are informative reference points that may be useful to implementers for testing components (these test points will not typically be testable in an implemented system).

53.4.2 PMD transmit function

The PMD Transmit function shall convert the four electronic bit streams requested by the PMD service interface message PMD_UNITDATA.request (tx_bit<0:3>) into four separate optical signal streams. The four optical signal streams shall then be wavelength division multiplexed and delivered to the MDI, all according to the transmit optical specifications in this clause. The higher optical power level in each signal stream shall correspond to a tx_bit = ONE.

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53.4.3 PMD receive function

The PMD Receive function shall demultiplex the composite optical signal stream received from the MDI into four separate optical signal streams. The four optical signal streams shall then be converted into four electronic bit streams for delivery to the PMD service interface using the message PMD_UNITDATA.indication (rx_bit<0:3>), all according to the receive optical specifications in this clause. The higher optical power level in each signal stream shall correspond to a rx_bit = ONE.

The PMD shall convey the bits received from the PMD_UNITDATA.request(tx_bit<0:3>) service primitive to the PMD service interface using the message PMD_UNITDATA.indication(rx_bit<0:3>), where rx_bit<0:3> = tx_bit<0:3>.

53.4.4 Global PMD signal detect function

The Global PMD Receive Signal OK function shall report the state of SIGNAL_DETECT via the PMD service interface. The SIGNAL_DETECT parameter is signaled continuously, while the PMD_SIGNAL.indication message is generated when a change in the value of SIGNAL_DETECT occurs.

SIGNAL_DETECT shall be a global indicator of the presence of optical signals on all four lanes. The PMD receiver is not required to verify whether a compliant 10GBASE-LX4 signal is being received. This standard imposes no response time requirements on the generation of the SIGNAL_DETECT parameter.

Table 53–4—SIGNAL_DETECT value definition

Receive conditions	Receive Signal OK value
For any lane; Input_optical_power ≤ –30 dBm	FAIL
For all lanes; [(Input_optical_power ≥ Receiver sensitivity (max) in OMA in Table 53–8) AND (compliant 10GBASE-LX4 signal input)]	OK
All other conditions	Unspecified

As an unavoidable consequence of the requirements for the setting of the SIGNAL_DETECT parameter, implementations must provide adequate margin between the input optical power level at which the SIGNAL_DETECT parameter is set to OK, and the inherent noise level of the PMD due to crosstalk, power supply noise, etc..

Various implementations of the Signal Detect function are permitted by this standard, including implementations that generate the SIGNAL_DETECT parameter values in response to the amplitude of the modulation of the optical signal and implementations that respond to the average optical power of the modulated optical signal.

53.4.5 PMD lane by lane signal detect function

Various implementations of the Signal Detect function are permitted by this standard. When the MDIO is implemented, each PMD_signal_detect_n, where n represents the lane number in the range 0:3, value shall be continuously set in response to the amplitude of the average optical power of the modulated optical signal on its associated lane, according to the requirements of Table 53–4.

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53.4.6 PMD reset function

If the MDIO interface is implemented, and if PMD_reset is asserted, the PMD shall be reset as defined in 45.2.1.1.1.

53.4.7 Global PMD transmit disable function

The Global_PMD_transmit_disable function is optional and allows all of the optical transmitters to be disabled.

a) When a Global_PMD_transmit_disable variable is set to ONE, this function shall turn off all of the optical transmitters so that the each transmitter meets the requirements of the Average Launch Power of the OFF Transmitter in Table 53–7.
b) If a PMD_fault is detected, then the PMD may set the Global_PMD_transmit_disable to ONE, turning off the optical transmitter in each lane.

53.4.8 PMD lane by lane transmit disable function

The PMD_transmit_disable function is optional and allows the optical transmitters in each lane to be selectively disabled.

a) When a PMD_transmit_disable_n variable is set to ONE, this function shall turn off the optical transmitter associated with that variable so that the transmitter meets the requirements of the Average Launch Power of the OFF Transmitter in Table 53–7.
b) If a PMD_fault is detected, then the PMD may set each PMD_transmit_disable_n to ONE, turning off the optical transmitter in each lane.

If the optional PMD_lane_by_lane_transmit_disable function is not implemented in MDIO, an alternative method shall be provided to independently disable each transmit lane.

53.4.9 PMD fault function

If the MDIO is implemented, and the PMD has detected a local fault on any of the transmit or receive paths, the PMD shall set PMD_fault to ONE.

53.4.10 PMD transmit fault function (optional)

If the MDIO is implemented, and the PMD has detected a local fault on any transmit lane, the PMD shall set the PMD_transmit_fault variable to ONE.

53.4.11 PMD receive fault function (optional)

If the MDIO is implemented, and the PMD has detected a local fault on any receive lane, the PMD shall set the PMD_receive_fault variable to ONE.

53.5 Wavelength-division multiplexed-lane assignments

The wavelengths for each multiplexed lane of the 10GBASE-LX4 PMD shall be as defined in Table 53–5.

53.6 Operating ranges for 10GBASE-LX4 PMD

The operating ranges for 10GBASE-LX4 PMD are defined in Table 53–6. A 10GBASE-LX4 compliant transceiver supports all media types listed in Table 53–6 (i.e., 50 µm and 62.5 µm multimode fiber, and

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Table 53–5—Wavelength-division-multiplexed lane assignments

Lane	Wavelength ranges	PMD Service Interface transmit bit stream	PMD Service Interface receive bit stream
L_0	1269.0 – 1282.4 nm	tx_lane<0>	rx_lane<0>
L_1	1293.5 – 1306.9 nm	tx_lane<1>	rx_lane<1>
L_2	1318.0 – 1331.4 nm	tx_lane<2>	rx_lane<2>
L_3	1342.5 – 1355.9 nm	tx_lane<3>	rx_lane<3>

10 µm single-mode fiber) according to the specifications defined in 53.14. A transceiver that exceeds the operational range requirement while meeting all other optical specifications is considered compliant (e.g., a single-mode solution operating at 10 500 m meets the minimum range requirement of 2 m to 10 000 m).

Table 53–6—Operating range for 10GBASE-LX4 PMD over each optical fiber type

Fiber type	Modal bandwidth at 1300 nm (min. overfilled launch) (MHz•km)	Minimum range (meters)
62.5 µm MMF	500	2 to 300
50 µm MMF	400	2 to 240
50 µm MMF	500	2 to 300
10 µm SMF	n/a	2 to 10 000

For MMF links, to ensure that the specifications of Table 53–6 are met with MMF links, the wavelength-division-multiplexed 10GBASE-LX4 transmitter outputs shall be coupled through a single-mode fiber offset-launch mode-conditioning patch cord, as defined in 38.11.4.

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53.7 PMD to MDI optical specifications for 10GBASE-LX4

53.7.1 Transmitter optical specifications

The 10GBASE-LX4 transmitters shall meet the specifications defined in Table 53–7 per measurement techniques defined in 53.9.

Table 53–7—Transmit characteristics for the 10GBASE-LX4 over each optical fiber type

Description	62.5 µm and 50 µm MMF	10 µm SMF	Units
Transmitter type	Longwave Laser		
Signaling speed per lane (nominal)	3.125 ± 100 ppm		GBd
Lane wavelengths (range)	1269.0 – 1282.4 1293.5 – 1306.9 1318.0 – 1331.4 1342.5 – 1355.9		nm
Trise/Tfall (max. 20–80 % response time)	120		ps
Side-mode suppression ratio (SMSR), (min)	0.0		dB
RMS spectral width (max)[a]	0.62		nm
Average launch power, four lanes (max)	5.5		dBm
Average launch power, per lane (max)	–0.5		dBm
Optical Modulation Amplitude (OMA), per lane (max)	750 (–1.25)		µW (dBm)
Optical Modulation Amplitude (OMA), per lane (min)[b]	211 (–6.75)	237 (–6.25)	µW (dBm)
Extinction Ratio (min)	3.5		dB
Average launch power of OFF transmitter, per lane (max)	–30		dBm
RIN_{12} (OMA)	–120		dB/Hz

[a]For sources with a distribution of two discrete modes, the spectral window containing 90% of source spectral power (max) equals 1.0 nm and the spectral window containing 99% of source spectral power (max) equals 1.4 nm. For sources with a continuous spectral distribution, the spectral window containing 90% of source spectral power (max) equals 2.0 nm and the spectral window containing 99% of source spectral power (max) equals 3.2 nm. The spectral window specifications for the continuous case is consistent with a Gaussian spectral distribution having an RMS spectral width of 0.62 nm.

[b]Transmitter values are specified at TP2. For MMF, the values in the above table include a 0.5dB attenuation for the offset launch patch cord.

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53.7.2 Receive optical specifications

The 10GBASE-LX4 receiver shall meet the specifications defined in Table 53–8 per measurement techniques defined in 53.9. The receive sensitivity includes the extinction ratio penalty.

Table 53–8—10GBASE-LX4 receive characteristics

Description	62.5 µm MMF 50 µm MMF	10 µm SMF	Unit
Signaling speed per lane (nominal)	3.125 ± 100 ppm		GBd
Lane wavelengths (range)	1269.0 – 1282.4 1293.5 – 1306.9 1318.0 – 1331.4 1342.5 – 1355.9		nm
Average receive power, four lanes (max)	5.5		dBm
Average receive power, per lane (max)	–0.5		dBm
Return loss (min)	12		dB
Receive sensitivity (OMA), per lane	37.4 (–14.25)	35.9 (–14.45)	µW (dBm)
Stressed receive sensitivity (OMA),[a,b] per lane	89.0 (–10.5)	45.7 (–13.4)	µW (dBm)
Vertical eye closure penalty,[c] per lane	3.7	1.1	dB
Receive electrical 3 dB upper cutoff frequency, per lane (max)	3750		MHz

[a]Measured with conformance test signal at TP3 (see 53.9.14) for BER = 10^{-12}.
[b]The stressed sensitivity values in the table are for system level BER measurements which include the effects of CDR circuits. It is recommended that at least 0.4dB additional margin be allocated if component level measurements are made without the effect of CDR circuits.
[c]Vertical eye closure penalty is a test condition for measuring stressed receive sensitivity. It is not a required characteristic of the receiver.

53.7.3 Worst case 10GBASE-LX4 link power budget and penalties (informative)

The worst case power budget and link penalties for a 10GBASE-LX4 channel are shown in Table 53–9.

53.8 Jitter specifications for each lane of the 10GBASE-LX4 PMD

53.8.1 Transmit jitter specification

The transmit jitter is tested using a bit error ratio tester[15] (BERT), where the tester horizontally scans the eye opening across the centerline at a virtual TP3 (hereafter referred to as simply TP3) and measures the bit error ratio at each point in time. The plot of BER as a function of sampling time is called the "bathtub curve."

All points on the BER "bathtub curve" shall have an eye opening greater than specified by the bit error ratio tester (BERT) mask at the respective BER when measured using the jitter compliance test methodology for

[15]In this document, BERT is intended to include any test measurement device that can generate a BER bathtub curve. Here, it is implied that the BERT includes the Reference Receiver, filters, PLLs, etc.

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Table 53–9—Worst case 10GBASE-LX4 link power budget and penalties[a]

Parameter	62.5 µm MMF	50 µm MMF		10 µm SMF	Unit
Modal bandwidth as measured at 1300 nm (minimum, overfilled launch)	500	400	500	n/a	MHz•km
Link power budget	7.5	7.5	7.5	8.2	dB
Operating distance[b]	300	240	300	10 000	m
Channel insertion loss[c, d]	2.0	1.9	2.0	6.2	dB
Allocation of penalties	5.0	5.5	5.5	1.9	dB
Additional insertion loss allowed[e]	0.5	0.1	0.0	0.1	dB

[a]Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.
[b]An offset launch patch cord is required for MMF.
[c]The channel insertion loss is calculated using the maximum distance values specified in Table 53–6 plus an allocation of 1.5dB for MMF and 2.0dB for SMF for connection and splice loss. Channel insertion loss is specified from TP2 to TP3 in Figure 53–2. The total insertion loss for cabled multimode optical fiber, including the attenuation of the offset launch patch cord, is allowed to be 0.5 dB higher than shown in the table.
[d]A wavelength of 1269 nm, a minimum receiver bandwidth of 2550 MHz, and a DCD_DJ of 14 ps is used to calculate lane insertion loss, link power penalties, and unallocated margin.
[e]This portion of the link budget is permitted to be used to overcome insertion loss higher than the "Channel insertion loss" value.

the transmitter as defined in 53.9.10. The BERT mask (see example in Figure 53–3) is specified by the following polynomial:

$$\log_{10}(BER) \le A - B\left(\frac{t - 0.5W}{\sigma}\right)^2 \quad (53\text{–}1)$$

$$\log_{10}(BER) \le A - B\left(\frac{1 - t - 0.5W}{\sigma}\right)^2 \quad (53\text{–}2)$$

where:

$$A = -1.75, B = \frac{\log_{10}(e)}{2} \approx 0.217$$

and the variables "W" and "σ" for the polynomial are specified in Table 53–10. The variables "W" and "σ" are the effective DJ and RJ respectively although the DJ and RJ values are not normative in the standard. In the above equations the variable "t" is time specified in unit intervals (UI). The BER mask is defined for $10^{-12} < BER < 10^{-6}$. The DJ and RJ values do not need to be individually met, the required mask is defined by the formulas above.

Table 53–10—BERT mask specifications

PMD	W (UI pk to pk)	σ (UI rms)
10GBASE-LX4	0.3	0.015

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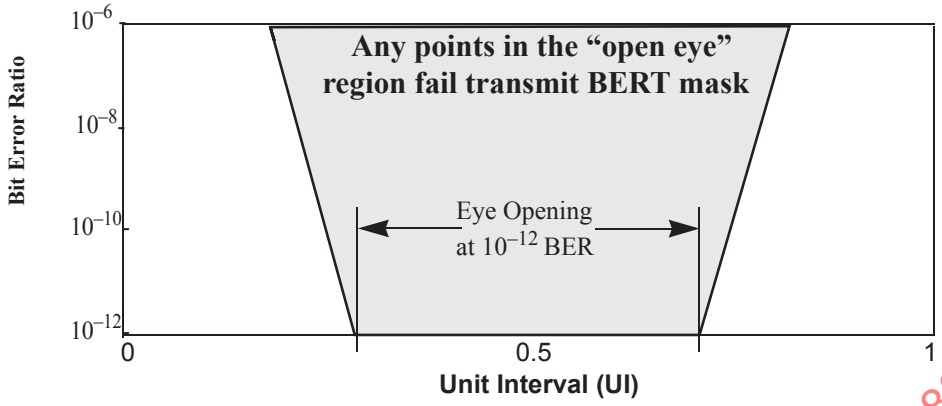

Figure 53–3—Example transmit BER mask at TP3 (informative)

53.8.1.1 Channel requirements for transmit jitter testing

The optical channel for 10GBASE-LX4 shall

a) Have an ITU-T G.652 fiber or fibers with lengths chosen to have a total dispersion larger than specified in Table 53–12 for the wavelength of the device under test. To verify that the fiber has the correct amount of dispersion, use the measurement method defined in ANSI/TIA/EIA-455-175A-92.
b) Meet these requirements in the linear regime of the single-mode fiber.
c) Meet the requirements in Table 53–14 for the case of a 2 to 5 meter offset launch patch cord.

The transmitter shall be tested for single-mode fiber use using the single-mode simulation channel defined in 53.9.10.2. The transmitter shall also be tested for multimode fiber use using the multimode simulation channel defined in 53.9.10.2.

53.8.1.2 Test pattern requirements for transmit jitter testing

Test patterns for 10GBASE-LX4 are specified in Annex 48A.

53.8.2 Receive jitter tolerance specification

The jitter compliance methodology for the receiver is defined in Annex 48B. The receiver shall operate at a BER less than 10^{-12} when tested with an input signal defined in 53.8.2.1 through 53.8.2.1.

The input signal used for jitter tolerance is comprised of the appropriate test pattern, the stressed receiver conformance test signal, the minimum specified input jitter (TJ and DJ) and added sinusoidal jitter.

53.8.2.1 Input jitter for receiver jitter test

The input jitter used to test receiver jitter tolerance shall meet the requirements of the receiver input jitter mask defined by the following equations and Table 53–10.

$$\log_{10}(BER) \geq A - B\left(\frac{t - 0.5W}{\sigma}\right)^2 \qquad (53–3)$$

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$$\log_{10}(BER) \geq A - B\left(\frac{1 - t - 0.5W}{\sigma}\right)^2 \quad (53\text{–}4)$$

where:

$$A = -1.75, B = \frac{\log_{10}(e)}{2} \approx 0.217$$

The mask is defined for a BER range of $10^{-12} < BER < 10^{-6}$. An explanation of the variables W, σ, and t can be found in 53.8.1.

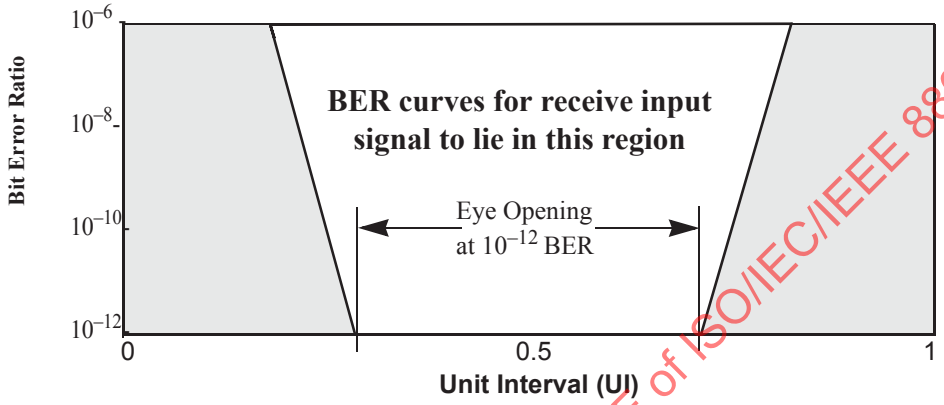

Figure 53–4—Input jitter mask for receiver test (informative)

The random jitter (RJ) component of the input signal shall have uniform spectral content over the measurement frequency range of 18.75kHz to 1.5GHz.

The test method for verification of the input jitter is defined in 53.8.1. A Clock Recovery Unit shall be used for verification of the input jitter. It shall have a high-frequency corner of less than or equal to 1.875MHz and a slope of 20dB/decade. The low-frequency corner corresponds to the point at which the PLL must begin to track low-frequency jitter. The filter used for RX input signal characterization shall be a fourth-order Bessel-Thomson filter as specified in section 53.9.7.

53.8.2.2 Added sinusoidal jitter for receiver jitter test

The sinusoidal jitter used to test receiver jitter tolerance shall meet the requirements of Table 53–11. Sinusoidal jitter shall be added to the test signal that complies with 53.8.2.1.

Table 53–11—Applied sinusoidal jitter

Frequency range	Sinusoidal amplitude jitter (UI pk-pk)
f <18.75 kHz	NA
18.75 kHz < f < 1.875 MHz	$\frac{93750}{f}$
1.875 MHz < f < 10 LB[a]	0.05

[a]LB = Loop Bandwidth; Recommended minimum value of upper bound of 0.05 UI added range is 10 times loop bandwidth.

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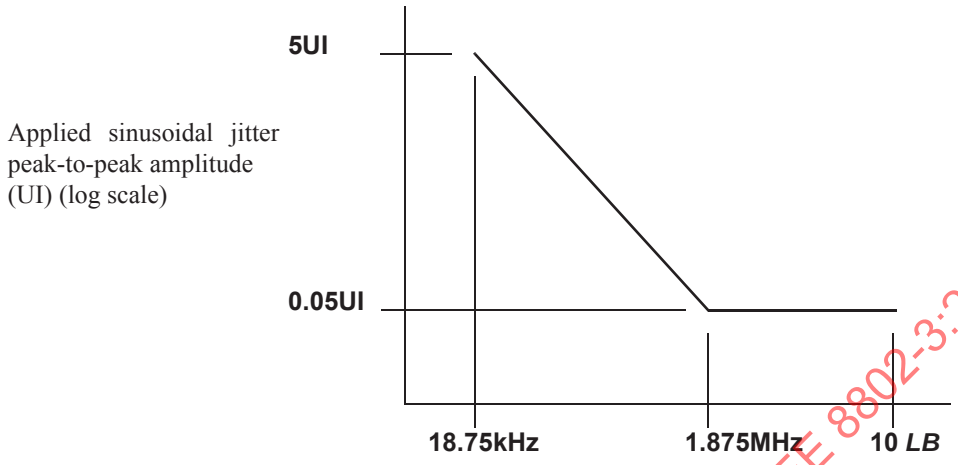

Figure 53–5—Mask of the sinusoidal component of jitter tolerance (informative)

53.9 Optical measurement requirements

All optical measurements shall be made through a short patch cable, between 2 m and 5 m in length. If a single-mode fiber offset-launch mode-conditioning patch cord is used, the optical transmit signal is defined at the output end (TP2) of the single-mode fiber offset-launch mode-conditioning patch cord.

It is recommended that wavelength measurements, RIN measurements, optical power measurements, source spectral window measurements, extinction ratio measurements, optical modulation amplitude measurements, and transmit rise/fall characteristics be performed using a low-frequency square-wave pattern (K28.7).

It is recommended that the receiver 3dB electrical upper cutoff frequency characterization be performed using CRPAT or another reasonable mixed frequency pattern.

Furthermore, it is recommended that the transmitter optical waveform, receive sensitivity measurements, transmitter jitter conformance tests, stressed receiver conformance tests, and jitter tolerance measurements be characterized using CJPAT.

The recommendation of specific test patterns is provided in an effort to meet the overall objective of ensuring compliance of the standard under any and all valid data patterns.

53.9.1 Wavelength range measurements

The wavelength ranges of each wavelength lane shall be measured with an optical spectrum analyzer (OSA) or equivalent device over the wavelength range specified in Table 53–8; with the following conditions:

a) The resolution bandwidth equal to the spectral window values for the particular source type as specified in Table 53–8, and
b) The channel under test is modulated using valid 10GBASE-LX4 signals.

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53.9.2 Optical power measurements

The absolute optical power of each channel shall be measured using the methods in TIA/EIA-455-95, with the sum of the optical power from all of the channels not under test below –30 dBm, per the test set-up in Figure 53–6.

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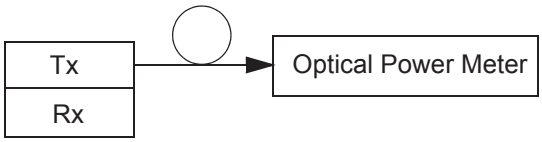

Figure 53–6—Optical power measurement test set-up

53.9.3 Source spectral window measurements

The source spectral window shall be measured for each channel individually with the sum of the optical power from all of the channels not under test below –30dBm, per the test set-up in Figure 53–7. The channel under test shall be modulated using valid 10GBASE-LX4 signals.

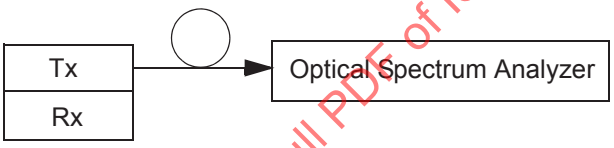

Figure 53–7—Source spectral window measurement test set-up

53.9.4 Extinction ratio measurements

Extinction ratio shall be measured using the methods specified in IEC 61280-2-2. The extinction ratio is measured under fully modulated conditions.

53.9.5 Optical Modulation Amplitude (OMA) measurements

The OMA measurement methodology is defined in 52.9.5 with the exception that each channel will be tested individually and the sum of the optical power from all of the channels not under test shall be below –30 dBm.

53.9.6 Relative Intensity Noise [RIN_{12}(OMA)]

The RIN measurement methodology is defined in 52.9.6 with the exception that each channel will be tested individually, the sum of the optical power from all of the channels not under test shall be below –30 dBm, and the upper –3 dB limit of the measurement apparatus is to be approximately equal to the bit rate (i.e., 3.125 GHz).

53.9.7 Transmitter optical waveform (transmit eye)

The required transmitter pulse shape characteristics are specified in the form of a mask of the transmitter eye diagram as shown in Figure 53–8. Measurements shall be made as per IEC 61280-2-2. The transmit mask is not used for response time and jitter specification.

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Normalized amplitudes of 0.0 and 1.0 represent the amplitudes of logic ZERO and ONE respectively.

The eye shall be measured with respect to the mask of the eye using a fourth-order Bessel-Thomson filter having a transfer function given by Equation (53–5):

$$H(p) = \frac{105}{105 + 105\,y + 45\,y^2 + 10\,y^3 + y^4} \tag{53–5}$$

where:

$$y = 2.114\,p; \qquad p = \frac{j\omega}{\omega_r}; \qquad \omega_r = 2\pi f_r \; ; \qquad f_r = 2.344 \text{ GHz}$$

and where the filter response vs. frequency range for this fourth-order Bessel-Thomson filter is defined in ITU-T G.957, along with the allowed tolerances (STM-16 values) for its physical implementation.

This Bessel-Thomson filter is not intended to represent the noise filter used within an optical receiver, but is intended to provide uniform measurement conditions at the transmitter.

The fourth-order Bessel-Thomson filter is reactive. In order to suppress reflections, a 6 dB attenuator may be required at the filter input and/or output.

A Clock Recovery Unit shall be used to trigger the scope for mask measurements. It shall have a low-frequency corner of less than or equal to 1.875 MHz and a slope of 20 dB/decade.

For each lane, the transmit optical waveform is tested with the receive section in operation on all four lanes and with the transmit lanes not under test in operation. CJPAT, CRPAT, or valid 8B/10B encoded data, may be sent to the receive section of the transmitter under test. The data being received must be asynchronous to the transmitted data.

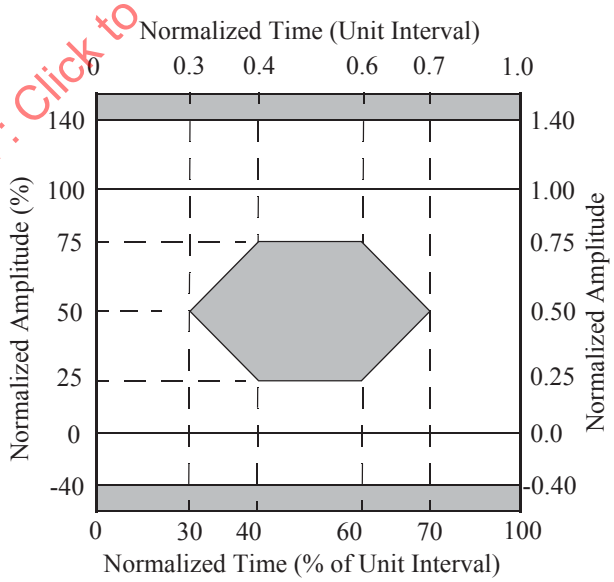

Figure 53–8—Transmitter eye mask definition

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53.9.8 Transmit rise/fall characteristics

Optical response time specifications are based on unfiltered waveforms. Some lasers have overshoot and ringing on the optical waveforms, which, if unfiltered, reduce the accuracy of the measured 20–80% response times. For the purpose of standardizing the measurement method, measured waveforms shall conform to the mask defined in Figure 53–8. If a filter is needed to conform to the mask, the filter response shall be removed using Equation (53–6):

$$T_{rise,\,fall} = \sqrt{(T_{rise,\,fall_measured})^2 - (T_{rise,\,fall_filter})^2} \quad (53\text{–}6)$$

where the filter may be different for rise and fall. Any filter shall have an impulse response equivalent to a fourth-order Bessel-Thomson filter. The fourth-order Bessel-Thomson filter defined in 53.9.7 may be a convenient filter for this measurement; however, its low bandwidth adversely impacts the accuracy of the $T_{rise,fall}$ measurements.

53.9.9 Receive sensitivity measurements

The stressed receive sensitivity shall be measured using the conformance test signal at TP3, as specified in 53.9.14 and meet the conditions specified in Table 53–8.

53.9.10 Transmitter jitter conformance (per lane)

53.9.10.1 Block diagram and general description of test set up

A block diagram for the transmitter jitter conformance test is shown in Figure 53–9. The transmitter (Tx) of the system under test is tested for conformance by continuously generating the test pattern specified in Annex 48A. Depending on the port type, a “Test Fiber” is added to the channel so that the jitter can be measured at a virtual TP3 (hereafter simply referred to simply as TP3) and thus include dispersion and other chromatic and channel induced penalties.

A “Reference Optical Filter” selects the wavelength channel under test in the presence of all channels operating.

A “Reference Receiver (Rx)” converts the optical signal to the electrical domain for input to the BERT.

For 10GBASE-LX4 (single-mode) the receiver shall have a fourth-order Bessel-Thomson response with the transfer function specified in 53.9.7.

Since there is no known way to create a channel using multimode fiber that would yield consistent results, the fiber is omitted from TP2 to TP3.

For 10GBASE-LX4 (multimode), the receiver shall have a fourth-order Bessel-Thomson response with the transfer function specified in 53.9.7 followed by a transversal filter with two equal amplitude paths with a differential delay of 157ps.

The PLL is used in the jitter measurement. It shall have a corner frequency of less than or equal to 1.875MHz and a slope of 20dB/decade. When using a Clock Recovery Unit as a clock for BER measurements, passing of low-frequency jitter from the data to the clock removes this low-frequency jitter from the measurement. The corner frequency corresponds to the point at which the PLL must begin to track this low-frequency jitter.

Jitter shall be measured at the average value of the overall waveform. This can be accomplished with AC-coupling to ground and measuring at ground.

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The measurement in this section shall be satisfied with asynchronous data flowing into all four optical receiver channels of the system under test.

The method by which the test pattern is loaded into, or generated by, the BERT is outside the scope of this document.

For each lane, the transmit jitter is tested with the receive section in operation on all four lanes and with the transmit lanes not under test in operation. CJPAT, CRPAT, or valid 8B/10B encoded data, may be sent to the receive section of the transmitter under test. The data being received must be asynchronous to the transmitted data.

Annex 48B contains both theoretical and practical information on jitter testing.

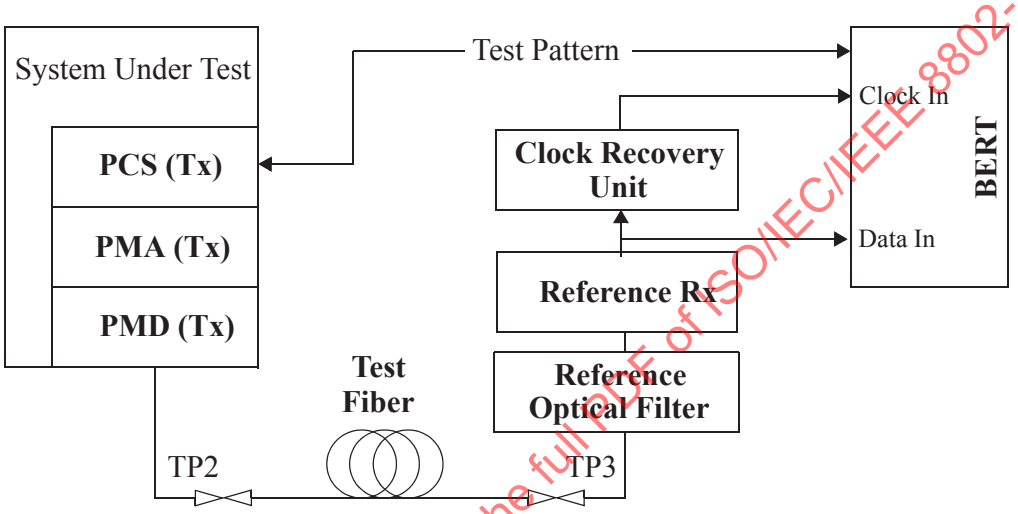

Figure 53–9—Transmit jitter test block diagram

53.9.10.2 Channel requirements for transmit jitter testing

The optical channel used to test the transmitter shall meet the requirements listed in Table 53–12.

Table 53–12—Transmit jitter compliance channel specifications

PMD Type	Minimum dispersion[a] (ps/nm)		Insertion loss[b]	Minimum Return loss[c]
	Minimum	Maximum		
10GBASE-LX4 (multimode)	N/A	N/A	Minimum	See Table 53–8
10GBASE-LX4 (single-mode)	$0.2325 \cdot \lambda \cdot [1 - (1300 / \lambda)^4]$	$0.2325 \cdot \lambda \cdot [1 - (1324 / \lambda)^4]$	Minimum	See Table 53–8

[a]The dispersion is measured for the wavelength of the device under test. The coefficient assumes 10 km for the case of single-mode fiber.
[b]There is no intent to stress the sensitivity of the BERT's optical receiver.
[c]The return loss is applied at TP2. Note that the referenced return losses are maximums. Here, the return loss is a minimum.

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For 10GBASE-LX4 (single-mode), the transmitter shall be compliant with dispersion at least as negative as the "minimum dispersion" and at least as positive as the "maximum dispersion" columns. This shall be achieved using ITU-T G.652 fiber or fibers with lengths chosen to have a total dispersion larger than specified in Table 53–12 for the wavelength of the device under test. To verify that the fiber has the correct amount of dispersion, the measurement method defined in ANSI/TIA/EIA-455-175A-92 may be used. The channel shall meet these requirements in the linear regime of the fiber. The channel shall provide an optical back reflection specified in Table 53–7 for 10GBASE-LX4. The state of polarization of the back reflection shall be adjusted to create the greatest RIN. The methods of 52.9.6.2 and 52.9.6.3 may be used.

The channel for 10GBASE-LX4 (multimode) is a 2 to 5 meter patch cord meeting the requirements in Table 53–12. The channel shall provide back reflection to the transmitter at –12 dB. The polarization adjustment does not apply, as noted in 52.9.6.3 item c).

53.9.10.3 Transmit jitter test procedure

After setting up the test as described above, the BERT is scanned horizontally across the center of the eye, from 0 unit intervals (UI) to 1 unit interval, while measuring the error ratio to develop a BER "bathtub curve" as described in 53.8.1.1. This clause also specifies the BER mask. It is not necessary to measure the error ratio in the center of the eye where the BER is less than 10^{-12} or at the edges where the BER is worse than 10^{-4}. The mask natively includes those components of jitter (random, deterministic, bounded) historically measured independently.

A Clock Recovery Unit having a low-frequency corner of less than or equal to 1.875 MHz and a slope of 20 dB/decade shall be used to generate the reference clock for transmit jitter measurements.

NOTE—The specifications for the Reference Optical Filter, Reference Rx, Clock Recovery Unit, and BERT, except as specified above, are outside the scope of this document. The Reference Rx and Clock Recovery Unit are intended to provide consistent and repeatable measurements, not to represent the worst case receiver. It should also be noted that a poorer grade of test equipment will force a greater burden onto the system-under-test to meet specifications. Similarly, a better grade of test equipment will ease the development and manufacture of the system and system components. It is expected that trade-offs needed to optimize the overall cost of development, manufacture and test will change over time and are best left to the implementer.

53.9.11 Receive sensitivity measurements

The receiver sensitivity, which is defined for an ideal input signal is informative. Receivers are tested with a conditioned input signal where both vertical eye closure and jitter have been added according to 53.9.12. When tested according to 53.9.12, the stressed sensitivity shall meet the specifications in Table 53–8 for 10GBASE-LX4.

53.9.12 Stressed receiver conformance test

The measurements in this subclause shall be satisfied with asynchronous data flowing out of the optical transmitter of the system under test. This data shall be consistent with normal signal properties and content.

53.9.12.1 Block diagram of stressed receiver tolerance test set up

A block diagram for the receiver jitter conformance test is shown in Figure 53–10. The receiver of the system under test is tested for conformance by putting the PCS in test mode as specified in Annex 48A. A suitable pattern generator is used to continuously generate a test pattern defined in Annex 48A. The optical test signal is conditioned (stressed) using the stressed receiver methodology defined in 53.9.14 and applying sinusoidal jitter as defined in 53.8.2.2. As defined in section Annex 48A, the PCS is capable of detecting the data pattern and reporting any errors received.

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A BER test set or other suitable test set is needed to characterize and verify that the signal used to test the receiver has the appropriate characteristics. This measurement is made using the same method as the transmit jitter test method described in 52.8. The "Test Fiber" called out for LX4 is not needed to characterize the receiver input signal. A "Clock Recovery Unit" meeting the requirements of 53.8.2.1 shall be used.

Jitter shall be calibrated at the average value of the overall optical waveform. This can be accomplished by AC-coupling.

The method by which the test pattern is loaded into, or generated by, the BERT is outside the scope of this document.

Annex 48B contains both theoretical and practical information on jitter testing.

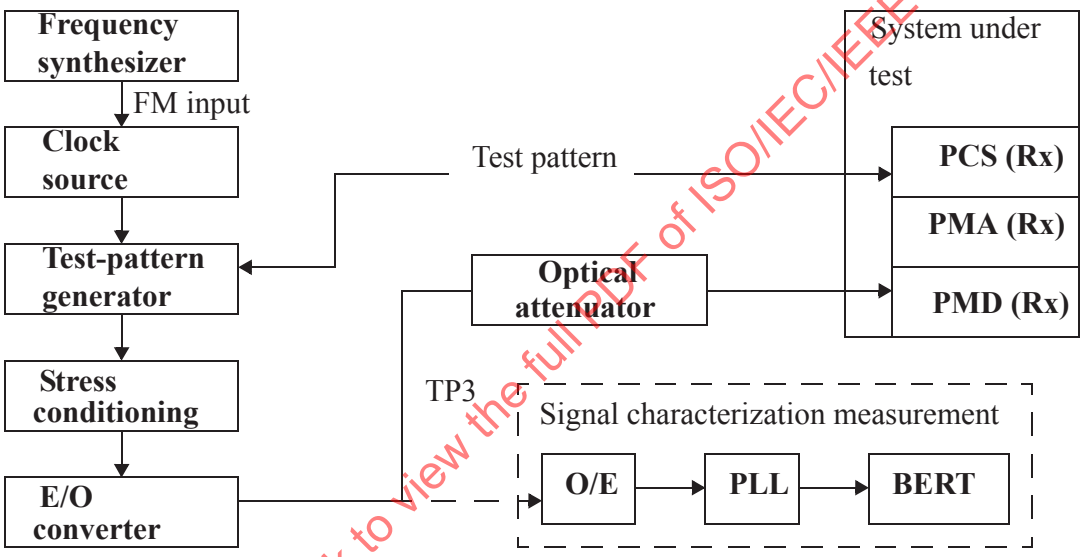

Figure 53–10—Receive jitter test block diagram

53.9.12.2 Stressed receiver conformance test procedure

A BER test set, or other suitable test set, is needed to characterize and verify that the signal used to test the receiver has the appropriate characteristics. This measurement is made using the same method as the transmit jitter test method described in 53.9.10. The "Test Fiber" called out for LX4 (single-mode) and the transversal filter called out for LX4 (multimode) are not needed to characterize the receiver input signal. A Clock Recovery Unit meeting the requirements of 53.8.2.1 shall be used.

53.9.12.3 Characterization of receiver input signal

Care should be taken when characterizing the signal used to make receiver tolerance measurements. In the case of a transmit jitter measurement, excessive and/or uncalibrated noise/jitter in the test system makes it more difficult to meet the specification and may have a negative impact on yield, but will not effect interoperability. In the case of the receiver input calibration measurement, however, excessive noise/jitter will result in an input signal that does not meet the mask requirements defined in 53.8.2.1. Running the receiver tolerance test with a signal that is under-stressed may result in the deployment of non-compliant

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receivers. Care should be taken to minimize the noise/jitter introduced by the reference O-E, filters and BERT and/or to correct for this noise. While the details of a BER scan measurement and test equipment are beyond the scope of this document, it is recommended that the implementer fully characterize their test equipment and apply appropriate guard bands to ensure that the RX input signal meets the mask specified in 53.8.2.1.

53.9.12.4 Jitter tolerance test procedure

Set up the test apparatus as described in 53.9.12.1 and adjust the optical input power to the receiver under test to meet the requirements of 53.8.2.1. The sinusoidal jitter is then swept across the frequency and amplitude range specified in 53.8.2.1 while monitoring BER at the receiver. This method does not result in values for TJ, DJ, or RJ contributed by the receiver. It does, however, guarantee that a receiver meeting the requirements of this test will operate with the worst-case optical input

For each lane, the receive jitter tolerance is tested with the transmit section in operation on all four lanes and with the receive lanes not under test in operation. CJPAT, CRPAT, or valid 8B/10B encoded data, may be sent from the transmit section of the receiver under test. The data being transmitted must be asynchronous to the received data.

53.9.13 Measurement of the receiver 3 dB electrical upper cutoff frequency

The receiver cutoff frequency measurement shall be performed on each wavelength channel independently using a laser source with its output wavelength within the specified wavelength range of the channel to be tested. The test setup is shown in Figure 53–11. The test is performed with a tunable laser that is suitable for analog signal transmission. The laser is modulated by a digital data signal. In addition to the digital modulation the laser is modulated with an analog signal. The analog and digital signals should be asynchronous. The data pattern to be used for this test is the short continuous random test pattern defined in Annex 48A. The frequency response of the laser must be sufficient to allow it to respond to both the digital modulation and the analog modulation. The laser should be biased so that it remains linear when driven by the combined signals. The test may use two optical sources and an optical combiner as defined in 52.9.11.

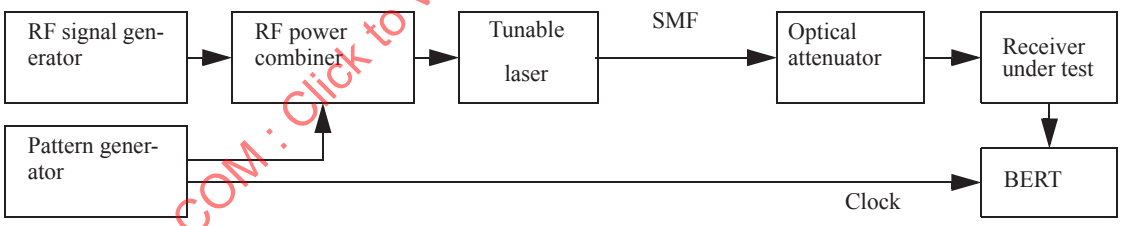

Figure 53–11—Test setup for receiver bandwidth measurement

The 3 dB upper cutoff frequency shall be measured using the following steps:

a) Calibrate the frequency response characteristics of the test equipment including the analog radio frequency (RF) signal generator, RF power combiner, and laser source, with the optical source meeting the requirements of this clause.
b) Configure the test equipment as shown in Figure 53–11. Take care to minimize changes to the signal path that could affect the system frequency response after the calibration in step a). Connect the laser output with no RF modulation applied to the receiver under test through an optical attenuator and

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taking into account the extinction ratio of the source, set the optical power to a level that approximates the stressed receive sensitivity level in Table 53–8.

c) Locate the center of the eye with the BERT. Turn on the RF modulation while maintaining the same average optical power established in step b).

d) Measure the necessary RF modulation amplitude (in dBm) required to achieve a constant BER (e.g., 10^{-8}) for a number of frequencies.

e) The receiver 3 dB electrical upper cutoff frequency is that frequency where the corrected RF modulation amplitude (the measured amplitude in "d" corrected with the calibration data in "a") increases by 3 dB (electrical). If necessary, interpolate between the measured response values.

53.9.14 Conformance test signal at TP3 for receiver testing

Receivers being tested for conformance to the stressed receive sensitivity requirements of 53.9.9 and the total jitter requirements of 53.9.10 shall be tested using a conformance test signal at TP3 conforming to the requirements described in Figure 53–12. It is recommended that the conformance test signal be generated using a short continuous random test pattern as defined in Annex 48A. The conformance test signal is conditioned by applying deterministic jitter (DJ) and intersymbol interference (ISI). The conditioned conformance test signal is shown schematically in Figure 53–12. The horizontal eye closure (reduction of pulse width) caused by the duty cycle distortion (DCD) component of DJ shall be no less than 14 ps.

The vertical eye closure penalty shall be greater than or equal to the value specified in Table 53–8. The DJ cannot be added with a simple phase modulation, which does not account for the DCD component of DJ.

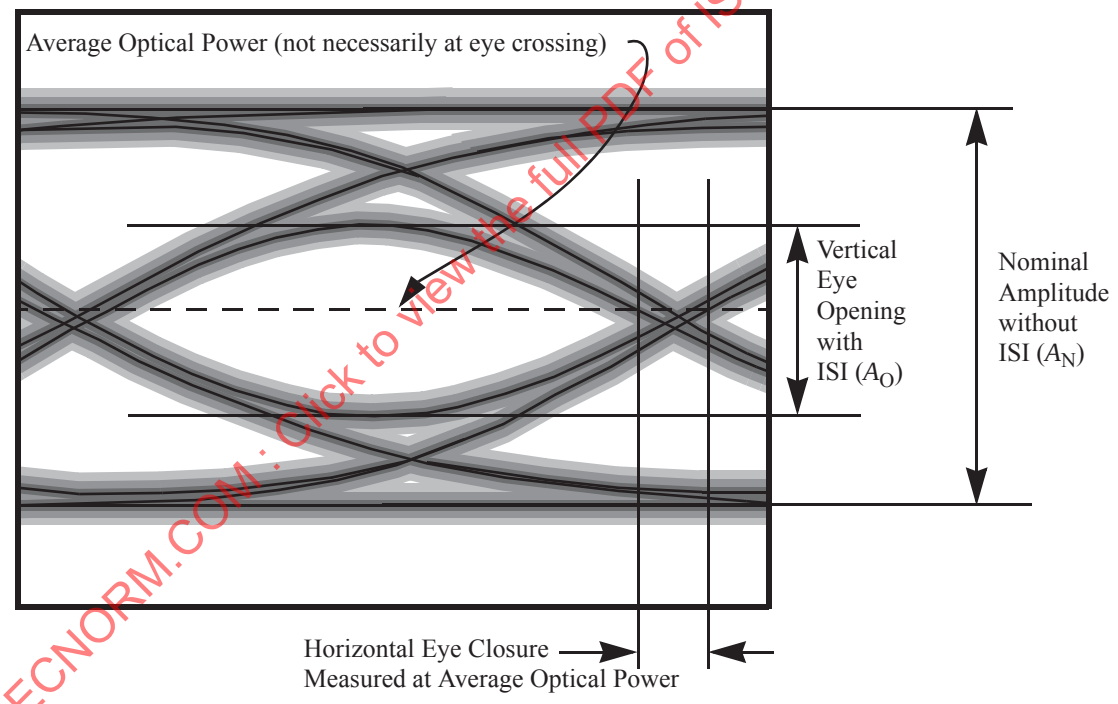

Figure 53–12—Required characteristics of the conformance test signal at TP3

The vertical eye closure penalty is given by:

$$\text{Vertical eye closure penalty [dB]} = 10 \times \log \frac{A_O}{A_N}$$

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where, A_O is the amplitude of the eye opening and A_N is the normal amplitude without ISI, as measured in Figure 53–12.

Figure 53–13 shows a possible test set up for producing the conformance test signal at TP3. The coaxial cable is adjusted in length to produce the correct DCD component of DJ. Since the coaxial cable can produce the incorrect ISI, a limiting amplifier is used to restore fast rise and fall times. A Bessel-Thomson filter is selected to produce the minimum ISI induced eye closure as specified per Figure 53–12. This conditioned signal is used to drive a high bandwidth, tunable, wavelength tunable source.

Figure 53–13 shows this function being performed by a tunable source in combination with an external optical modulator. However, any other method capable of this combined function will suffice. Similarly, the remaining sources supply to their respective channels modulated signals at specific wavelengths, as specified in 53.9.15. This could be accomplished with tunable or fixed sources at the wavelengths required. The vertical and horizontal eye closures to be used for receiver conformance testing are verified using a fast photodetector and amplifier coupled to the oscilloscope input through a filter. The combined filtering effect of the photodetector, amplifier, and filter shall be a fourth-order Bessel-Thomson filter of 2.34 GHz bandwidth. Special care should be taken to ensure that all the light from the fiber is collected by the fast photodetector and that there is negligible mode selective loss, especially in the optical attenuator.

The source for the channel under test shall be set to supply a signal at the output of the optical multiplexer at the minimum OMA with all other remaining channels set to the maximum OMA. Each channel is to be tested with its adjacent channels set at the near end of their wavelength range. This is to occur sequentially, as described in 53.9.15. The channel under test is to be tuned over its wavelength range during a given measurement to account for wavelength dependent losses within the channel.

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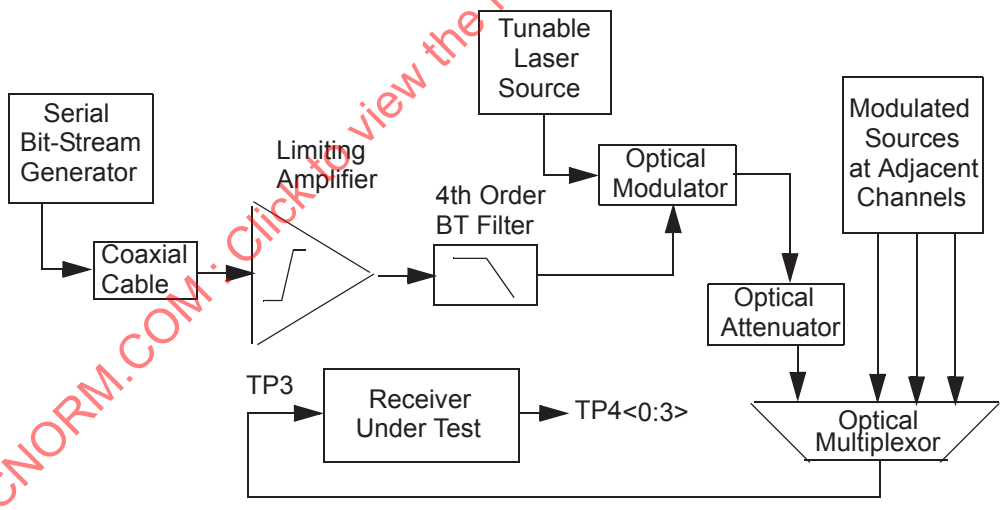

Figure 53–13—Setup for generating receiver conformance test signal at TP3

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53.9.15 Receiver test suite for WDM conformance testing

The receiver tests requiring the TP3 conformance test signal are performed on a per channel basis and shall meet the following test conditions:

a) All channels are modulated simultaneously, using valid 10GBASE-LX4 signals.
b) The center wavelengths of channels adjacent to the channel under test are tuned to the edge of their wavelength band nearest the channel under test.
c) When setting the wavelength of the channels adjacent to the channel under test, the center wavelength of the adjacent channels are set within 0.5 nm of the edge of that channel's wavelength band while remaining within that channel's wavelength band.
d) In the case of the interior channels, which have two adjacent channels, each adjacent channel is tuned individually and receiver testing is done twice, once for each adjacent channel.
e) The non-adjacent channels are to be tuned to the center of their respective wavelength ranges.
f) The transmitter of the transceiver under test is operating with valid test patterns as defined in Annex 48A.

These conditions are summarized graphically in Figure 53–14 for each channel under test.

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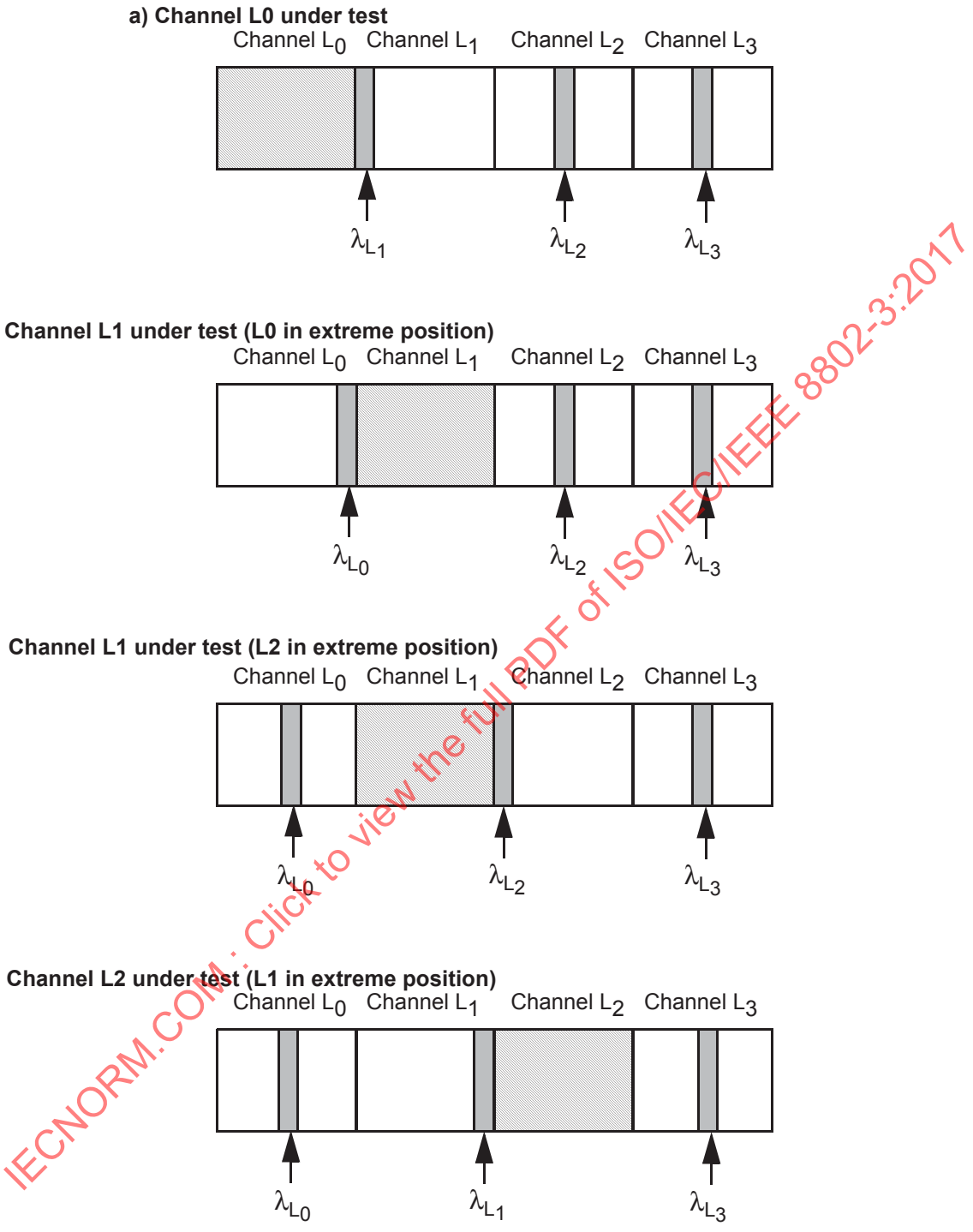

Figure 53–14—Channel test conditions for conformance test at TP3

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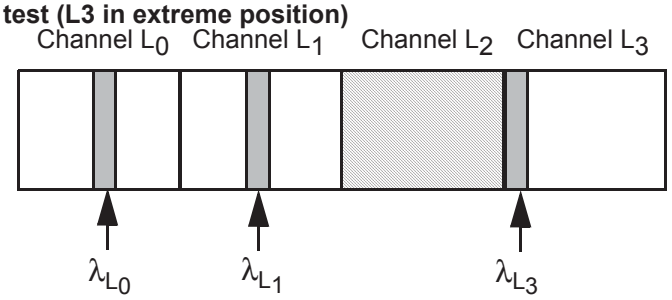
) Channel L2 under test (L3 in extreme position)



Channel L3 under test (L2 in extreme position)

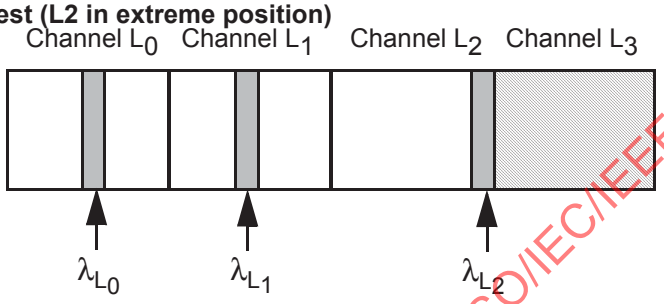


Figure 53–14—Channel test conditions for conformance test at TP3 *(continued)*

NOTE—The two interior channels (L_1, L_2) require two different wavelength configurations since they have two adjacent channels. Therefore, there will be twice as many tests to perform on these channels as on exterior channels L_0, L_3.

53.10 Environmental specifications

53.10.1 General safety

All equipment meeting this standard shall conform to IEC-60950-1.

53.10.2 Laser safety

The 10GBASE-LX4 optical transceivers shall be Hazard Level 1 laser certified under any condition of operation in conformance to IEC 60825-1 and IEC 60825-2. This includes single fault conditions whether coupled into a fiber or out of an open bore.

Conformance to additional laser safety standards may be required for operation within specific geographic regions.

Laser safety standards and regulations require that the manufacturer of a laser product provide information about the product's laser, safety features, labeling, use, maintenance, and service. This documentation explicitly define requirements and usage restrictions on the host system necessary to meet these safety certifications.[16]

[16]A host system that fails to meet the manufacturers requirements and/or usage restrictions may emit laser radiation in excess of the safety limits of one or more safety standards. In such a case, the host manufacturer is required to obtain its own laser safety certification.

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53.10.3 Installation

It is recommended that proper installation practices, as defined by applicable local codes and regulation, be followed in every instance in which such practices are applicable.

53.11 Environment

Normative specifications in this clause shall be met by a system integrating a 10GBASE-LX4 PMD over the life of the product while the product operates within the manufacturer's range of environmental, power, and other specifications.

It is recommended that manufacturers indicate in the literature associated with the PHY the operating environmental conditions to facilitate selection, installation, and maintenance.

It is recommended that manufacturers indicate, in the literature associated with the components of the optical link, the distance and operating environmental conditions over which the specifications of this clause will be met.

53.11.1 Electromagnetic emission

A system integrating a 10GBASE-LX4 PMD shall comply with applicable local, national, and international codes for the limitation of electromagnetic interference.

53.11.2 Temperature, humidity, and handling

The optical link is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

53.12 PMD labeling requirements

It is recommended that each PHY (and supporting documentation) be labeled in a manner visible to the user with at least the following parameters, according to the PMD-MDI type.

PMD MDI type 10GBASE-LX4:

a) 10GBASE-LX4.
b) Applicable safety warnings.

Labeling requirements for Hazard Level 1 lasers are given in the laser safety standards referenced in 53.10.2.

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53.13 Fiber optic cabling model

The fiber optic cabling model is shown in Figure 53–15.

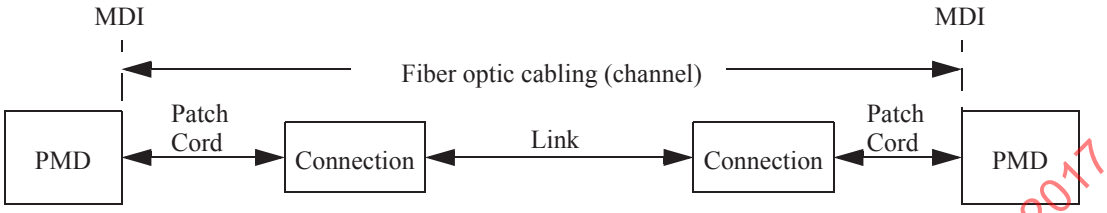

Figure 53–15—Fiber optic cabling model

The channel insertion loss is given in Table 53–13. Insertion loss measurements of installed fiber cables are made in accordance with ANSI/TIA/EIA-526-14A/method B, and ANSI/TIA/EIA-526-7/method A-1. The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment. The term channel is used here for consistency with generic cabling standards.

Table 53–13—Fiber optics cabling (channel) characteristics

Description	62.5 μm MMF	50 μm MMF		SMF	Unit
Modal bandwidth at 1300nm (min; overfilled launch)	**500**	**400**	**500**	**n/a**	**MHz•km**
Operating distance (max)	300	240	300	10 000	m
Channel insertion loss (max)[a]	2.5	2.0	2.0	6.6	dB

[a]These channel insertion loss numbers are calculated using a wavelength of 1300nm for MMF and 1310nm for SMF. An offset launch patch cord is assumed. Channel insertion loss is specified from TP2 to TP3 in Figure 53–2. The total insertion loss, when including the attenuation of the offset launch patch cord, is allowed to be 0.5dB higher than shown in the table.

53.14 Characteristics of the fiber optic cabling (channel)

The 10GBASE-LX4 fiber optic cabling shall meet the specifications defined in Table 53–13. The fiber optic cabling consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together. The fiber optic cabling spans from one MDI to another MDI, as shown in Figure 53–15.

53.14.1 Optical fiber and cable

The fiber optic cable requirements are satisfied by the fibers specified in IEC 60793-2:1992. Types A1a (50/125 μm multimode), A1b (62.5/125 μm multimode), and B1.1 (dispersion un-shifted single-mode) and B1.3 (low water peak single-mode) with the exceptions noted in Table 53–14.

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Table 53–14—Optical fiber and cable characteristics

Description	62.5 μm MMF	50 μm MMF	Type B1.1, B1.3 SMF	Unit
Nominal fiber specification wavelength	1300	1300	1310	nm
Cabled optical fiber attenuation (max)	1.5	1.5	0.4[a] or 0.5[b]	dB/km
Modal Bandwidth	500	400	N/A	MHz km
(min; overfilled launch)		500	N/A	MHz km
Zero dispersion wavelength (λ_0)	$1320 \le \lambda 0 \le 1365$	$1295 \le \lambda 0 \le 1320$	$1300 \le \lambda 0 \le 1324$	nm
Dispersion slope (max) (S_0)	0.11 for $1320 \le \lambda_0 \le 1348$ and $0.001(1458 - \lambda_0)$ for $1348 \le \lambda_0 \le 1365$	0.11 for $1300 \le \lambda_0 \le 1320$ and $0.001(\lambda_0 - 1190)$ for $1295 \le \lambda_0 \le 1300$	0.093	ps/nm^2 km

[a]For the single-mode case, the 0.4 dB/km attenuation for optical fiber cables is defined in ITU-T G.652.
[b]For the single-mode case, the 0.5 dB/km attenuation is provided for Outside Plant cable as defined in ANSI/TIA 568-C.3. Using 0.5 dB/km may not support operation at 10 km.

53.14.2 Optical fiber connection

An optical fiber connection as shown in Figure 53–15 consists of a mated pair of optical connectors. The 10GBASE-LX4 PMD is coupled to the fiber optic cabling through a connector plug into the MDI optical receptacle, as shown in 53.14.3.

53.14.2.1 Connection insertion loss

The insertion loss is specified for a connection that consists of a mated pair of optical connectors.

The maximum link distances for multimode fiber are calculated based on an allocation of 1.5 dB total connection and splice loss. For example, this allocation supports three connections with an average insertion loss equal to 0.5 dB (or less) per connection. Connections with different loss characteristics may be used provided the requirements of Table 53–13 and Table 53–14 are met.

The maximum link distances for single-mode fiber are calculated based on an allocation of 2.0 dB total connection and splice loss. For example, this allocation supports four connections with an average insertion loss per connection of 0.5 dB. Connections with different loss characteristics may be used provided the requirements of Table 53–13 and Table 53–14 are met.

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53.14.2.2 Connection return loss

The return loss for multimode connections shall be greater than 20 dB.

The return loss for single-mode connections shall be greater than 26 dB.

53.14.3 Medium Dependent Interface (MDI)

The 10GBASE-LX4 PMD is coupled to the fiber optic cabling at the MDI. The MDI is the interface between the PMD and the fiber optic cabling. Examples of an MDI include the following:

a) Connectorized fiber pigtail.
b) PMD receptacle.

When connected to the fiber optic cabling, the MDI shall meet the interface performance specifications of:

c) IEC 61753-1-1—Fibre optic interconnecting devices and passive component performance standard—Part 1-1: General and guidance—Interconnecting devices (connectors).
d) IEC 61753-021-2—Fibre optic passive component performance standard—Part 021-2:Fibre optic connectors terminated on single-mode fibre for Category C—Controlled environment, performance Class S.
e) IEC 61753-022-2—Fibre optic passive component performance standard—Part 022-2:Fibre optic connectors terminated on multimode fibre for Category C—Controlled environment, performance Class M.

NOTE—Compliance testing is performed at TP2 and TP3 as defined in 53.4.1, not at the MDI.

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53.15 Protocol implementation conformance statement (PICS) proforma for Clause 53, Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-LX4[17]

53.15.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 53, Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-LX4 (Long Wavelength Laser), shall complete the following protocol implementation conformance statement (PICS) proforma. A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

53.15.2 Identification

53.15.2.1 Implementation identification

Supplier[1]	
Contact point for inquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1,3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

53.15.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 53, Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-LX4
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	

Date of Statement	

[17]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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53.15.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
LX4	10GBASE-LX4 PMD	53.1	Device supports long wavelength operation (1269–1356 nm)	O/1	Yes [ ] No [ ]
*INS	Installation / cable	53.13	Items marked with INS include installation practices and cable specifications not applicable to a PHY manufacturer	O	Yes [ ] No [ ]
OFP	Single-mode offset-launch mode-conditioning patch cord	53.6	Items marked with OFP include installation practices and cable specifications not applicable to a PHY manufacturer	O	Yes [ ] No [ ]
TP1	Standardized reference point TP1 exposed and available for testing	53.4.1	This point may be made available for use by implementers to certify component conformance	O	Yes [ ] No [ ]
TP4	Standardized reference point TP4 exposed and available for testing	53.4.1	This point may be made available for use by implementers to certify component conformance	O	Yes [ ] No [ ]
DC	Delay constraints	53.2	Device conforms to delay constraints	M	Yes [ ]
*MD	MDIO capability	53.3	Registers and interface supported	O	Yes [ ] No [ ]

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53.15.4 PICS proforma tables for 10GBASE-LX4 and baseband medium

53.15.4.1 PMD Functional specifications

Item	Feature	Sub clause	Value/Comment	Status	Support
FN1	Integration with 10GBASE-X PCS and PMA and management functions	53.1		M	Yes [ ]
FN2	Transmit function	53.4.2	Convey bits requested by PMD_UNITDATA.request() to the MDI	M	Yes [ ]
FN3	Optical multiplexing and delivery to the MDI	53.4.2	Optically multiplexes the four optical signal streams for delivery to the MDI	M	Yes [ ]
FN4	Mapping between optical signal and logical signal for transmitter	53.4.2	Higher optical power is a one	M	Yes [ ]
FN5	Receive function	53.4.3	Convey bits received from the MDI to PMD_UNITDATA.indication(rx_bit<0:3>)	M	Yes [ ]
FN6	Conversion of four optical signals to four electrical signals	53.4.3	Converts the four optical signal streams into four electrical bit streams for delivery to the PMD service	M	Yes [ ]
FN7	Mapping between optical signal and logical signal for receiver	53.4.3	Higher optical power is a one	M	Yes [ ]
FN8	Receive function behavior	53.4.3	Conveys bits from PMD service primitive to the PMD service interface	M	Yes [ ]
FN9	Global Signal Detect function	53.4.4	Report to the PMD service interface the message PMD_SIGNAL.indication(SIGNAL_DETECT)	M	Yes [ ]
FN10	Global Signal Detect behavior	53.4.4	SIGNAL_DETECT is a global indicator of the presence of optical signals on all four lanes	M	Yes [ ]
FN11	Lane-by-Lane Signal Detect function	53.4.5	Sets PMD_signal_detect_n values on a lane-by-lane basis per requirements of Table 53–4	MD:O	Yes [ ] No [ ] N/A [ ]
FN12	PMD_reset function	53.4.6	Resets the PMD sublayer	MD:O	Yes [ ] No [ ] N/A [ ]

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53.15.4.2 PMD to MDI optical specifications for 10GBASE-LX4

Item	Feature	Subclause	Value/Comment	Status	Support
PMS1	Wavelength division multiplexed lane assignment	53.5	Device supports passbands defined in Table 53–5	M	Yes [ ] N/A [ ]
PMS2	Transmitter meets specifications in Table 53–7	53.7.1	Per measurement techniques in 53.9	M	Yes [ ] N/A [ ]
PMS3	Receiver meets specifications in Table 53–8	53.7.2	Per measurement techniques in 53.9	M	Yes [ ] N/A [ ]

53.15.4.3 Management functions

Item	Feature	Subclause	Value/Comment	Status	Support
MR1	Management register set	53.3		MD:M	Yes [ ] N/A [ ]
MR2	Global transmit disable function	53.4.7	Disables all of the optical transmitters with the Global_PMD_transmit_disable variable	MD:O	Yes [ ] No [ ] N/A [ ]
MR3	PMD_lane_by_lane_transmit_disable function	53.4.8	Disables the optical transmitter on the lane associated with the PMD_transmit_disable_n variable	MD:O.2	Yes [ ] No [ ] N/A [ ]
MR4	PMD_lane_by_lane_transmit_disable	53.4.8	Disables each optical transmitter independently if MR3 = NO	O.2	Yes [ ] No [ ]
MR5	PMD_fault function	53.4.9	Sets PMD_fault to a logical 1 if any local fault is detected	MD:O	Yes [ ] No [ ] N/A [ ]
MR6	PMD_transmit_fault function	53.4.10	Sets PMD_transmit_fault to a logical 1 if a local fault is detected on any transmit lane	MD:O	Yes [ ] No [ ] N/A [ ]
MR7	PMD_receive_fault function	53.4.11	Sets PMD_receive_fault to a logical 1 if a local fault is detected on any receive lane	MD:O	Yes [ ] No [ ] N/A [ ]

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53.15.4.4 Jitter specifications

Item	Feature	Subclause	Value/Comment	Status	Support
JS1	Transmit jitter	53.8.1	Meet BER "bathtub curve" specifications	M	Yes [ ]
JS2	Channel transmit jitter	53.8.1.1	As described in steps a) through c) in 53.8.1.1	M	Yes [ ]
JS3	Channel transmit jitter	53.8.1.1	Also tested on MMF as defined in 53.9.10.1	M	Yes [ ]
JS4	Receive jitter	53.8.2	BER less than 10^{-12}	M	Yes [ ]
JS5	Receive jitter	53.8.2.1	Meets requirements of the receiver input jitter mask	M	Yes [ ]
JS6	Receive jitter	53.8.2.1	Uniform spectral content over the measurement frequency range of 18.75kHz to 1.5GHz	M	Yes [ ]
JS7	Receive jitter	53.8.2.1	Using a Clock Recovery Unit	M	Yes [ ]
JS8	Receive jitter	53.8.2.1	Using a low-frequency corner of less than or equal to 1.875MHz and a slope of 20dB/decade	M	Yes [ ]
JS9	Receive jitter	53.8.2.1	Using fourth-order Bessel-Thomson filter	M	Yes [ ]
JS10	Receive jitter	53.8.2.2	Meets the requirements of Table 53–11	M	Yes [ ]
JS11	Receive jitter	53.8.2.2	Sinusoidal jitter added to the test signal in compliance with 53.8.2.1	M	Yes [ ]

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53.15.4.5 Optical measurement requirements

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	Length of patch cord used for measurements	53.9	2 to 5 m	M	Yes [ ]
OM2	Wavelength ranges	53.9.1	Wavelengths fall within ranges specified inTable 53–5, and under modulated conditions using valid 10GBASE-X signals	M	Yes [ ]
OM3	Optical power measurements	53.9.2	Per TIA/EIA-455-95	M	Yes [ ]
OM4	Source spectral window measurements	53.9.3	Individually measured per test setup in Figure 53–7, with all other channels below –30 dBm	M	Yes [ ]
OM5	Source spectral window measurements	53.9.3	Under modulated conditions using valid 10GBASE-X signals	M	Yes [ ]
OM6	Extinction ratio measurements	53.9.4	Per IEC 61280-2-2	M	Yes [ ]
OM7	OMA measurements	53.9.5	Each channel tested individually per methodology defined in 52.9.5	M	Yes [ ]
OM8	$RIN_{12}OMA$	53.9.6	Each channel tested individually per methodology defined in 52.9.6		Yes [ ]
OM9	Transmit eye	53.9.7	Per IEC 61280-2-2	M	Yes [ ]
OM10	Transmit eye mask measurement conditions	53.9.7	Using fourth-order Bessel-Thomson filter	M	Yes [ ]
OM11	Transmit eye mask measurement conditions	53.9.7	Using a Clock Recovery Unit to trigger the scope	M	Yes [ ]
OM12	Transmit eye mask measurement conditions	53.9.7	Using a low-frequency corner of less than or equal to 1.875MHz and a slope of 20dB/decade	M	Yes [ ]
OM13	Transmit rise/fall characteristics conditions	53.9.8	Waveforms conform to mask in Figure 53–8, measured from 20% to 80%, using a patch cord	M	Yes [ ]
OM14	Transmit rise/fall characteristics conditions	53.9.8	Removed mask conforming filter mathematically	M	Yes [ ]
OM15	Transmit rise/fall characteristics conditions	53.9.8	Mask filters use a fourth-order Bessel-Thomson filter	M	Yes [ ]
OM16	Receive sensitivity measurement conditions	53.9.9	Using conformance test at TP3 and meeting conditions specified in Table 53–8	M	Yes [ ]
OM17	Transmit jitter conformance measurement conditions	53.9.10.1	Using a fourth-order Bessel-Thomson filter for single-mode fiber	M	Yes [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
OM18	Transmit jitter conformance measurement conditions	53.9.10.1	Using a fourth-order Bessel-Thomson filter followed by a transversal filter with 2 equal amplitude paths with a differential delay of 157 ps for multimode fiber	M	Yes [ ]
OM19	Transmit jitter conformance measurement conditions	53.9.10.1	Using a low-frequency corner of less than or equal to 1.875MHz and a slope of 20dB/decade	M	Yes [ ]
OM20	Transmit jitter conformance measurement conditions	53.9.10.1	Measured at the average value of the overall waveform	M	Yes [ ]
OM21	Transmit jitter conformance measurement conditions	53.9.10.1	Asynchronous data flowing in all four optical receiver channels	M	Yes [ ]
OM22	Transmit jitter conformance measurement conditions	53.9.10.2	Meets requirements listed in Table 53–12	M	Yes [ ]
OM23	Transmit jitter conformance measurement conditions	53.9.10.2	For single-mode fiber, compliant with dispersion at least as negative as the “minimum dispersion” and at least as positive as the “maximum dispersion”	M	Yes [ ]
OM24	Transmit jitter conformance measurement conditions	53.9.10.2	Achieved using ITU-T G.652 fiber	M	Yes [ ]
OM25	Transmit jitter conformance measurement conditions	53.9.10.2	Using the linear regime of the single-mode fiber	M	Yes [ ]
OM26	Transmit jitter conformance measurement conditions	53.9.10.2	Provide an optical back reflection specified in Table 53–7	M	Yes [ ]
OM27	Transmit jitter conformance measurement conditions	53.9.10.2	Back reflection adjusted to create the greatest RIN	M	Yes [ ]
OM28	Transmit jitter conformance measurement conditions	53.9.10.2	For multimode fiber, back reflection set to –12 dB	M	Yes [ ]
OM29	Transmit jitter conformance measurement conditions	53.9.10.3	Using a low-frequency corner of less than or equal to 1.875MHz and a slope of 20dB/decade	M	Yes [ ]
OM30	Receiver sensitivity	53.9.11	Meet the specifications in Table 53–8	M	Yes [ ]
OM31	Stressed receiver conformance conditions	53.9.12	Asynchronous data flowing out of the optical transmitter of the system under test	M	Yes [ ]
OM32	Stressed receiver conformance conditions	53.9.12	Data is consistent with normal signal properties and content	M	Yes [ ]
OM33	Stressed receiver conformance conditions	53.9.12.1	Using a Clock Recovery Unit meeting the requirements of 53.8.2.1	M	Yes [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
OM34	Stressed receiver conformance conditions	53.9.12.1	Calibrated at the average value of the overall optical waveform	M	Yes [ ]
OM35	Stressed receiver conformance conditions	53.9.12.3	Using a Clock Recovery Unit meeting the requirements of 53.8.2.1	M	Yes [ ]
OM36	Receiver 3dB electrical upper cutoff frequency	53.9.13	Performed on each channel independently using a laser source with its output wavelength within the specified wavelength range of the channel to be tested	M	Yes [ ]
OM37	Receiver 3dB electrical upper cutoff frequency	53.9.13	As described in steps a) through e) of 53.9.13	M	Yes [ ]
OM38	Compliance test signal at TP3	53.9.14	Meets the requirements of Figure 53–12	M	Yes [ ]
OM39	Compliance test signal at TP3	53.9.14	DJ eye closure no less than 14 ps	M	Yes [ ]
OM40	Compliance test signal at TP3	53.9.14	Vertical eye-closure penalty meets requirements of Table 53–8	M	Yes [ ] N/A [ ]
OM41	Compliance test signal at TP3	53.9.14	Bandwidth of photodetector > 2.34GHz, and couple through fourth-order Bessel-Thomson filter	M	Yes [ ]
OM42	Receiver WDM conformance conditions	53.9.15	As described in steps a) through f) of 53.9.15	M	Yes [ ]
OM43	General safety	53.10.1	Conform to IEC-60950-1	M	Yes [ ]
OM44	Laser safety	53.10.2	Hazard Level 1	M	Yes [ ]
OM45	Compliance with all requirements over the life of the product	53.11		M	Yes [ ]
OM46	Compliance with applicable local and national codes for the limitation of electromagnetic interference	53.11.1		M	Yes [ ]

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53.15.4.6 Characteristics of the fiber optic cabling

Item	Feature	Subclause	Value/Comment	Status	Support
LI1	Fiber optic cabling	53.13	Meets specifications in Table 53–13	INS:M	Yes [ ] N/A [ ]
LI2	Return loss for multimode connections	53.14.2.2	> 20 dB	INS:M	Yes [ ] No [ ] N/A [ ]
LI3	Return loss for single-mode connections	53.14.2.2	> 26 dB	INS:M	Yes [ ] No [ ] N/A [ ]
LI4	MDI	53.14.3	IEC 61753-1-1 and IEC 61753-3-2	M	Yes [ ]

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54. Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-CX4

54.1 Overview

This clause specifies the 10GBASE-CX4 PMD (including MDI) and the baseband medium. In order to form a complete PHY (Physical Layer device), a PMD is combined with the appropriate sublayers (see Table 54–1) and with the management functions, which are optionally accessible through the management interface defined in Clause 45, or equivalent.

Table 54–1—Physical Layer clauses associated with the 10GBASE-CX4 PMD

Associated clause	10GBASE-CX4
46—XGMII[a]	Optional
47—XGXS and XAUI	Optional
48—10GBASE-X PCS/PMA	Required

[a]The XGMII is an optional interface. However, if the XGMII is not implemented, a conforming implementation must behave functionally as though the RS and XGMII were present.

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Figure 54–1 shows the relationship of the 10GBASE-CX4 PMD sublayers and MDI to the ISO/IEC Open System Interconnection (OSI) reference model.

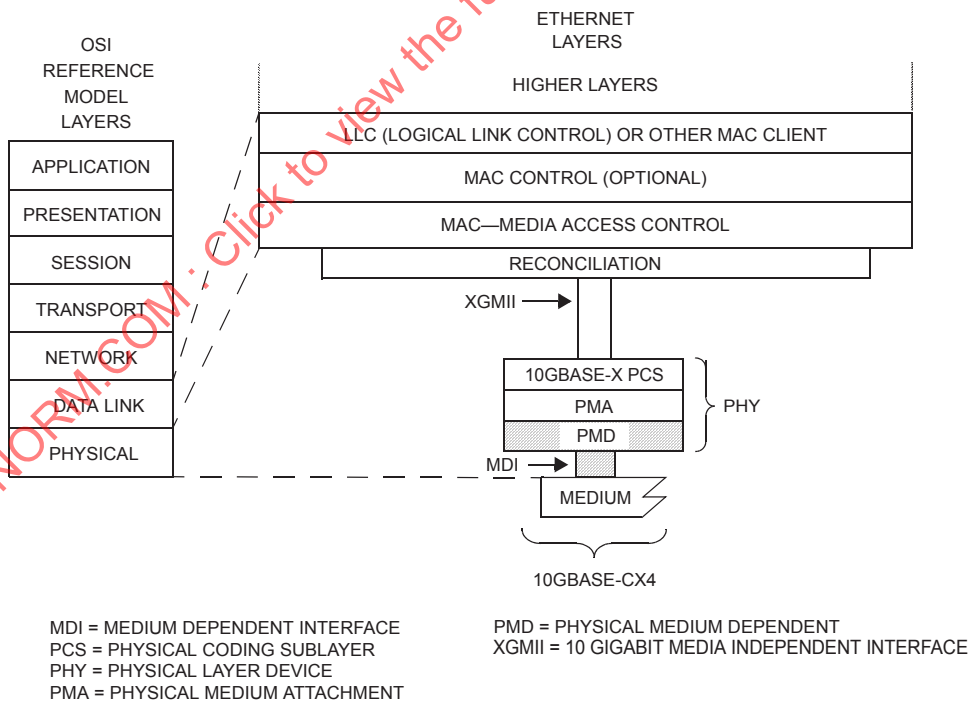

Figure 54–1—10GBASE-CX4 PMD relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

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54.2 Physical Medium Dependent (PMD) service interface

The 10GBASE-CX4 PMD utilizes the PMD service interface defined in 53.1.1. The PMD service interface is summarized as follows:

PMD_UNITDATA.request
PMD_UNITDATA.indication
PMD_SIGNAL.indication

54.3 Delay constraints

Predictable operation of the MAC Control PAUSE operation (Clause 31, Annex 31B) demands that there be an upper bound on the propagation delays through the network. This implies that implementers of MAC, MAC Control, and PHY must consider the delay maxima, and that network planners and administrators consider the delay constraints regarding the cable topology and concatenation of devices. A description of overall system delay constraints and the definitions for bit-times and pause_quanta can be found in 44.3.

The sum of the transmit and the receive delays contributed by the 10GBASE-CX4 PMD shall be no more than 512 BT or 1 pause_quantum.

54.4 PMD MDIO function mapping

The 10GBASE-CX4 PMD uses the same MDIO function mapping as 10GBASE-LX4, as defined in 53.3.

54.5 PMD functional specifications

The 10GBASE-CX4 PMD performs the transmit and receive functions (which convey data between the PMD service interface and the MDI), and provides various management functions if the optional MDIO is implemented.

54.5.1 Link block diagram

A 10GBASE-CX4 link is shown in Figure 54–2. For purposes of system conformance, the PMD sublayer is standardized at the points described in this subclause. The electrical transmit signal is defined at the output end of the mated connector (TP2). Unless specified otherwise, all transmitter measurements and tests defined in 54.6.3 are made at TP2. Unless specified otherwise, all receiver measurements and tests defined in 54.6.4 are made at the input end of the mated connector (TP3). A mated connector pair has been included in both the transmitter and receiver specifications defined in 54.6.3 and 54.6.4. Two mated connector pairs have been included in the cable assembly specifications defined in 54.7.

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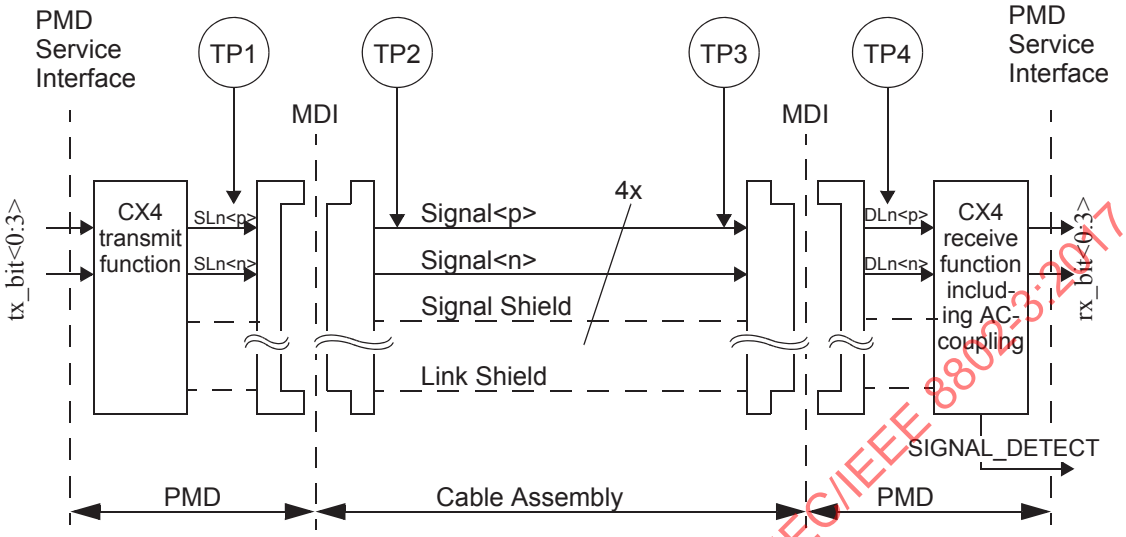

Figure 54–2—10GBASE-CX4 link (half link is shown)

NOTE—SLn<p> and SLn<n> are the positive and negative sides of the transmit differential signal pair and DLn<p> and DLn<n> are the positive and negative sides of the receive differential signal pair for lane n (n = 0, 1, 2, 3).

54.5.2 PMD Transmit function

The PMD Transmit function shall convert the four logical bit streams requested by the PMD service interface message PMD_UNITDATA.request (tx_bit<0:3>) into four separate electrical signal streams. The four electrical signal streams shall then be delivered to the MDI, all according to the transmit electrical specifications in 54.6.3. A positive output voltage of SLn<p> minus SLn<n> (differential voltage) shall correspond to tx_bit = ONE.

The PMD shall convey the bits received from the PMD service interface using the message PMD_UNITDATA.request(tx_bit<0:3>) to the MDI lanes, where (SL0<p>/<n>, SL1<p>/<n>, SL2<p>/<n>, SL3<p>/<n>) = tx_bit<0:3>.

54.5.3 PMD Receive function

The PMD Receive function shall convert the four electrical signal streams from the MDI into four logical bit streams for delivery to the PMD service interface using the message PMD_UNITDATA.indication (rx_bit<0:3>), all according to the receive electrical specifications in 54.6.4. A positive input voltage level in each signal stream of DLn<p> minus DLn<n> (differential voltage) shall correspond to a rx_bit = ONE.

The PMD shall convey the bits received from the MDI lanes to the PMD service interface using the message PMD_UNITDATA.indication(rx_bit<0:3>), where rx_bit<0:3> = (DL0<p>/<n>, DL1<p>/<n>, DL2<p>/<n>, DL3<p>/<n>).

54.5.4 Global PMD signal detect function

The Global_PMD_signal_detect function shall report the state of SIGNAL_DETECT via the PMD service interface. The SIGNAL_DETECT parameter is signaled continuously, while the PMD_SIGNAL.indication message is generated when a change in the value of SIGNAL_DETECT occurs.

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SIGNAL_DETECT is a global indicator of the presence of electrical signals on all four lanes. The PMD receiver is not required to verify whether a compliant 10GBASE-CX4 signal is being received; however, it shall assert SIGNAL_DETECT = OK within 100 µs after the absolute differential peak-to-peak input voltage on each of the four lanes at the MDI has exceeded 175 mV for at least 1 UI (unit interval).

After any such assertion of SIGNAL_DETECT = OK, SIGNAL_DETECT = FAIL shall not be asserted for at least 250 µs. The PMD shall have asserted SIGNAL_DETECT = FAIL when the absolute differential peak-to-peak input voltage on any of the four lanes at the MDI has dropped below 50 mV and has remained below 50 mV for longer than 500 µs.

Table 54–2—SIGNAL_DETECT summary (informative)

Parameter	Value	Units
SIGNAL_DETECT = OK level (maximum differential peak-to-peak amplitude)	175	mV
SIGNAL_DETECT = OK width (minimum)	1	UI
SIGNAL_DETECT = OK assertion time (maximum)	100	µs
SIGNAL_DETECT = FAIL level (minimum differential peak-to-peak amplitude)	50	mV
SIGNAL_DETECT = FAIL de-assertion time maximum minimum	 500 250	 µs µs

NOTE—SIGNAL_DETECT may not activate with a continuous 1010… pattern, such as the high-frequency pattern of 48A.1, but it will be activated by an interpacket gap (IPG).

54.5.5 PMD lane-by-lane signal detect function

When the MDIO is implemented, each PMD_signal_detect_n value, where n represents the lane number in the range 0:3, shall be continuously updated in response to the amplitude of the receive signal on its associated lane, according to the requirements of 54.5.4.

54.5.6 Global PMD transmit disable function

The Global_PMD_transmit_disable function is optional. When implemented, it allows all of the transmitters to be disabled with a single variable.

a) When a Global_PMD_transmit_disable variable is set to ONE, this function shall turn off all of the transmitters such that each transmitter drives a constant level (i.e., no transitions) and does not exceed the maximum differential peak-to-peak output voltage in Table 54–3.
b) If a PMD_fault (54.5.9) is detected, then the PMD may turn off the electrical transmitter in all lanes.
c) Loopback, as defined in 54.5.8, shall not be affected by Global_PMD_transmit_disable.

54.5.7 PMD lane-by-lane transmit disable function

The PMD_transmit_disable_n function is optional. It allows the electrical transmitters in each lane to be selectively disabled.

a) When a PMD_transmit_disable_n variable is set to ONE, this function shall turn off the transmitter associated with that variable such that the corresponding transmitter drives a constant level (i.e., no

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transitions) and does not exceed the maximum differential peak-to-peak output voltage in Table 54–3.

b) If a PMD_fault (54.5.9) is detected, then the PMD may turn off the electrical transmitter in all lanes.
c) Loopback, as defined in 54.5.8, shall not be affected by PMD_transmit_disable_n.

NOTE—Turning off a transmitter can be disruptive to a network.

54.5.8 Loopback mode

Loopback mode shall be provided for the 10GBASE-CX4 PMD by the transmitter and receiver of a device as a test function to the device. When loopback mode is selected, transmission requests passed to the transmitter are shunted directly to the receiver, overriding any signal detected by the receiver on its attached link. The transmitters shall not be disabled when loopback mode is enabled. A device must be explicitly placed in loopback mode because loopback mode is not the normal mode of operation of a device. Loopback applies to all lanes as a group (the lane 0 transmitter is directly connected to the lane 0 receiver, the lane 1 transmitter is directly connected to the lane 1 receiver, etc.). The method of implementing loopback mode is not defined by this standard.

Control of the loopback function is specified in 45.2.1.1.5.

NOTE 1—The signal path that is exercised in the loopback mode is implementation specific, but it is recommended that this signal path encompass as much of the circuitry as is practical. The intention of providing this loopback mode of operation is to permit diagnostic or self-test functions to test the transmit and receive data paths using actual data. Other loopback signal paths may also be enabled independently using loopback controls within other devices or sublayers.

NOTE 2—Placing a network port into loopback mode can be disruptive to a network.

54.5.9 PMD fault function

If the MDIO is implemented, and the PMD has detected a local fault on any of the transmit or receive paths, the PMD shall set PMD_fault to ONE; otherwise, the PMD shall set PMD_fault to ZERO.

54.5.10 PMD transmit fault function

If the MDIO is implemented, and the PMD has detected a local fault on any transmit lane, the PMD shall set the PMD_transmit_fault variable to ONE; otherwise, the PMD shall set PMD_transmit_fault to ZERO.

54.5.11 PMD receive fault function

If the MDIO is implemented, and the PMD has detected a local fault on any receive lane, the PMD shall set the PMD_receive_fault variable to ONE; otherwise, the PMD shall set PMD_receive_fault to ZERO.

54.6 MDI Electrical specifications for 10GBASE-CX4

54.6.1 Signal levels

The 10GBASE-CX4 MDI is a low-swing AC-coupled differential interface. Transmitter to receiver path AC-coupling, as defined in 54.6.4.3, allows for interoperability between components operating from different supply voltages. Low-swing differential signaling provides noise immunity and improved electromagnetic interference (EMI).

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54.6.2 Signal paths

The 10GBASE-CX4 MDI signal paths are point-to-point connections. Each path corresponds to a 10GBASE-CX4 MDI lane and comprises two complementary signals, which form a balanced differential pair. There are four differential paths in each direction for a total of eight pairs, or sixteen connections. The signal paths are intended to operate on twinaxial cable assemblies up to 15 m in length, as described in 54.7.

54.6.3 Transmitter characteristics

Transmitter characteristics shall meet specifications at TP2, unless otherwise noted. The specifications are summarized in Table 54–3 and detailed in 54.6.3.1 through 54.6.3.9.

Table 54–3—Transmitter characteristics' summary (informative)

Parameter	Subclause reference	Value	Units
Signaling speed, per lane	54.6.3.3	3.125 ± 100 ppm	GBd
Unit interval nominal	54.6.3.3	320	ps
Differential peak-to-peak output voltage maximum minimum	54.6.3.4	 1200 800	 mV mV
Differential peak-to-peak output voltage difference (maximum)	54.6.3.4	150	mV
Common-mode voltage limits maximum minimum	54.6.3.4	 1.9 –0.4	 V V
Differential output return loss minimum	54.6.3.5	[See Equation (54–1) and Equation (54–2)]	dB
Differential output template	54.6.3.6	(See Figure 54–6 and Table 54–4)	V
Transition time maximum minimum	54.6.3.7	 130 60	 ps ps
Output jitter (peak-to-peak) Random jitter Deterministic jitter[a] Total jitter	54.6.3.8	 0.27 0.17 0.35	 UI UI UI

[a]Deterministic jitter is already incorporated into the differential output template.

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54.6.3.1 Test fixtures

The test fixture of Figure 54–3, or its functional equivalent, is required for measuring the transmitter specifications described in 54.6.3.

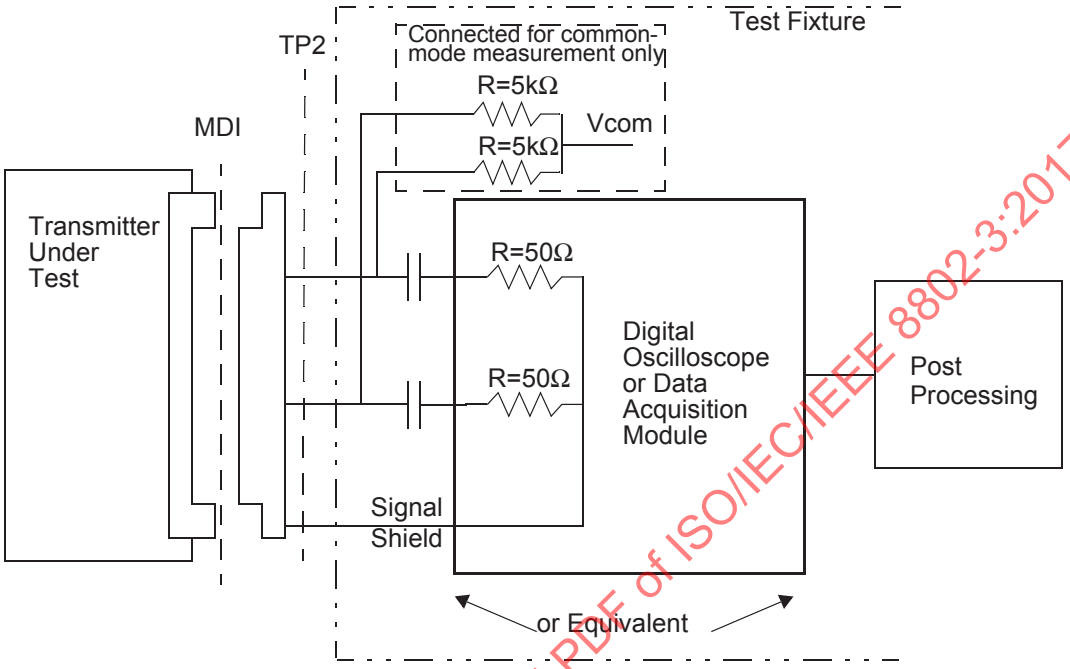

Figure 54–3—Transmit test fixture

54.6.3.2 Test-fixture impedance

The differential load impedance applied to the transmitter output by the test fixture depicted in Figure 54–3 shall have a return loss greater than 20 dB from 100 MHz to 2000 MHz. The reference impedance for differential return loss measurements shall be 100 Ω.

54.6.3.3 Signaling speed range

The 10GBASE-CX4 MDI signaling speed shall be 3.125 GBd ±100 ppm. The corresponding unit interval is nominally 320 ps.

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54.6.3.4 Output amplitude

While transmitting the test pattern specified in 48A.2:

a) The transmitter maximum differential peak-to-peak output voltage shall be less than 1200 mV.
b) The minimum differential peak-to-peak output voltage shall be greater than 800 mV.
c) The maximum difference between any two lanes' differential peak-to-peak output voltage shall be less than or equal to 150 mV.

See Figure 54–4 for an illustration of the definition of differential peak-to-peak output voltage.

DC-referenced logic levels are not defined since the receiver is AC-coupled. The common-mode voltage of SLn<p> and SLn<n> shall be between –0.4 V and 1.9 V with respect to Signal Shield as measured at Vcom in Figure 54–3.

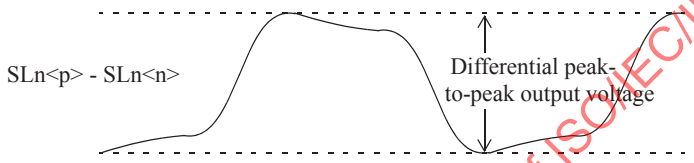

Figure 54–4—Transmitter differential peak-to-peak output voltage definition

NOTE—SLn<p> and SLn<n> are the positive and negative sides of the differential signal pair for Lane n (n = 0,1,2,3).

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54.6.3.5 Output return loss

For frequencies from 100 MHz to 2000 MHz, the differential return loss, in dB with f in MHz, of the transmitter shall meet Equation (54–1) and Equation (54–2). This output impedance requirement applies to all valid output levels. The reference impedance for differential return loss measurements shall be 100 Ω.

$$Return\ Loss\ (f) \geq 10 \tag{54–1}$$

for 100 MHz ≤ f < 625 MHz and

$$Return\ Loss\ (f) \geq 10 - 10 \times \log\left(\frac{f}{625}\right) \tag{54–2}$$

for 625 MHz ≤ f ≤ 2000 MHz.

The minimum transmit differential output return loss is shown in Figure 54–5.

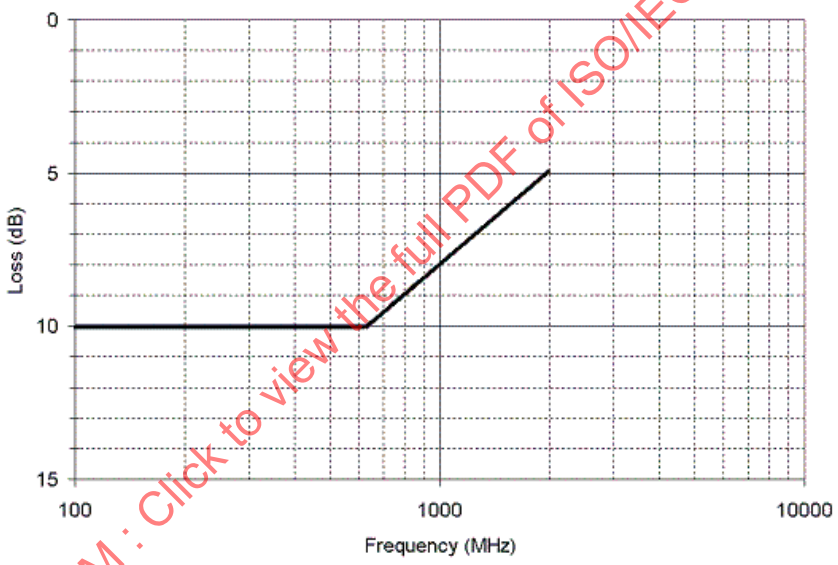

Figure 54–5—Minimum transmit differential output return loss (informative)

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54.6.3.6 Differential output template

The transmitter differential output signal is defined at TP2, as shown in Figure 54–2. The transmitter shall provide equalization such that the output waveform falls within the template shown in Figure 54–6 for the test pattern specified in 48A.2, with all other transmitters active. Voltage and time coordinates for inflection points on Figure 54–6 are given in Table 54–4. The signals on each pair at TP2 shall meet the transmit template specifications when connected to the transmitter test fixture shown in Figure 54–3, with all other transmitters active. The waveform under test shall be normalized by using the following procedure:

1) Align the output waveform under test, to achieve the best fit along the horizontal time axis.
2) Calculate the +1 low frequency level as V_{lowp} = average of any 2 successive unit intervals (2UI) between 2.5 UI and 5.5 UI.
3) Calculate the 0 low frequency level as V_{lowm} = average of any 2 successive unit intervals (2UI) between 7.5 UI and 10.5 UI.
4) Calculate the vertical offset to be subtracted from the waveform as $V_{off} = (V_{lowp} + V_{lowm}) / 2$.
5) Calculate the vertical normalization factor for the waveform as $V_{norm} = (V_{lowp} - V_{lowm}) / 2$.
6) Calculate the normalized waveform as Normalized_Waveform=(Original_Waveform – V_{off}) × (0.69/V_{norm}).
7) Align the Normalized_Waveform under test, to achieve the best fit along the horizontal time axis.

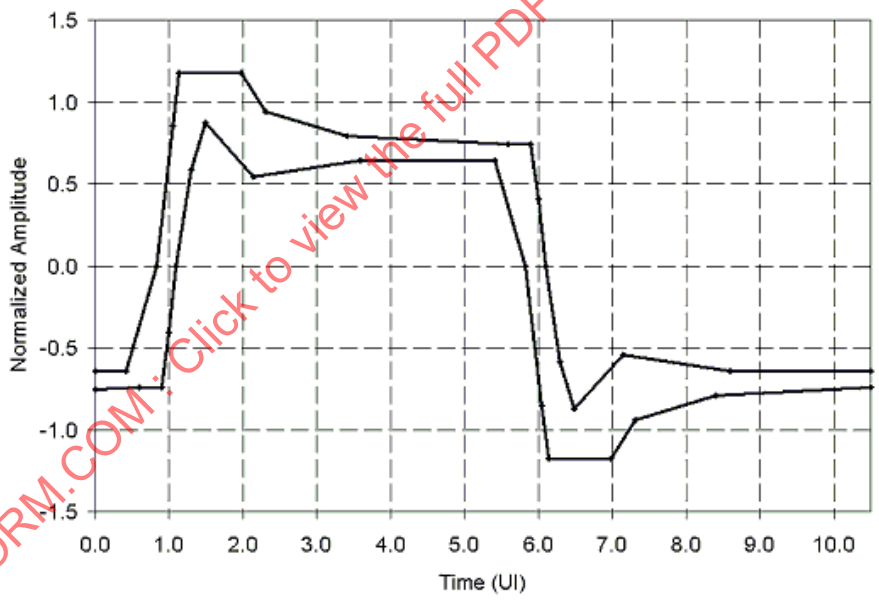

Figure 54–6—Normalized transmit template

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Table 54–4—Normalized transmit time domain template

Upper limit				Lower limit			
Time (UI)	Amplitude	Time (UI)	Amplitude	Time (UI)	Amplitude	Time (UI)	Amplitude
0.000	–0.640	5.897	0.740	0.000	–0.754	5.409	0.640
0.409	–0.640	5.997	0.406	0.591	–0.740	5.828	0.000
0.828	0.000	6.094	0.000	0.897	–0.740	6.050	–0.856
1.050	0.856	6.294	–0.586	0.997	–0.406	6.134	–1.175
1.134	1.175	6.491	–0.870	1.094	0.000	6.975	–1.175
1.975	1.175	7.141	–0.546	1.294	0.586	7.309	–0.940
2.309	0.940	8.591	–0.640	1.491	0.870	8.500	–0.790
3.409	0.790	10.500	–0.640	2.141	0.546	10.500	–0.742
5.591	0.740	—	—	3.591	0.640	—	—

54.6.3.7 Transition time

The rising-edge transition time shall be between 60 ps and 130 ps as measured at the 20% and 80% levels of the peak-to-peak differential value of the waveform using the high-frequency test pattern of 48A.1. The falling edge transition time shall be between 60 ps and 130 ps as measured at the 80% and 20% levels of the peak-to-peak differential value of the waveform using the high-frequency test pattern of 48A.1.

54.6.3.8 Transmit jitter

The transmitter shall satisfy the jitter requirements of 54.6.3.9 with a maximum total jitter of 0.350 UI peak-to-peak, a maximum deterministic component of 0.170 UI peak-to-peak and a maximum random component of 0.270 UI peak-to-peak. Jitter specifications include all but 10^{-12} of the jitter population. Transmit jitter test requirements are specified in 54.6.3.9.

54.6.3.9 Transmit jitter test requirements

Transmit jitter is defined with respect to a test procedure resulting in a BER bathtub curve such as that described in Annex 48B. For the purpose of jitter measurement, the effect of a single-pole, high-pass filter with a 3 dB point at 1.875 MHz is applied to the jitter. The data pattern for jitter measurements shall be the CJPAT pattern defined in 48A.5. All four lanes of the 10GBASE-CX4 transceiver are active in both directions, and opposite ends of the link use asynchronous clocks. Crossing times are defined with respect to the mid-point (0 V) of the AC-coupled differential signal.

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54.6.4 Receiver characteristics

Receiver characteristics are summarized in Table 54–5 and detailed in 54.6.4.1 through 54.6.4.5.

Table 54–5—Receiver characteristics' summary (informative)

Parameter	Subclause reference	Value	Units
Bit error ratio	54.6.4.1	10^{-12}	
Signaling speed, per lane	54.6.4.2	3.125 ± 100 ppm	GBd
Unit interval (UI) nominal	54.6.4.2	320	ps
Receiver coupling	54.6.4.3	AC	—
Differential input peak-to-peak amplitude (maximum)	54.6.4.4	1200	mV
Return loss[a] differential (minimum)	54.6.4.5	[See Equation (54–1) and Equation (54–2)]	dB

[a]Relative to 100 Ω differential.

54.6.4.1 Bit error ratio

The receiver shall operate with a BER of better than 10^{-12} when receiving a compliant transmit signal, as defined in 54.6.3, through a compliant cable assembly as defined in 54.7.

NOTE—The BER should be met with a worst-case insertion loss, long cable, as well as a low-loss, short cable. The low-loss cable may be a more stringent requirement on the system due to higher reflections and crosstalk than with long cables.

54.6.4.2 Signaling speed range

A 10GBASE-CX4 receiver shall comply with the requirements of 54.6.4.1 for any signaling speed in the range 3.125 GBd ± 100 ppm. The corresponding unit interval is nominally 320 ps.

54.6.4.3 AC-coupling

The 10GBASE-CX4 receiver shall be AC-coupled to the cable assembly to allow for maximum interoperability between various 10 Gb/s components. AC-coupling is considered to be part of the receiver for the purposes of this standard unless explicitly stated otherwise. It should be noted that there may be various methods for AC-coupling in actual implementations.

NOTE—It is recommended that the maximum value of the coupling capacitors be limited to 470 pF. This will limit the inrush currents to the receiver that could damage the receiver circuits when repeatedly connected to transmit modules with a higher voltage level.

54.6.4.4 Input signal amplitude

10GBASE-CX4 receivers shall accept differential input signal peak-to-peak amplitudes produced by compliant transmitters connected without attenuation to the receiver, and still meet the BER requirement specified in 54.6.4.1. Note that this may be larger than the 1200 mV differential maximum of 54.6.3.4 due to the actual transmitter output and receiver input impedances. The input impedance of a receiver can cause the minimum signal into a receiver to differ from that measured when the receiver is replaced with a 100 Ω test

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load. Since the 10GBASE-CX4 receiver is AC-coupled, the absolute voltage levels with respect to the receiver ground are dependent on the receiver implementation.

54.6.4.5 Input return loss

For frequencies from 100 MHz to 2000 MHz, the differential return loss (in dB with *f* in MHz) of the receiver shall be greater than or equal to Equation (54–1) and Equation (54–2). This input impedance requirement applies to all valid input levels. The reference impedance for differential return loss measurements is 100 Ω.

54.7 Cable assembly characteristics

The 10GBASE-CX4 cable assembly contains insulated conductors terminated in a connector at each end for use as a link segment between MDIs. This cable assembly is primarily intended as a point-to-point interface of up to 15 m between network ports using controlled impedance cables. All cable assembly measurements are to be made between TP1 and TP4 as shown in Figure 54–2. These cable assembly specifications are based upon twinaxial cable characteristics, but other cable types are acceptable if the specifications are met.

Table 54–6—Cable assembly differential characteristics' summary (informative)

Description	Reference	Value	Unit
Maximum Insertion loss at 1.5625 GHz	54.7.2 and 54.7.3	16	dB
Minimum Return loss at 1.5625 GHz	54.7.3	12.0	dB
Minimum NEXT loss at 1.5625 GHz	54.7.4.1	31.8	dB
Minimum MDNEXT loss at 1.5625 GHz	54.7.4.2	29.8	dB
Minimum ELFEXT loss at 1.5625 GHz	54.7.5.1	23.3	dB
Minimum MDELFEXT loss at 1.5625 GHz	54.7.5.2	21.1	dB

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54.7.1 Characteristic impedance and reference impedance

The nominal differential characteristic impedance of the cable assembly is 100 Ω. The differential reference impedance for cable assembly specifications shall be 100 Ω.

54.7.2 Cable assembly insertion loss

The insertion loss (in dB with f in MHz) of each pair of the 10GBASE-CX4 cable assembly shall be:

$$Insertion\ Loss\ (f) \le (0.2629 \times \sqrt{f}) + (0.0034 \times f) + \left(\frac{12.76}{\sqrt{f}}\right) \quad (54\text{–}3)$$

for all frequencies from 100 MHz to 2000 MHz. This includes the attenuation of the differential cabling pairs and the assembly connectors.

The maximum cable assembly insertion loss is shown in Figure 54–7.

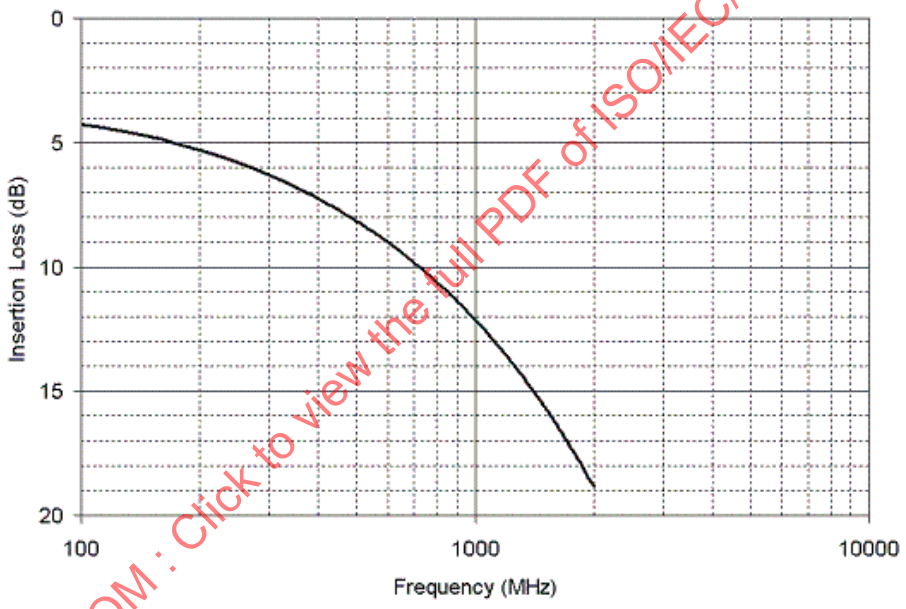

Figure 54–7—Maximum cable assembly insertion loss (informative)

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54.7.3 Cable assembly return loss

The return loss (in dB with *f* in MHz) of each pair of the 10GBASE-CX4 cable assembly shall be:

$$Return\ Loss(f) \geq 22.35 - 17.19 \times \log\left(\frac{f}{100}\right) \quad (54\text{–}4)$$

for 100 MHz ≤ *f* < 400 MHz.

$$Return\ Loss(f) \geq 12 \quad (54\text{–}5)$$

for 400 MHz ≤ *f* ≤ 2000 MHz.

The minimum cable assembly return loss is shown in Figure 54–8.

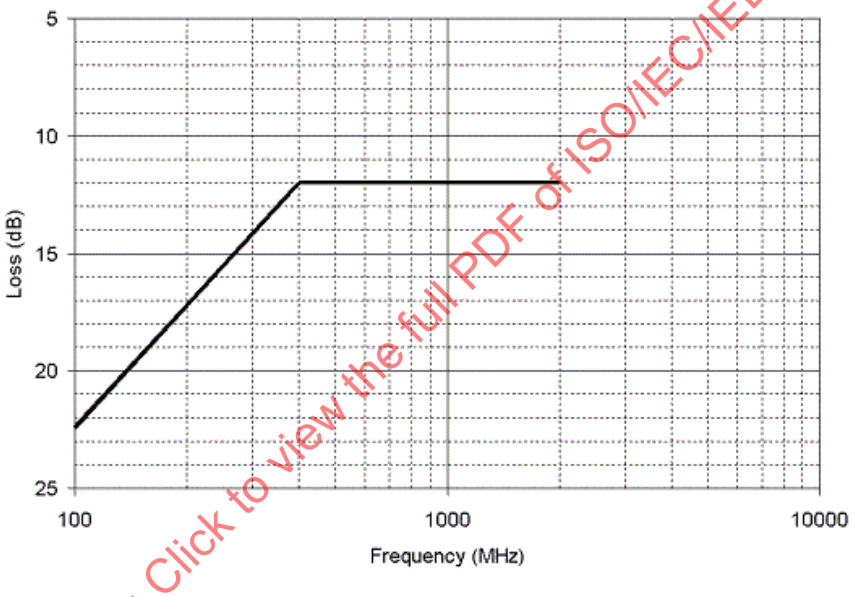

Figure 54–8—Minimum cable assembly return loss (informative)

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54.7.4 Near-End Crosstalk (NEXT)

54.7.4.1 Differential Near-End Crosstalk

In order to limit the crosstalk at the near end of a link segment, the differential pair-to-pair Near-End Crosstalk (NEXT) loss between any of the four transmit lanes and any of the four receive lanes is specified to meet the BER objective specified in 54.6.4.1. The NEXT loss between any transmit and receive lane of a link segment (in dB with *f* in MHz) shall be at least:

$$NEXT(f) \geq 30 - 17 \times \log\left(\frac{f}{2000}\right) \quad (54\text{–}6)$$

for all frequencies from 100 MHz to 2000 MHz.

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54.7.4.2 Multiple Disturber Near-End Crosstalk (MDNEXT)

Since four transmit and four receive lanes are used to transfer data between PMDs, the NEXT that is coupled into a receive lane will be from the four transmit lanes. To ensure the total NEXT coupled into a receive lane is limited, multiple disturber NEXT loss is specified as the power sum of the individual NEXT losses.

The Power Sum loss between a receive lane and the four transmit lanes (in dB with f in MHz) shall be at least:

$$MDNEXT(f) \geq 28 - 17 \times \log\left(\frac{f}{2000}\right) \quad (54\text{–}7)$$

for all frequencies from 100 MHz to 2000 MHz.

MDNEXT loss is determined by summing the power of the four individual pair-to-pair differential NEXT loss values over the frequency range 100 MHz to 2000 MHz as follows:

$$MDNEXT_{\text{loss}}(f) = -10 \times \log\left(\sum_{i=0}^{i=3} 10^{-NL(f)_i/10}\right) \quad (54\text{–}8)$$

where

$MDNEXT_{\text{loss}}(f)$ is the MDNEXT loss at frequency f,
$NL(f)_i$ is the power of the NEXT loss at frequency f of pair combination i, in dB,
f is frequency ranging from 100 MHz to 2000 MHz,
i is the 0, 1, 2, or 3 (pair-to-pair combination).

The minimum cable assembly NEXT / MDNEXT loss is shown in Figure 54–9.

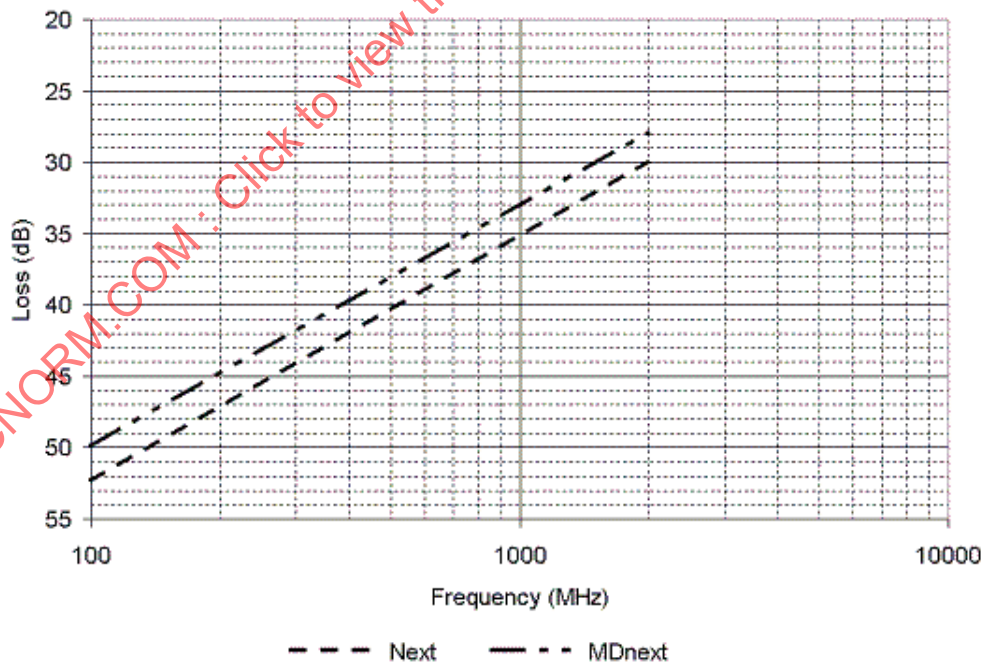

Figure 54–9—Minimum cable assembly NEXT / MDNEXT loss (informative)

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54.7.5 Far-End Crosstalk (FEXT)

54.7.5.1 Equal Level Far-End Crosstalk (ELFEXT) loss

Equal Level Far-End Crosstalk (ELFEXT) loss is specified in order to limit the crosstalk at the far end of each link segment and meet the BER objective specified in 54.6.4.1. Far-End Crosstalk (FEXT) is crosstalk that appears at the far end of a lane (disturbed lane), which is coupled from another lane (disturbing lane) with the noise source (transmitters) at the near end. FEXT loss is defined as

$$FEXT_Loss(f) = 20 \times \log(Vpds(f)/Vpcn(f))$$

and ELFEXT Loss is defined as

$$ELFEXT_Loss(f) = 20 \times \log(Vpds(f)/Vpcn(f)) - SLS_Loss(f)$$

where

FEXT_Loss(*f*)is the FEXT loss at frequency *f*,
ELFEXT_Loss(*f*)is the ELFEXT loss at frequency *f*,
*V*pds is the peak voltage of the disturbing signal (near-end transmitter),
*V*pcn is the peak crosstalk noise at the far end of the disturbed lane,
SLS_Loss(*f*)is the insertion loss of the disturbed lane in dB,
f is frequency ranging from 100 MHz to 2000 MHz.

The worst pair ELFEXT loss between any two lanes shall be at least:

$$ELFEXT(f) \geq 21 - 20 \times \log\left(\frac{f}{2000}\right) \quad (54\text{–}9)$$

for all frequencies from 100 MHz to 2000 MHz.

54.7.5.2 Multiple Disturber Equal Level Far-End Crosstalk (MDELFEXT) loss

Since four lanes are used to transfer data between PMDs, the FEXT that is coupled into a data carrying lane will be from the three other lanes in the same direction. To ensure the total FEXT coupled into a lane is limited, multiple disturber ELFEXT loss is specified as the power sum of the individual ELFEXT losses.

The Power Sum loss (labeled as MDELFEXT) between a lane and the three adjacent disturbers shall be at least:

$$MDELFEXT(f) \geq 19 - 20 \times \log\left(\frac{f}{2000}\right) \quad (54\text{–}10)$$

for all frequencies from 100 MHz to 2000 MHz.

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MDELFEXT loss is determined by summing the power of the three individual pair-to-pair differential ELFEXT loss values over the frequency range 100 MHz to 2000 MHz as follows:

$$MDELFEXT_{\text{loss}}(f) = -10 \times \log\left(\sum_{i=0}^{i=3} 10^{-NL(f)_i/10}\right) \quad (54\text{–}11)$$

where

$MDELFEXT_{\text{loss}}(f)$is the MDELFEXT loss at frequency f,
$NL(f)_i$ is the power of ELFEXT loss at frequency f of pair combination i, in dB,
f is frequency ranging from 100 MHz to 2000 MHz,
i is the 1, 2, or 3 (pair-to-pair combination).

The minimum cable assembly ELFEXT / MDELFEXT loss is shown in Figure 54–10.

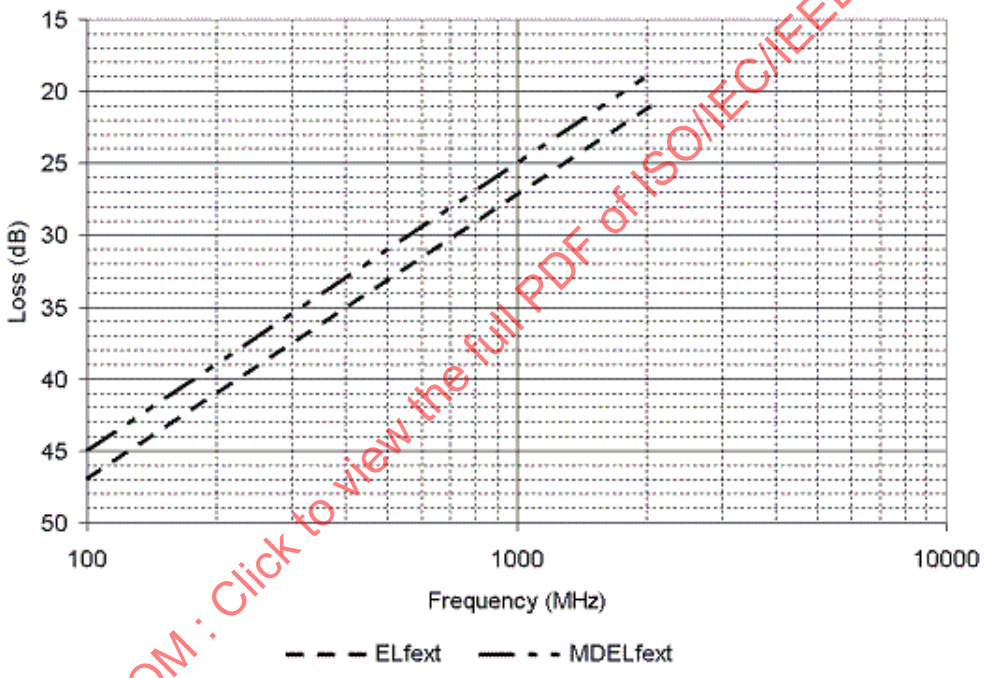

Figure 54–10—Minimum cable assembly ELFEXT / MDELFEXT loss (informative)

54.7.6 Shielding

The cable assembly shall provide Class 2 or better shielding in accordance with IEC 61196-1.

54.7.7 Crossover function

The cable assembly shall be wired in a crossover fashion as shown in Figure 54–11, with each of the four pairs being attached to the transmitter contacts at one end and the receiver contacts at the other end.

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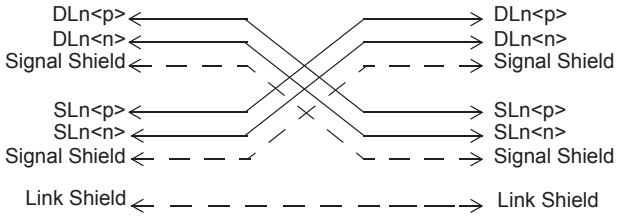

Figure 54–11—Cable wiring

NOTE—SLn<p> and SLn<n> are the positive and negative sides of the differential signal pair for Lane n (n = 0,1,2,3)

54.8 MDI specification

This subclause defines the Media Dependent Interface (MDI). The 10GBASE-CX4 PMD, as per 54.6, is coupled to the cable assembly, as per 54.7, by the MDI.

54.8.1 MDI connectors

The connector for each end of the cable assembly shall be the latch-type plug with the mechanical mating interface defined by IEC 61076-3-113 and illustrated in Figure 54–12. The MDI connector shall be the latch-type receptacle with the mechanical mating interface defined by IEC 61076-3-113 and illustrated in Figure 54–13. These connectors have a pinout matching that in Table 54–7, and electrical performance consistent with the signal quality and electrical requirements of 54.6 and 54.7.

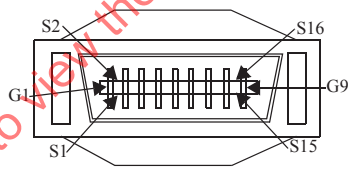

Figure 54–12—Example cable assembly plug (informative)

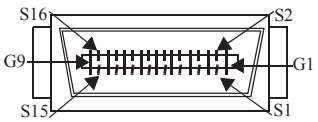

Figure 54–13—Example MDI board receptacle (informative)

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54.8.2 Connector pin assignments

The MDI connector of the PMD comprises 16 signal connections, eight signal shield connections, and one link shield connection. The 10GBASE-CX4 PMD MDI connector pin assignments shall be as defined in Table 54–7.

Table 54–7—CX4 lane to MDI connector pin mapping

Rx lane	MDI Connector pin	Tx lane	MDI Connector pin
DL0<p>	S1	SL0<p>	S16
DL0<n>	S2	SL0<n>	S15
DL1<p>	S3	SL1<p>	S14
DL1<n>	S4	SL1<n>	S13
DL2<p>	S5	SL2<p>	S12
DL2<n>	S6	SL2<n>	S11
DL3<p>	S7	SL3<p>	S10
DL3<n>	S8	SL3<n>	S9
Signal Shield	G1	Signal Shield	G5
Signal Shield	G2	Signal Shield	G6
Signal Shield	G3	Signal Shield	G7
Signal Shield	G4	Signal Shield	G8
—		Link Shield	G9

54.9 Environmental specifications

All equipment subject to this clause shall conform to the applicable requirements of 14.7.

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54.10 Protocol implementation conformance statement (PICS) proforma for Clause 54, Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-CX4[18]

54.10.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 54 Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-CX4, shall complete the following protocol implementation conformance statement (PICS) proforma. A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

54.10.2 Identification

54.10.2.1 Implementation identification

Supplier[1]	
Contact point for inquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1,3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

54.10.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 54., Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-CX4
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	

Date of Statement	

[18]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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54.10.3 PICS proforma tables for 10GBASE-CX4 and baseband medium

Item	Feature	Subclause	Value/Comment	Status	Support
CC1	Environmental specifications	54.9		M	Yes [ ]

54.10.4 Major capabilities/options

Item[a]	Feature	Subclause	Value/Comment	Status	Support
XGE	XGMII interface	46, 54.1	Interface is supported	O	Yes [ ] No [ ]
XGXS	XGXS and XAUI	47, 54.1		O	Yes [ ] No [ ]
PCS	Support of 10GBASE-X PCS / PMA	48, 54.1		O	Yes [ ] No [ ]
DC	Delay constraints	54.3	Delay no more than 512 BT or 1 pause_quantum	M	Yes [ ]
*MD	MDIO capability	54.4	Registers and interface supported	O	Yes [ ] No [ ]
*CBL	Cable assembly	54.7	Items marked with CBL include cable assembly specifications not applicable to a PHY manufacturer	O	Yes [ ] No [ ]

[a]A "*" preceding an "Item" identifier indicates there are other PICS that depend on whether or not this item is supported.

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54.10.4.1 PMD Functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
PF1	Transmit function	54.5.2	Convert the four logical signals requested by PMD_UNIT-DATA.request (tx_bit<0:3>) to 4 electrical signals	M	Yes [ ]
PF2	Delivery to the MDI	54.5.2	Supplies four electrical signal streams for delivery to the MDI	M	Yes [ ]
PF3	Mapping between logical signal and electrical signal for transmit-ter	54.5.2	A positive differential voltage is a one	M	Yes [ ]
PF4	Transmit Signal order	54.5.2	PMD_UNITDATA.request (tx_bit<0:3>) = (SL0<p>/<n>, SL1<p>/<n>, SL2<p>/<n>, SL3<p>/<n>)	M	Yes [ ]
PF5	Receive function	54.5.3	Convert the four electrical signals received from the MDI to 4 logical signals PMD_UNITDATA.indica-tion(rx_bit<0:3>) per 54.6.4	M	Yes [ ]
PF6	Mapping between electrical sig-nal and logical signal for receiver	54.5.3	A positive differential voltage is a one	M	Yes [ ]
PF7	Receive Signal order	54.5.3	(DL0<p>/<n>, DL1<p>/<n>, DL2<p>/<n>, DL3<p>/<n>) = PMD_UNITDATA.indication (rx_bit<0:3>)	M	Yes [ ]
PF8	Global PMD Signal Detect func-tion	54.5.4	Report state via PMD_SIGNAL.indi-cation (SIGNAL_DETECT)	M	Yes [ ]
PF9	Global PMD Signal Detect OK threshold	54.5.4	SIGNAL_DETECT = OK for signal value ≥ 175 mV for at least 1 UI on each of the four lanes	M	Yes [ ]
PF10	Global PMD Signal Detect FAIL threshold, minimum	54.5.4	SIGNAL_DETECT = FAIL not asserted for signal level < 50 mV for < 250 µs on all four lanes	M	Yes [ ]
PF11	Global PMD Signal Detect FAIL threshold, maximum	54.5.4	SIGNAL_DETECT = FAIL asserted for signal level < 50 mV for > 500 µs on any of the four lanes	M	Yes [ ]
PF12	Global_PMD_transmit_disable	54.5.6	Disables all transmitters by forcing a constant output state	O	Yes [ ] No [ ]
PF13	PMD_fault disables transmitter	54.5.6	Disables all transmitters by forcing a constant output state when a fault is detected	O	Yes [ ] No [ ]
PF14	Effect on loopback of Global_PMD_transmit_disable	54.5.6	Global_PMD_transmit_disable does not affect loopback function	M	Yes [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
PF15	PMD_transmit_disable_n	54.5.7	Disables transmitter n (n=0:3) by forcing a constant output state	O	Yes [ ]
PF16	PMD_fault disables transmitter n	54.5.7	Disables transmitter n (n=0:3) by forcing a constant output state when a fault is detected	O	Yes [ ] No [ ]
PF17	Effect on loopback of PMD_transmit_disable_n	54.5.7	PMD_transmit_disable_n does not affect loopback function	M	Yes [ ]
PF18	Loop Back	54.5.8	Loopback function provided	M	Yes [ ]
PF19	Transmitters on during loopback	54.5.8	Loopback function does not disable the transmitters	M	Yes [ ]

54.10.4.2 Management functions

Item	Feature	Subclause	Value/Comment	Status	Support
MF1	Lane-by-Lane Signal Detect function	54.5.5	Sets PMD_signal_detect_n values on a lane-by-lane basis per requirements of 54.5.4	MD:M	Yes [ ] N/A [ ]
MF2	PMD_fault function	54.5.9	Sets PMD_fault to a logical 1 if any local fault is detected otherwise set to 0	MD:M	Yes [ ] N/A [ ]
MF3	PMD_transmit_fault function	54.5.10	Sets PMD_transmit_fault to a logical 1 if a local fault is detected on the transmit path otherwise set to 0	MD:M	Yes [ ] N/A [ ]
MF4	PMD_receive_fault function	54.5.11	Sets PMD_receive_fault to a logical 1 if a local fault is detected on the receive path otherwise set to 0	MD:M	Yes [ ] N/A [ ]

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54.10.4.3 Transmitter specifications

Item	Feature	Subclause	Value/Comment	Status	Support
DS1	Meets specifications at TP2	54.6.3		M	Yes [ ]
DS2	Test load	54.6.3.2	100 Ω differential load with return loss > 20 dB	M	Yes [ ]
DS3	Signaling speed	54.6.3.3	3.125 GBd ± 100 ppm	M	Yes [ ]
DS4	Maximum transmitter differential peak-to-peak output amplitude	54.6.3.4	Less than 1200 mV	M	Yes [ ]
DS5	Minimum transmitter differential peak-to-peak output amplitude	54.6.3.4	Greater than 800 mV	M	Yes [ ]
DS6	Maximum transmitter differential peak-to-peak amplitude difference	54.6.3.4	Less than 150 mV	M	Yes [ ]
DS7	Common-mode output voltage	54.6.3.4	Between –0.4 V and +1.9 V	M	Yes [ ]
DS8	Transmitter output return loss	54.6.3.5	Per Equation (54–1) and Equation (54–2)	M	Yes [ ]
DS9	Transmitter output return loss reference impedance	54.6.3.5	100 Ω	M	Yes [ ]
DS10	Transmitter output template test pattern	54.6.3.6	Per 48A.2	M	Yes [ ]
DS11	Transmitter output template compliance	54.6.3.6	Met while connected to test fixture shown in Figure 54–3, with all outputs active	M	Yes [ ]
DS12	Transmitter output normalization	54.6.3.6	Per process defined in 54.6.3.6	M	Yes [ ]
DS13	Transmitter output template	54.6.3.6	Lies within template of Figure 54–6 and Table 54–4	M	Yes [ ]
DS14	Rising edge transition time	54.6.3.7	Between 60 ps and 130 ps as measured per 54.6.3.7	M	Yes [ ]
DS15	Falling edge transition time	54.6.3.7	Between 60 ps and 130 ps as measured per 54.6.3.7	M	Yes [ ]
DS16	Jitter requirements	54.6.3.8	Meet BER bathtub curve, See Annex 48B	M	Yes [ ]
DS17	Transmit jitter, peak-to-peak	54.6.3.8	Meet BER bathtub curve, See Annex 48B, with Total jitter < 0.35 UI Deterministic jitter < 0.17 UI Random jitter < 0.27 UI	M	Yes [ ]
DS18	Jitter test patterns	54.6.3.9	As per Annex 48A.5	M	Yes [ ]

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54.10.4.4 Receiver specifications

Item	Feature	Subclause	Value/Comment	Status	Support
RS1	Bit Error Ratio	54.6.4.1	BER of better than 10^{-12}	M	Yes [ ]
RS2	Signaling speed	54.6.4.2	3.125 GBd ± 100 ppm	M	Yes [ ]
RS3	AC-coupling	54.6.4.3	—	M	Yes [ ]
RS4	Input peak-to-peak amplitude tolerance	54.6.4.4	Accepts signals compliant with 54.6.3, may be larger than 1200 mV	M	Yes [ ]
RS5	Receiver input return loss	54.6.4.5	Per Equation (54–1) and Equation (54–2)	M	Yes [ ]

54.10.4.5 Cable assembly specifications

Item	Feature	Subclause	Value/Comment	Status	Support
CA1	Differential reference impedance	54.7.1	100 Ω	CBL:M	Yes [ ] N/A [ ]
CA2	Insertion loss	54.7.2	Per Equation (54–3)	CBL:M	Yes [ ] N/A [ ]
CA3	Return loss	54.7.2	Per Equation (54–4), Equation (54–5), and Equation (54–6)	CBL:M	Yes [ ] N/A [ ]
CA4	NEXT	54.7.4.1	Per Equation (54–6)	CBL:M	Yes [ ] N/A [ ]
CA5	MDNEXT	54.7.4.2	Per Equation (54–7)	CBL:M	Yes [ ] N/A [ ]
CA6	ELFEXT	54.7.5.1	Per Equation (54–9)	CBL:M	Yes [ ] N/A [ ]
CA7	MDELFEXT	54.7.5.2	Per Equation (54–10)	CBL:M	Yes [ ] N/A [ ]
CA8	Shielding	54.7.6	Class 2 or better in accordance with IEC 61196-1	CBL:M	Yes [ ] N/A [ ]
CA9	Crossover function	54.7.7	Per Figure 54–11	CBL:M	Yes [ ] N/A [ ]
CA10	Cable assembly connector type	54.8.1	IEC 61076-3-113 latch-type plug	CBL:M	Yes [ ] N/A [ ]
CA11	Pin assignments	54.8.2	Per Table 54–7	CBL:M	Yes [ ] N/A [ ]

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54.10.4.6 MDI connector specifications

Item	Feature	Subclause	Value/Comment	Status	Support
MDC1	MDI connector type	54.8.1	IEC 61076-3-113 latch-type receptacle	M	Yes [ ]

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55. Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer and baseband medium, type 10GBASE-T

55.1 Overview

The 10GBASE-T PHY is one of the 10 Gigabit Ethernet family of high-speed network specifications. The 10GBASE-T Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA), and baseband medium specifications are intended for users who want 10 Gb/s performance over balanced twisted-pair structured cabling systems. 10GBASE-T signaling requires four pairs of balanced cabling, as specified in ISO/IEC 11801:2002 with appropriate augmentation as specified in 55.7. It is recommended that the guidelines in TIA TSB-155-A, ISO/IEC TR 24750, ANSI/TIA-568-C.2, and ISO/IEC 11801:2002/ Amendment 1 be considered before the installation of 10GBASE-T equipment for any cabling system.

This clause defines the type 10GBASE-T PCS, type 10GBASE-T PMA sublayer, and type 10GBASE-T Medium Dependent Interface (MDI). Together, the PCS and the PMA sublayer define a 10GBASE-T Physical Layer (PHY). Functional, electrical, and mechanical specifications for the type 10GBASE-T PCS, PMA, and MDI are provided in this document. This clause also specifies the baseband medium used with 10GBASE-T. Management is specified in Clause 30.

This clause also specifies 10GBASE-T Low Power Idle (LPI) as part of Energy-Efficient Ethernet (EEE). This allows the PHY to enter a low power mode of operation during periods of low link utilization as described in Clause 78. 10GBASE-T PHYs may optionally support a fast retrain mechanism.

55.1.1 Objectives

The objectives of 10GBASE-T are as follows:

a) Support full duplex operation only
b) Support star-wired local area networks using point-to-point links and structured cabling topologies
c) Support a speed of 10 Gb/s at the MAC/PLS service interface
d) Support copper medium from ISO/IEC 11801:2002, with appropriate augmentation as specified in 55.7
e) Support operation over 4-connector structured 4-pair, twisted copper cabling for all supported distances and Classes
f) Define a single 10 Gb/s PHY that would support links of up to 100 m on 4-pair balanced copper cabling as specified in 55.7
g) Preserve the IEEE 802.3/Ethernet frame format at the MAC client service interface
h) Preserve minimum and maximum frame size of the current IEEE 802.3 standard
i) Support Auto-Negotiation (Clause 28)
j) Meet CISPR/FCC Class A EMC requirements
k) Support a BER of less than or equal to 10^{-12} on all supported distances and Classes
l) Support a EEE capability as part of Energy-Efficient Ethernet (Clause 78)

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55.1.2 Relationship of 10GBASE-T to other standards

Relations between the 10GBASE-T PHY, the ISO Open Systems Interconnection (OSI) reference model, and the IEEE 802.3 Ethernet model are shown in Figure 55–1. The PHY sublayers (shown shaded) in Figure 55–1 connect the IEEE 802.3 MAC to the medium.

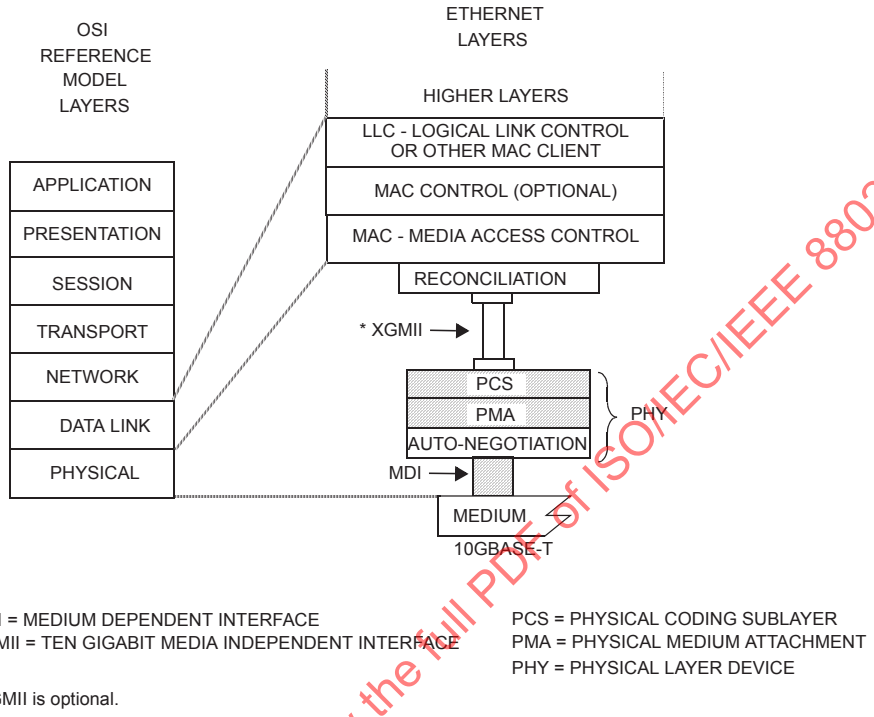

Figure 55–1—Type 10GBASE-T PHY relationship to the ISO Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

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55.1.3 Operation of 10GBASE-T

The 10GBASE-T PHY employs full duplex baseband transmission over four pairs of balanced cabling. The aggregate data rate of 10 Gb/s is achieved by transmitting 2500 Mb/s in each direction simultaneously on each wire pair, as shown in Figure 55–2. Baseband 16-level PAM signaling with a modulation rate of 800 Megasymbol per second is used on each of the wire pairs. Ethernet data and control characters are encoded at a rate of 3.125 information bits per PAM16 symbol, along with auxiliary channel bits. Two consecutively transmitted PAM16 symbols are considered as one two-dimensional (2D) symbol. The 2D symbols are selected from a constrained constellation of 128 maximally spaced 2D symbols, called DSQ128[19] (double square 128). After link startup, PHY frames consisting of 512 DSQ128 symbols are continuously transmitted. The DSQ128 symbols are determined by 7-bit labels, each comprising 3 uncoded bits and 4 LDPC-encoded bits. The 512 DSQ128 symbols of one PHY frame are transmitted as 4×256 PAM16 symbols over the four wire pairs. Data and Control symbols are embedded in a framing scheme that runs continuously after startup of the link. The modulation symbol rate of 800 Msymbols/s results in a symbol period of 1.25 ns.

[19]The DSQ128 symbols are obtained by concatenating two time-adjacent 1D PAM16 symbols and retaining among the 256 possible Cartesian product combinations, 128 maximally spaced 2D symbols. The resulting checkerboard constellation is based on a lattice called RZ^2 in the literature (see Forney [B31]). DSQ constellations have previously been introduced under the name "AMPM" (see [B32] for examples of 8 point and 32 point AMPM/DSQ constellations).

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A 10GBASE-T PHY can be configured either as a MASTER PHY or as a SLAVE PHY. The MASTER-SLAVE relationship between two stations sharing a link segment is established during Auto-Negotiation (see Clause 28, 55.6, Annex 28B, Annex 28C, and Annex 28D). The MASTER PHY uses a local clock to determine the timing of transmitter operations. The MASTER-SLAVE relationship may include loop timing. If loop timing is implemented, the SLAVE PHY recovers the clock from the received signal and uses it to determine the timing of transmitter operations, i.e., it performs loop timing, as illustrated in Figure 55–3. If loop timing is not implemented, the SLAVE PHY transmit clocking is identical to the MASTER PHY transmit clocking.

10GBASE-T PHYs optionally provide support for LPI as part of EEE (see Clause 78). This extension allows PHYs to enter an LPI mode when either the local or link partner system requests low power operation. The transmit and receive functions may enter and leave the LPI mode independently so that both symmetric and asymmetric operation is supported. While the PHY is in the LPI mode, the PHY periodically transmits a refresh signal to allow the remote PHY to refresh its receiver state (e.g., timing recovery, adaptive filter coefficients) and thereby track long-term variation in the timing of the link or the underlying channel characteristics. An easily detectable alert signal is transmitted to signal an end to the LPI mode. The alert signal is followed by a wake signal to enable a rapid transition back to the normal operational mode.

10GBASE-T PHYs may optionally support a fast retrain mechanism. This function allows PHYs to quickly recover from link degradation without a normal two second retrain.

The PCS and PMA subclauses of this document are summarized in 55.1.3.1 and 55.1.3.2. The EEE capability is summarized in 55.1.3.3. Figure 55–3 shows the functional block diagram.

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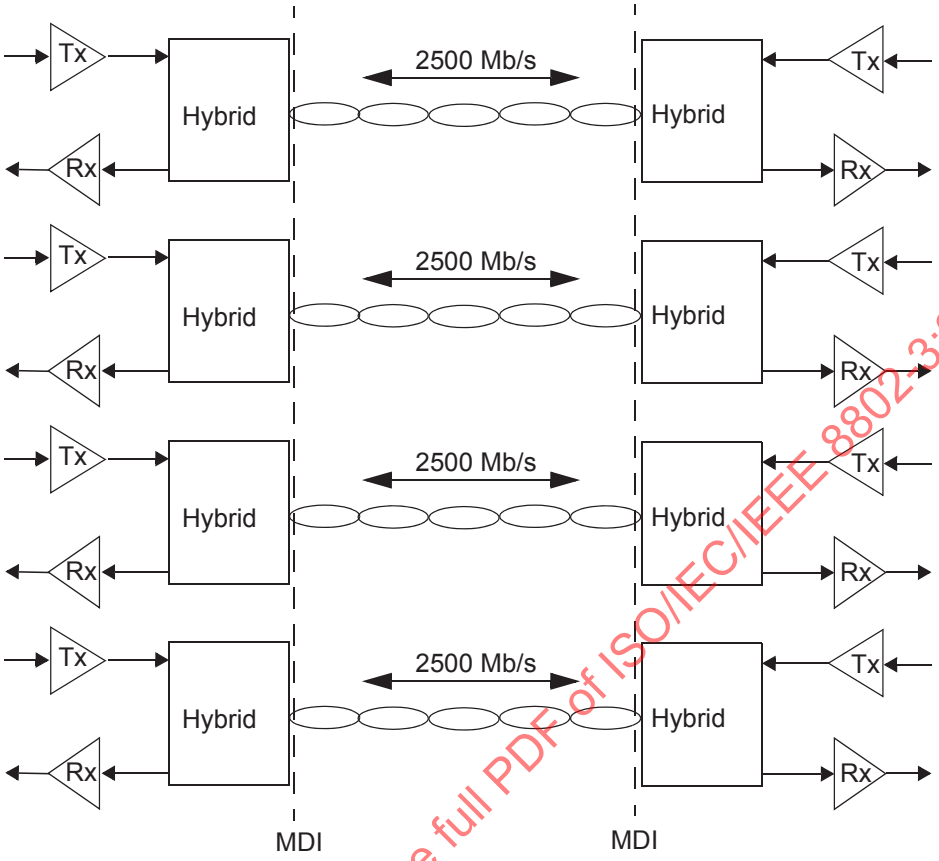

Figure 55–2—10GBASE-T topology

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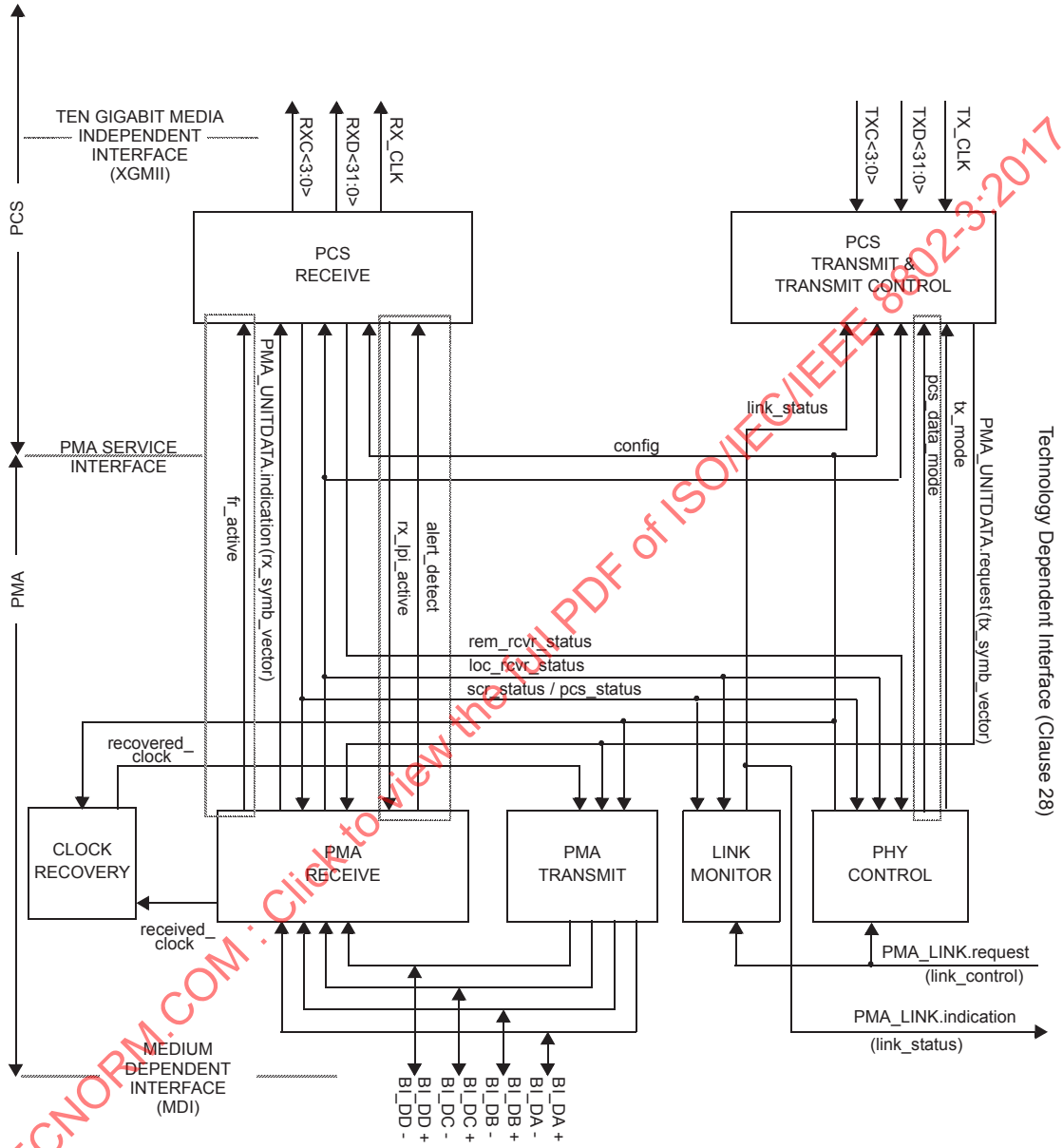

NOTE 1—The recovered_clock arc is shown to indicate delivery of the received clock signal back to PMA TRANSMIT for loop timing.

NOTE 2—pcs_data_mode is required only for the EEE or fast retrain capabilities; alert_detect and rx_lpi_active are only required for the EEE capability; fr_active is only required for the fast retrain capability.

Figure 55–3—Functional block diagram

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55.1.3.1 Physical Coding Sublayer (PCS)

The 10GBASE-T PCS couples a Ten Gigabit Media Independent Interface (XGMII), as described in Clause 46, to the 10GBASE-T Physical Medium Attachment (PMA) sublayer.

In addition to the normal mode of operation, the PCS supports a training mode. Furthermore, the PCS contains a management interface.

In the transmit direction, in normal mode, the PCS receives eight XGMII data octets provided by two consecutive transfers on the XGMII service interface on TXD<31:0> and groups them into 64-bit blocks with the 64-bit block boundaries aligned with the boundary of the two XGMII transfers. Each group of eight octets along with the data/control indications is transcoded into a 65-bit block. The resulting 65-bit blocks are scrambled and assembled in a group of 50 blocks. Adding CRC8 check bits yields a CRC-checked Ethernet payload of $50 \times 65 + 8 = 3258$ bits. An auxiliary channel bit is added to obtain a block of 3259 bits.

The 3259 bits are divided into 3×512 bits and 1723 bits. The 3×512 bits, among them the auxiliary channel bit, remain uncoded. The 1723 bits are encoded by a systematic LDPC(1723,2048) encoder, which adds 325 LDPC check bits to form an LDPC codeword of 2048 coded bits. The 3×512 uncoded bits and the $2048 = 4 \times 512$ coded bits are arranged in a frame of 512 7-bit labels. Each 7-bit label comprises 3 uncoded bits and 4 coded bits.

The 512 7-bit labels are mapped into 512 2D modulation symbols selected from a DSQ128 constellation. The DSQ128 symbols are obtained by concatenating two time-adjacent 1D PAM16 symbols and retaining among the 256 possible Cartesian product combinations, 128 maximally spaced 2D symbols. The resulting checkerboard constellation is based on a lattice called RZ^2 in the literature (see Forney [B31]).

The DSQ128 constellation is partitioned into 16 subsets, each subset containing eight maximally spaced 2D symbols. The four coded bits of each 7-bit label select one DSQ128 subset, and the three uncoded bits of the label select one 2D symbol in this subset.

The obtained PHY frame of 512 DSQ128 symbols is passed on to the PMA as PMA_UNITDATA.request. The PMA transmits the DSQ128 symbols over the four wire pairs in the form of 256 constituent PAM16 symbols per pair. Details of the PCS function are covered in 55.3.

In the receive direction, in normal mode, the PCS processes code-groups received from the remote PHY via the PMA in 256 4D symbol blocks and maps them to the XGMII service interface in the receive path. In this receive processing scheme, symbol clock synchronization is done by the PMA Receive function.

The PCS functions and state diagrams are specified in 55.3. The signals provided by the PCS at the XGMII conform to the interface requirements of Clause 46. The interface to the PMA is an abstract message-passing interface specified in 55.2.

55.1.3.2 Physical Medium Attachment (PMA) sublayer

The PMA couples messages from the PCS service interface onto the balanced cabling physical medium via the Medium Dependent Interface (MDI) and provides the link management and PHY Control functions. The PMA provides full duplex communications at 800 Msymbols/s over four pairs of balanced cabling up to 100 m in length.

The PMA Transmit function comprises four transmitters to generate continuous time analog signals on each of the four pairs BI_DA, BI_DB, BI_DC, and BI_DD, as described in 55.4.3.1. In normal mode, each four-dimensional (4D) symbol received from the PCS Transmit function undergoes multiple stages of processing. First the symbol goes through a Tomlinson-Harashima precoder (THP), which maps the PAM16 input (as described in 55.3.2.2.19) in each dimension of the four-dimensional symbol into a quasi-continuous discrete

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time value in the range $-16 \le x < 16$. This THP-processed four-dimensional symbol stream may be further processed by a digital transmit filter and is then passed on to four digital to analog converters (DACs). The DAC outputs may be further processed with continuous time filters to roll off the high-frequency spectral response to limit high-frequency emissions and are then applied to each of the four balanced pairs via the MDI port.

The PMA Receive function comprises four independent receivers for pulse-amplitude modulated signals on each of the four pairs BI_DA, BI_DB, BI_DC, and BI_DD, as described in 55.4.3.2. The receivers are responsible for acquiring symbol timing and, when operating in normal mode, for cancelling echo, near-end crosstalk, far-end crosstalk, and equalizing the signal. The 4D symbols are provided to the PCS Receive function via the PMA_UNITDATA.indication message. The PMA also contains functions for Link Monitor.

The PMA PHY Control function generates signals that control the PCS and PMA sublayer operations. PHY Control begins following the completion of Auto-Negotiation and provides the startup functions required for successful 10GBASE-T operation. It determines whether the PHY operates in a normal mode, enabling data transmission over the link segment, or whether the PHY sends special PAM2 code-groups that are used in the training mode. The latter occurs when either one or both of the PHYs that share a link segment are not operating reliably.

PMA functions and state diagrams are specified in 55.4. PMA electrical specifications are given in 55.5.

The PMA sublayer may also support a fast retrain function. The fast retrain function is specified in 55.4.2.5.15.

55.1.3.3 EEE capability

A 10GBASE-T PHY may optionally support the EEE capability, as described in 78.3. The EEE capability is a mechanism by which 10GBASE-T PHYs are able to reduce power consumption during periods of low link utilization. PHYs can enter this mode of operation after reaching PCS data mode. Each direction of the full duplex link is able to enter and exit the LPI mode independently, supporting symmetric and asymmetric LPI operation. This allows power savings when only one side of the full duplex link is in a period of low utilization. No data frames are lost or corrupted during the transition to or from the LPI mode.

In the transmit direction the transition to the LPI transmit mode begins when the PCS transmit function detects an LPI control character in all four lanes of two consecutive transfers of TXD[31:0] that will be mapped into a single 64B/65B block. Following this event a sleep signal is transmitted by the PMA. The sleep signal is composed of LDPC frames that contain only LP_IDLE 64B/65B blocks. The sleep signal indicates to the link partner that the transmit function of the PHY is entering the LPI transmit mode. Immediately after the transmission of the sleep frames, the transmit function of the local PHY enters the LPI transmit mode. While the transmit function is in the LPI mode the PHY may disable data path and control logic to save additional power. Periodically the transmit function of the local PHY transmits refresh frames that are used by the link partner to update adaptive filters and timing circuits in order to maintain link integrity. The LPI mode begins with quiet signaling or with a full refresh period. Partial refreshes (defined as a refresh signal shorter than 4 LDPC frames) that immediately follow the transition to the LPI mode are replaced with quiet signaling. The quiet-refresh cycle continues until the PCS function detects IDLE characters on the XGMII. These characters signal to the PHY that the LPI transmit mode should end. The PMA Transmit function in the PHY then sends an alert message to the link partner. The alert signal begins on a LDPC frame boundary, but has no fixed relationship to the quiet-refresh cycle. The alert signal wakes the link partner from sleep. The alert signal is followed by a wake signal, composed of LDPC frames containing only IDLE 64B/65B blocks. After a short recovery time the normal operational mode is resumed.

In the receive direction the transition to the LPI mode is triggered when the PCS Receive function detects LPI control characters within received LDPC frames. This indicates that the link partner is about to enter the LPI transmit mode. Following these frames the link partner ceases transmission and begins quiet-refresh

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signaling. During the quiet time it is highly recommended that the local receiver power off circuits to reduce power consumption. Periodically the link partner transmits refresh frames that are used by the receiver to update adaptive coefficients and timing circuits. This quiet-refresh cycle continues until the link partner transmits the alert signal, initiating a transition back to the normal operational mode. The alert signal is detected in the PMA and signals that normal data frames will follow. The alert signal is followed by a wake signal that allows the local receiver time to prepare for the normal operational mode. The wake signal is composed of repeated IDLE 64B/65B blocks. After a short recovery time the normal operational mode is resumed.

Support for the EEE capability is advertised during Auto-Negotiation. Transitions to and from the LPI transmit mode are controlled via XGMII signaling. Transitions to and from the LPI receive mode are controlled by the link partner using sleep, alert, and wake signaling.

The PCS 64B/65B Transmit state diagram in Figure 55–16 and Figure 55–17 includes additional states for EEE. The PCS 64B/65B Receive state diagram in Figure 55–18 and Figure 55–19 includes additional states for EEE. The EEE Transmit state diagram is contained in the PCS Transmit function and is specified in Figure 55–20.

55.1.4 Signaling

10GBASE-T signaling is performed by the PCS generating continuous code-group sequences that the PMA transmits over each wire pair. The signaling scheme achieves a number of objectives including:

a) Forward error correction (FEC) coded symbol mapping for data.
b) Algorithmic mapping from TXD<31:0> and TXC<3:0> to four-dimensional symbols in the transmit path.
c) Algorithmic mapping from the received four-dimensional signals on the MDI port to RXD<31:0> and RXC<3:0> on the XGMII interface.
d) Uncorrelated symbols in the transmitted symbol stream.
e) No correlation between symbol streams traveling both directions on any pair combination.
f) No correlation between symbol streams on pairs BI_DA, BI_DB, BI_DC, and BI_DD.
g) Block framing and other control signals.
h) Ability to signal the status of the local receiver to the remote PHY to indicate that the local receiver is not operating reliably and requires retraining.
i) Ability to automatically detect and correct for pair swapping and crossover connections.
j) Ability to automatically detect and correct for incorrect polarity in the connections.
k) Ability to automatically correct for differential delay variations across the wire-pairs.
l) Ability to support refresh, quiet and alert signaling during LPI operation.

The PHY operates in two modes—normal mode or training mode. In normal mode, PCS generates a continuous stream of four-dimensional symbols that are transmitted via the PMA at one of eight power levels. In training mode, the PCS is directed to generate only PAM2 symbols for transmission by the PMA, which enable the receiver at the other end to train until it is ready to operate in normal mode. (See the PCS reference diagram in 55.2.)

PHYs may also support the EEE capability as described in 55.1.3.3. Transitions to the LPI mode are supported after reaching normal mode.

55.1.5 Interfaces

All 10GBASE-T PHY implementations are compatible at the MDI and at a physically exposed XGMII, if made available. Physical implementation of the XGMII is optional. Designers are free to implement circuitry within the PCS and PMA in an application-dependent manner provided that the MDI and XGMII

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(if the XGMII is implemented) specifications are met. System operation from the perspective of signals at the MDI and management objects are identical whether the XGMII is implemented or not.

55.1.6 Conventions in this clause

The body of this clause contains state diagrams, including definitions of variables, constants, and functions. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

The notation used in the state diagrams follows the conventions of 21.5.

Default initializations, unless specifically specified, are left to the implementer.

55.2 10GBASE-T service primitives and interfaces

10GBASE-T transfers data and control information across the following four service interfaces:

a) Ten Gigabit Media Independent Interface (XGMII)
b) Technology Dependent Interface
c) PMA service interface
d) Medium dependent interface (MDI)

The XGMII is specified in Clause 46; the Technology Dependent Interface is specified in Clause 28. The PMA service interface is defined in 55.2.2 and the MDI is defined in 55.8.

55.2.1 Technology Dependent Interface

10GBASE-T uses the following service primitives to exchange status indications and control signals across the Technology Dependent Interface as specified in Clause 28:

PMA_LINK.request (link_control)

PMA_LINK.indication (link_status)

55.2.1.1 PMA_LINK.request

This primitive allows the Auto-Negotiation algorithm to enable and disable operation of the PMA as specified in 28.2.6.2.

55.2.1.1.1 Semantics of the primitive

PMA_LINK.request (link_control)

The link_control parameter can take on one of three values: SCAN_FOR_CARRIER, DISABLE, or ENABLE.

SCAN_FOR_CARRIER Used by the Auto-Negotiation algorithm prior to receiving any fast link pulses. During this mode the PMA reports link_status=FAIL. PHY processes are disabled.

DISABLE Set by the Auto-Negotiation algorithm in the event fast link pulses are detected. PHY processes are disabled. This allows the Auto-Negotiation algorithm to determine how to configure the link.

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ENABLE	Used by Auto-Negotiation to turn control over to the PHY for data processing functions.

55.2.1.1.2 When generated

Auto-Negotiation generates this primitive to indicate a change in link_control as described in Clause 28.

55.2.1.1.3 Effect of receipt

This primitive affects operation of the PMA Link Monitor function as defined in 55.4.2.6.

55.2.1.2 PMA_LINK.indication

This primitive is generated by the PMA to indicate the status of the underlying medium as specified in 28.2.6.1. This primitive informs the PCS, PMA PHY Control function, and the Auto-Negotiation algorithm about the status of the underlying link.

55.2.1.2.1 Semantics of the primitive

PMA_LINK.indication (link_status)

The link_status parameter can take on one of three values: FAIL, READY, or OK.

FAIL	No valid link established.
READY	For 10GBASE-T link_status does not take the value READY.
OK	The Link Monitor function indicates that a valid 10GBASE-T link is established. Reliable reception of signals transmitted from the remote PHY is possible.

55.2.1.2.2 When generated

The PMA generates this primitive to indicate a change in link_status in compliance with the state diagram given in Figure 55–31.

55.2.1.2.3 Effect of receipt

The effect of receipt of this primitive is specified in 55.3.6.2.

55.2.2 PMA service interface

10GBASE-T uses the following service primitives to exchange symbol vectors, status indications, and control signals across the service interfaces:

PMA_TXMODE.indication (tx_mode)

PMA_CONFIG.indication (config)

PMA_UNITDATA.request (tx_symb_vector)

PMA_UNITDATA.indication (rx_symb_vector)

PMA_SCRSTATUS.request (scr_status)

PMA_PCSSTATUS.request (pcs_status)

PMA_RXSTATUS.indication (loc_rcvr_status)

PMA_REMRXSTATUS.request (rem_rcvr_status)

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EEE-capable PHYs additionally support the following service primitives:

PMA_ALERTDETECT.indication (alert_detect)

PCS_RX_LPI_STATUS.request (rx_lpi_active)

PMA_PCSDATAMODE.indication (pcs_data_mode)

Fast retrain capable PHYs additionally support the following service primitive:

PMA_FR_ACTIVE.indication (fr_active)

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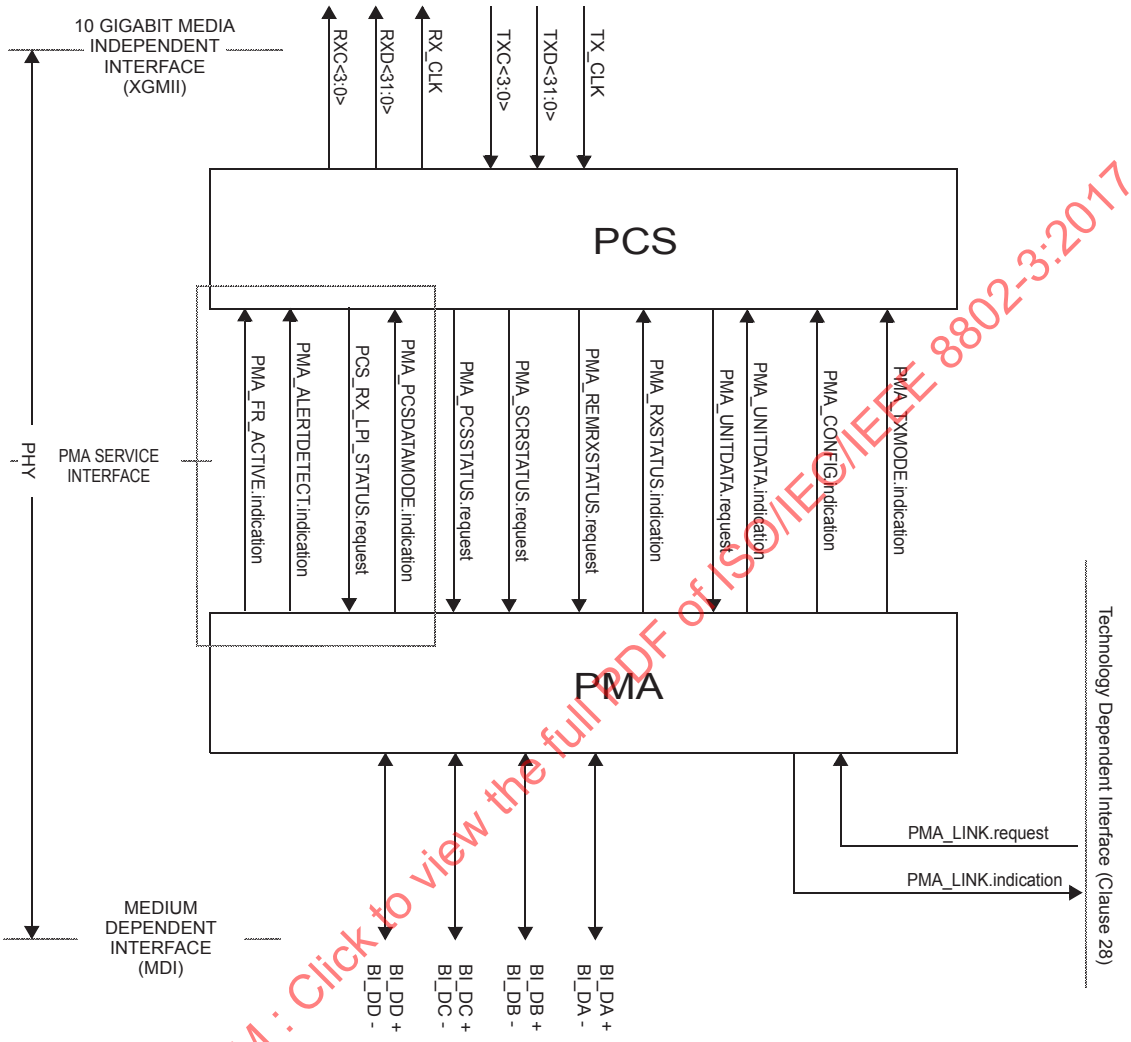
The use of these primitives is illustrated in Figure 55–4. Connections from the management interface (signals MDC and MDIO) to the sublayers are pervasive and are not shown in Figure 55–4.



NOTE—
PMA_PCSDATAMODE.indication is required only for the EEE or fast retrain capabilities.
PMA_ALERTDETECT.indication and PCS_RX_LPI_STATUS.request are only required for the EEE capability.
PMA_FR_ACTIVE.indication is only required for the fast retrain capability.

Figure 55–4—10GBASE-T service interfaces

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55.2.2.1 PMA_TXMODE.indication

The transmitter in a 10GBASE-T link normally sends over the four pairs, four-dimensional symbols that represent an XGMII data stream with framing, scrambling and encoding of data, control information, or idles.

55.2.2.1.1 Semantics of the primitive

PMA_TXMODE.indication (tx_mode)

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PMA_TXMODE.indication specifies to PCS Transmit via the parameter tx_mode what sequence of code-groups the PCS should be transmitting. The parameter tx_mode can take on one of the following three values of the form:

SEND_N	This value is continuously asserted when transmission of sequences of four-dimensional symbols representing an XGMII data stream in normal mode.
SEND_T	This value is continuously asserted in case transmission of sequences of code-groups representing the training mode is to take place.
SEND_Z	This value is continuously asserted in case transmission of zeros is required.

55.2.2.1.2 When generated

The PMA PHY Control function generates PMA_TXMODE.indication messages to indicate a change in tx_mode.

55.2.2.1.3 Effect of receipt

Upon receipt of this primitive, the PCS performs its transmit function as described in 55.3.2.2.

55.2.2.2 PMA_CONFIG.indication

Each PHY in a 10GBASE-T link is capable of operating as a MASTER PHY and as a SLAVE PHY. MASTER-SLAVE configuration is determined during Auto-Negotiation (55.6.1). The result of this negotiation is provided to the PMA.

55.2.2.2.1 Semantics of the primitive

PMA_CONFIG.indication (config)

PMA_CONFIG.indication specifies to PCS and PMA Transmit via the parameter config whether the PHY operates as a MASTER PHY or as a SLAVE PHY. The parameter config can take on one of the following two values of the form:

MASTER	This value is continuously asserted when the PHY operates as a MASTER PHY.
SLAVE	This value is continuously asserted when the PHY operates as a SLAVE PHY.

55.2.2.2.2 When generated

PMA generates PMA_CONFIG.indication messages to indicate a change in config.

55.2.2.2.3 Effect of receipt

PCS and PMA Clock Recovery perform their functions in MASTER or SLAVE configuration according to the value assumed by the parameter config.

55.2.2.3 PMA_UNITDATA.request

This primitive defines the transfer of code-groups in the form of the tx_symb_vector parameter from the PCS to the PMA. The code-groups are obtained in the PCS Transmit function using the encoding rules defined in 55.3.2.2 to represent XGMII data and control streams or other sequences.

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55.2.2.3.1 Semantics of the primitive

PMA_UNITDATA.request (tx_symb_vector)

During transmission, the PMA_UNITDATA.request simultaneously conveys to the PMA via the parameter tx_symb_vector the value of the symbols to be sent over each of the four transmit pairs BI_DA, BI_DB, BI_DC, and BI_DD. For EEE-capable PHYs, the vector also requests the PMA to send the ALERT signal during LPI. The tx_symb_vector parameter takes on the form:

SYMB_4D	A vector of four multi-level symbols, one for each of the four transmit pairs BI_DA, BI_DB, BI_DC, and BI_DD. In normal operation, each symbol may take on one of the values in the set {–15, –13, –11, –9, –7, –5, –3, –1, 1, 3, 5, 7, 9, 11, 13, 15}. The symbols may additionally take the value 0 when zeros are to be transmitted in the following two cases: 1) when PMA_TXMODE.indication is SEND_Z during PMA training, and 2) after data mode is reached, the transmit function is in the LPI transmit mode and lpi_tx_mode is QUIET
ALERT	A vector used to indicate that the PMA should transmit the alert sequence. ALERT will be asserted for a time equal to 4 LDPC frames.

The symbols that are elements of tx_symb_vector are called, according to the pair on which each is transmitted, tx_symb_vector[BI_DA], tx_symb_vector[BI_DB], tx_symb_vector[BI_DC], and tx_symb_vector[BI_DD].

55.2.2.3.2 When generated

The PCS generates PMA_UNITDATA.request (SYMB_4D) synchronously with every transmit clock cycle.

55.2.2.3.3 Effect of receipt

Upon receipt of this primitive the PMA transmits on the MDI the signals corresponding to the indicated symbols after processing with the THP, the transmit filter and other specified PMA Transmit processing. The parameter tx_symb_vector is also used by the PMA Receive function to process the signals received on pairs BI_DA, BI_DB, BI_DC, and BI_DD for cancelling the echo and near-end crosstalk (NEXT).

55.2.2.4 PMA_UNITDATA.indication

This primitive defines the transfer of code-groups in the form of the rx_symb_vector parameter from the PMA to the PCS.

55.2.2.4.1 Semantics of the primitive

PMA_UNITDATA.indication (rx_symb_vector)

During reception the PMA_UNITDATA.indication simultaneously conveys to the PCS via the parameter rx_symb_vector the values of the symbols detected on each of the four receive pairs BI_DA, BI_DB, BI_DC, and BI_DD. The rx_symb_vector parameter takes on the form:

SYMB_4D	A vector of the four 1D symbols that is the receiver's best estimate of the symbols that were sent by the remote transmitter across the four pairs with reliability measures.

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55.2.2.4.2 When generated

The PMA generates PMA_UNITDATA.indication (SYMB_4D) messages synchronously every four symbols received at the MDI. The nominal rate of the PMA_UNITDATA.indication primitive is 800 MHz, as governed by the recovered clock.

55.2.2.4.3 Effect of receipt

The effect of receipt of this primitive is unspecified.

55.2.2.5 PMA_SCRSTATUS.request

This primitive is generated by PCS Receive to communicate the status of the descrambler for the local PHY. The parameter scr_status conveys to the PMA Receive function the information that the training mode descrambler has achieved synchronization.

55.2.2.5.1 Semantics of the primitive

PMA_SCRSTATUS.request (scr_status)

The scr_status parameter can take on one of two values of the form:

OK	The training mode descrambler has achieved synchronization.
NOT_OK	The training mode descrambler is not synchronized.

55.2.2.5.2 When generated

PCS Receive generates PMA_SCRSTATUS.request messages to indicate a change in scr_status.

55.2.2.5.3 Effect of receipt

The effect of receipt of this primitive is specified in 55.4.2.4, 55.4.2.5, and 55.4.6.1.

55.2.2.6 PMA_PCSSTATUS.request

This primitive is generated by PCS Receive to indicate the fully operational state of the PCS for the local PHY. The parameter pcs_status conveys to the PMA Receive function the information that the PCS is operating reliably in data mode.

55.2.2.6.1 Semantics of the primitive

PMA_PCSSTATUS.request (pcs_status)

The pcs_status parameter can take on one of two values of the form:

OK	The PCS is operating reliably in data mode.
NOT_OK	The PCS is not operating reliably in data mode.

55.2.2.6.2 When generated

PCS Receive generates PMA_PCSSTATUS.request messages to indicate a change in pcs_status.

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55.2.2.6.3 Effect of receipt

The effect of receipt of this primitive is specified in 55.4.6.

55.2.2.7 PMA_RXSTATUS.indication

This primitive is generated by PMA Receive to indicate the status of the receive link at the local PHY. The parameter loc_rcvr_status conveys to the PCS Transmit, PCS Receive, PMA PHY Control function, and Link Monitor the information on whether the status of the overall receive link is satisfactory or not. Note that loc_rcvr_status is used by the PCS Receive decoding functions. The criterion for setting the parameter loc_rcvr_status is left to the implementer. It can be based, for example, on observing the mean-square error at the decision point of the receiver and detecting errors during reception of symbol streams.

55.2.2.7.1 Semantics of the primitive

PMA_RXSTATUS.indication (loc_rcvr_status)

The loc_rcvr_status parameter can take on one of two values of the form:

OK	This value is asserted and remains true during reliable operation of the receive link for the local PHY.
NOT_OK	This value is asserted whenever operation of the link for the local PHY is unreliable.

55.2.2.7.2 When generated

PMA Receive generates PMA_RXSTATUS.indication messages to indicate a change in loc_rcvr_status on the basis of signals received at the MDI.

55.2.2.7.3 Effect of receipt

The effect of receipt of this primitive is specified in Figure 55–28 and in subclauses 55.2 and 55.4.6.3.

55.2.2.8 PMA_REMRXSTATUS.request

This primitive is generated by PCS Receive to indicate the status of the receive link at the remote PHY as communicated by the remote PHY via its encoding of its loc_rcvr_status parameter. The parameter rem_rcvr_status conveys to the PMA PHY Control function the information on whether reliable operation of the remote PHY is detected or not. The criterion for setting the parameter rem_rcvr_status is left to the implementer. It can be based, for example, on asserting rem_rcvr_status is NOT_OK until loc_rcvr_status is OK and then asserting the detected value of rem_rcvr_status after proper PCS Receive decoding is achieved.

55.2.2.8.1 Semantics of the primitive

PMA_REMRXSTATUS.request (rem_rcvr_status)

The rem_rcvr_status parameter can take on one of two values of the form:

OK	The receive link for the remote PHY is operating reliably.
NOT_OK	Reliable operation of the receive link for the remote PHY is not detected.

55.2.2.8.2 When generated

The PCS generates PMA_REMRXSTATUS.request messages to indicate a change in rem_rcvr_status on the basis of signals received at the MDI.

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55.2.2.8.3 Effect of receipt

The effect of receipt of this primitive is specified in Figure 55–28.

55.2.2.9 PMA_ALERTDETECT.indication

This primitive is generated by PMA Receive to indicate the status of the receive link at the local PHY when rx_lpi_active is TRUE. The parameter alert_detect conveys to the PCS receive function information regarding the detection of the LPI alert signal by the PMA receive function. The criterion for setting the parameter alert_detect is left to the implementer.

55.2.2.9.1 Semantics of the primitive

PMA_ALERTDETECT.indication (alert_detect)

The alert_detect parameter can take on one of two values of the form:

TRUE	The alert signal has been reliably detected at the local receiver.
FALSE	The alert signal at the local receiver has not been detected.

55.2.2.9.2 When generated

The PMA generates PMA_ALERTDETECT.indication messages to indicate a change in the alert_detect status.

55.2.2.9.3 Effect of receipt

The effect of receipt of this primitive is specified in 55.3.2.3, Figure 55–18, and Figure 55–19.

55.2.2.10 PCS_RX_LPI_STATUS.request

When the PHY supports the EEE capability this primitive is generated by the PCS receive function to indicate the status of the receive link at the local PHY. The parameter PCS_RX_LPI_STATUS.request conveys to the PCS transmit and PMA receive functions information regarding whether the receive function is in the LPI receive mode. The parameter is generated by the Receive 64B/65B state diagram in Figure 55–18.

55.2.2.10.1 Semantics of the primitive

PCS_RX_LPI_STATUS.request (rx_lpi_active)

The rx_lpi_active parameter can take on one of two values of the form:

TRUE	The receive function is in the LPI receive mode.
FALSE	The receive function is not in the LPI receive mode.

55.2.2.10.2 When generated

The PCS generates PCS_RX_LPI_STATUS.request messages to indicate a change in the rx_lpi_active variable as determined by the receive state diagram in Figure 55–18.

55.2.2.10.3 Effect of receipt

The effect of receipt of this primitive is specified in 55.3.2.3 and Figure 55–32.

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55.2.2.11 PMA_PCSDATAMODE.indication

This primitive indicates whether or not the PCS state diagrams are able to transition from their initialization states. The pcs_data_mode variable is generated by the PMA PHY Control function. It is passed to the PCS Control function via the PMA_PCSDATAMODE.indication primitive.

55.2.2.11.1 Semantics of the primitive

PMA_PCSDATAMODE.indication (pcs_data_mode)

55.2.2.11.2 When generated

The PMA PHY Control function generates PMA_PCSDATAMODE.indication messages continuously.

55.2.2.11.3 Effect of receipt

Upon receipt of this primitive, the PCS performs its transmit function as described in 55.3.2.2.

55.2.2.12 PMA_FR_ACTIVE.indication

This primitive indicates whether or not the PMA is currently performing a fast retrain. The fr_active variable is generated by the PMA PHY Control function. It is passed to the PCS Receive Control function via the PMA_FR_ACTIVE.indication primitive. This primitive is only supported by PHYs with the fast retrain capability.

55.2.2.12.1 Semantics of the primitive

PMA_FR_ACTIVE.indication (fr_active)

55.2.2.12.2 When generated

The PMA PHY Control function generates PMA_FR_ACTIVE.indication messages continuously.

55.2.2.12.3 Effect of receipt

The effect of receipt of this primitive is specified in Figure 55–18.

55.3 Physical Coding Sublayer (PCS)

55.3.1 PCS service interface (XGMII)

The PCS service interface allows the 10GBASE-T PCS to transfer information to and from a PCS client. The PCS Interface is precisely defined as the 10 Gigabit Media Independent Interface (XGMII) in Clause 46.

55.3.2 PCS functions

The PCS comprises one PCS Reset function and two simultaneous and asynchronous operating functions. The PCS operating functions are: PCS Transmit and PCS Receive. All operating functions start immediately after the successful completion of the PCS Reset function.

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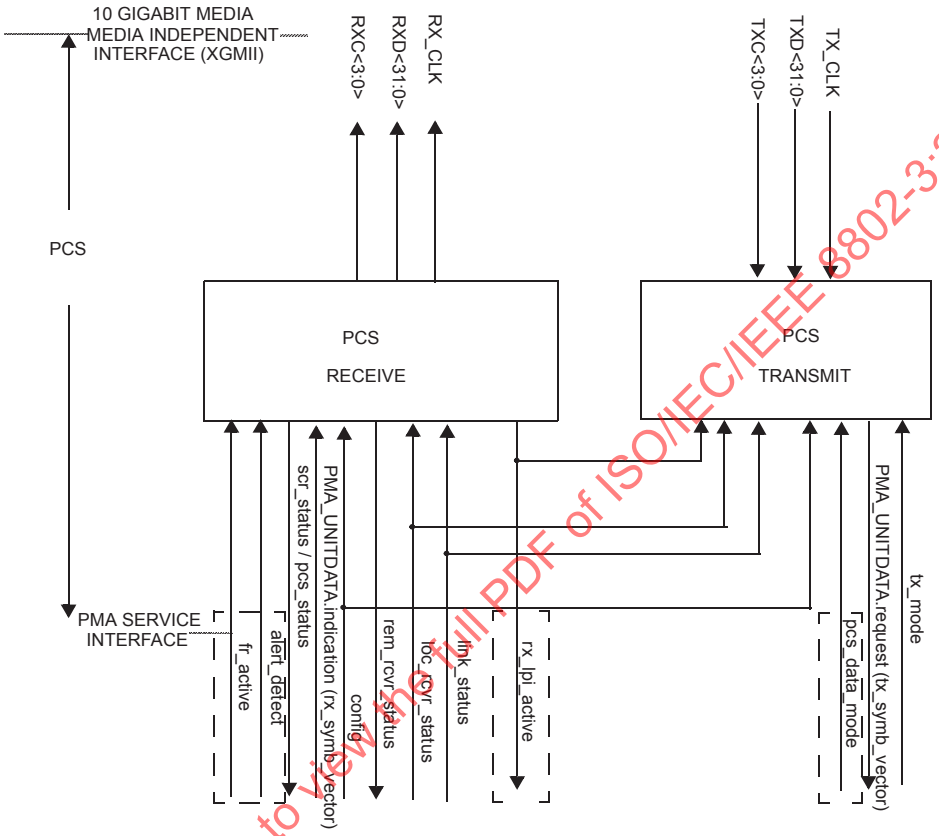
The PCS reference diagram, Figure 55–5, shows how the two operating functions relate to the messages of the PCS-PMA interface. Connections from the management interface (signals MDC and MDIO) to other layers are pervasive and are not shown in Figure 55–5.



NOTE—
pcs_data_mode is required only for the EEE or fast retrain capabilities.
alert_detect and rx_lpi_active are only required for the EEE capability.
fr_active is only required for the fast retrain capability.

Figure 55–5—PCS reference diagram

55.3.2.1 PCS Reset function

PCS Reset initializes all PCS functions. The PCS Reset function shall be executed whenever one of the following conditions occur:

a) Power on (see 55.3.6.2.2).
b) The receipt of a request for reset from the management entity.

PCS Reset sets pcs_reset=ON while any of the above reset conditions hold true. All state diagrams take the open-ended pcs_reset branch upon execution of PCS Reset. The reference diagrams do not explicitly show the PCS Reset function.

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55.3.2.2 PCS Transmit function

The PCS Transmit function shall conform to the PCS 64B/65B Transmit state diagram in Figure 55–16 and the PCS Transmit bit ordering in Figure 55–6 and Figure 55–8.

Dashed rectangles in Figure 55–16 and Figure 55–17 are used to indicate states and state transitions in the transmit process state diagram that shall be supported by PHYs with the EEE capability. PHYs without the EEE capability do not support these transitions.

When communicating with the XGMII, the PCS uses a four octet-wide, synchronous data path, with packet delimiting being provided by transmit control signals and receive control signals. Alignment to 64B/65B is performed in the PCS. The PMA sublayer operates independently of block and packet boundaries. The PCS provides the functions necessary to map packets between the XGMII format and the PMA service interface format.

When the transmit channel is in normal mode, the PCS Transmit process continuously generates 65B blocks based upon the TXD <31:0> and TXC <3:0> signals on the XGMII. The subsequent functions of the PCS Transmit process then pack the resulting blocks, and split the bits into the uncoded set and the coded set, which is processed by a low density parity check (LDPC) encoder and then joint mapped into a transmit LDPC frame of DSQ128 symbols. Transmit data-units are sent to the PMA service interface via the PMA_UNITDATA.request primitive.

In each symbol period, when communicating with the PMA, the PCS Transmit generates a code-group (A_n, B_n, C_n, D_n) that is transferred to the PMA via the PMA_UNITDATA.request primitive. The PMA transmits symbols A_n, B_n, C_n, D_n over wire-pairs BI_DA, BI_DB, BI_DC, and BI_DD respectively. The integer, n, is a time index that is introduced to establish a temporal relationship between different symbol periods. A symbol period, T, is 1.25 ns.

If a PMA_TXMODE.indication message has the value SEND_Z, PCS Transmit passes a vector of zeros at each symbol period to the PMA via the PMA_UNITDATA.request primitive.

If a PMA_TXMODE.indication message has the value SEND_T, PCS Transmit generates sequences of code-groups (TA_n, TB_n, TC_n, TD_n) defined in 55.3.4.2 to the PMA via the PMA_UNITDATA.request primitive. These code-groups are used for training mode and only transmit the values {–9, 9} to keep the transmit power in the training mode the same as the transmit power in normal mode.

During training mode an InfoField is transmitted at regular intervals containing messages for startup operation. By this mechanism, a PHY indicates the status of its own receiver to the link partner and makes requests for remote transmitter settings. (See 55.4.2.5.)

In the normal mode of operation, the PMA_TXMODE.indication message has the value SEND_N, and the PCS Transmit function uses a 65B-LDPC coding technique to generate at each symbol period code-groups that represent data or control. During transmission, the 65B bits are scrambled by the PCS using a PCS scrambler, 8 CRC check bits and an auxiliary channel bit are added, then frames are encoded into a code-group of four-dimensional symbols and transferred to the PMA. During data encoding, PCS Transmit utilizes a LDPC frame encoder.

After reaching the normal mode of operation, EEE-capable PHYs may enter the LPI transmit mode under the control of the MAC via the XGMII. The EEE Transmit state diagram is contained within the PCS Transmit function. The EEE capability is described in 55.3.2.2.22.

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55.3.2.2.1 Use of blocks

The PCS maps XGMII signals into 65-bit blocks inserted into an LDPC frame, and vice versa, using a 65B-LDPC coding scheme. The PAM2 PMA training frame synchronization allow establishment of LDPC frame and 65B boundaries by the PCS Synchronization process. Blocks and frames are unobservable and have no meaning outside the PCS. During the LPI mode, LDPC frame boundaries delimit sleep, wake, refresh, quiet, and alert cycles. The PCS functions ENCODE and DECODE generate, manipulate, and interpret blocks and frames as provided by the rules in 55.3.2.2.2.

55.3.2.2.2 65B-LDPC transmission code

The PCS uses a transmission code to improve the transmission characteristics of information to be transferred across the link and to support transmission of control and data characters. The encoding defined by the transmission code ensure that sufficient information is present in the PHY bit stream to make clock recovery possible at the receiver. The encoding also preserves the likelihood of detecting any LDPC frame errors that may occur during transmission and reception of information. In addition, the code enables the receiver to achieve PCS synchronization alignment on the incoming PHY bit stream.

The relationship of block bit positions to XGMII, PMA, and other PCS constructs is illustrated in Figure 55–6 for transmit and Figure 55–7 for receive. These figures illustrate the processing of a multiplicity of blocks containing 8 data octets. See 55.3.2.2.5 for information on how blocks containing control characters are mapped.

55.3.2.2.3 Notation conventions

For values shown as binary, the leftmost bit is the first transmitted bit.

64B/65B encodes 8 data octets or control characters into a block. Blocks containing control characters also contain a block type field. Data octets are labeled D_0 to D_7. Control characters other than /O/, /S/ and /T/ are labeled C_0 to C_7. The control character for ordered set is labeled as O_0 or O_4 since it is only valid on the first octet of the XGMII. The control character for start is labeled as S_0 or S_4 for the same reason. The control character for terminate is labeled as T_0 to T_7.

Two consecutive XGMII transfers provide eight characters that are encoded into one 65-bit transmission block. The subscript in the above labels indicates the position of the character in the eight characters from the XGMII transfers.

Contents of block type fields, data octets and control characters are shown as hexadecimal values. The LSB of the hexadecimal value represents the first transmitted bit. For instance, the block type field 0x1E is sent from left to right as 01111000. The bits of a transmitted or received block are labeled TxB<64:0> and RxB<64:0> respectively where TxB<0> and RxB<0> represent the first transmitted bit. The value of the data/ctrl header is shown as a binary value. Binary values are shown with the first transmitted bit (the LSB) on the left.

55.3.2.2.4 Transmission order

The PCS Transmit bit ordering shall conform to Figure 55–6 and Figure 55–8. Note that these figures show the mapping from XGMII to 64B/65B block for a block containing eight data characters.

55.3.2.2.5 Block structure

Blocks consist of 65 bits. The first bit of a block is the data/ctrl header. Blocks are either data blocks or control blocks. The data/ctrl header is 0 for data blocks and 1 for control blocks. The remainder of the block contains the payload.

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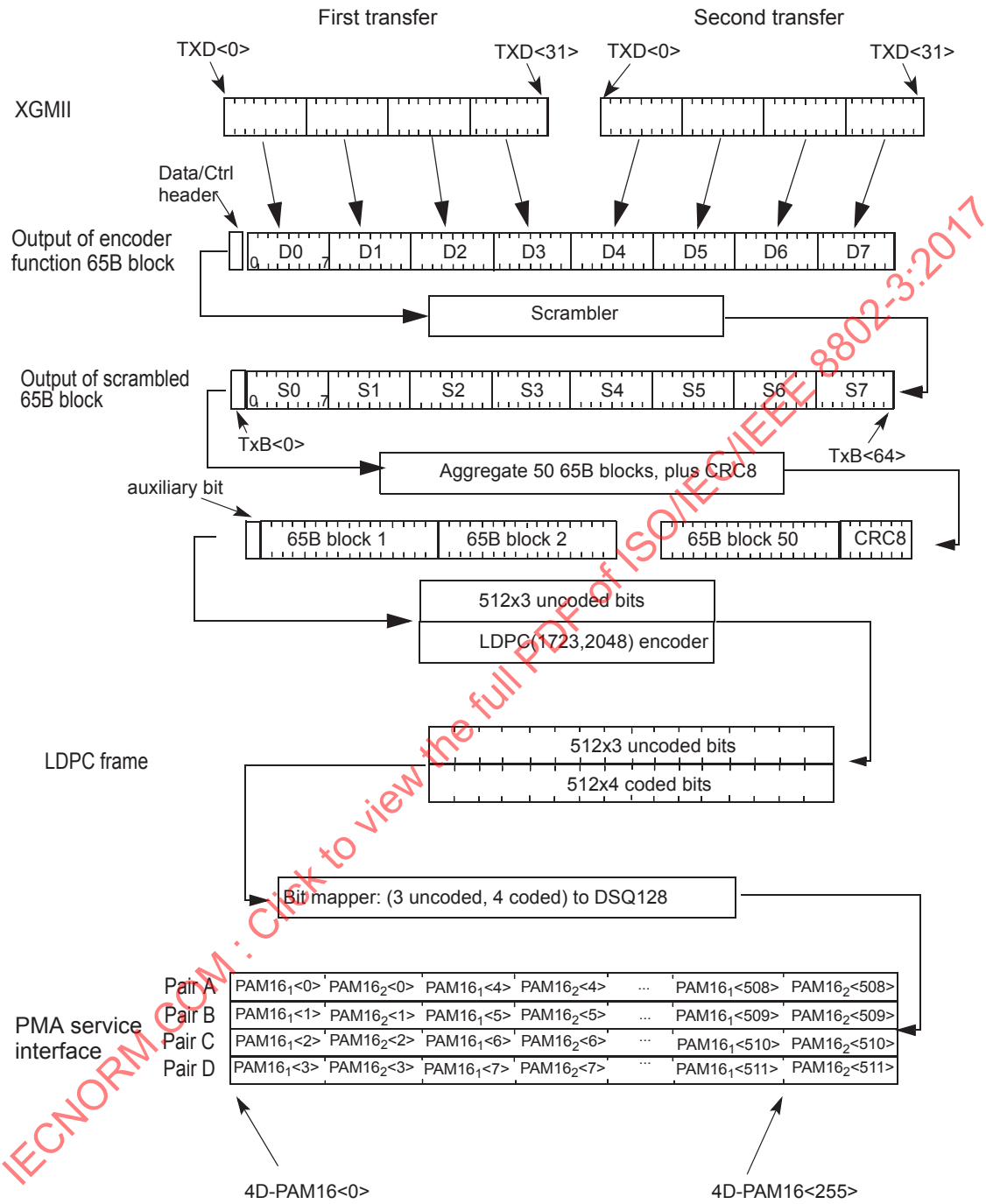

Figure 55–6—PCS Transmit bit ordering

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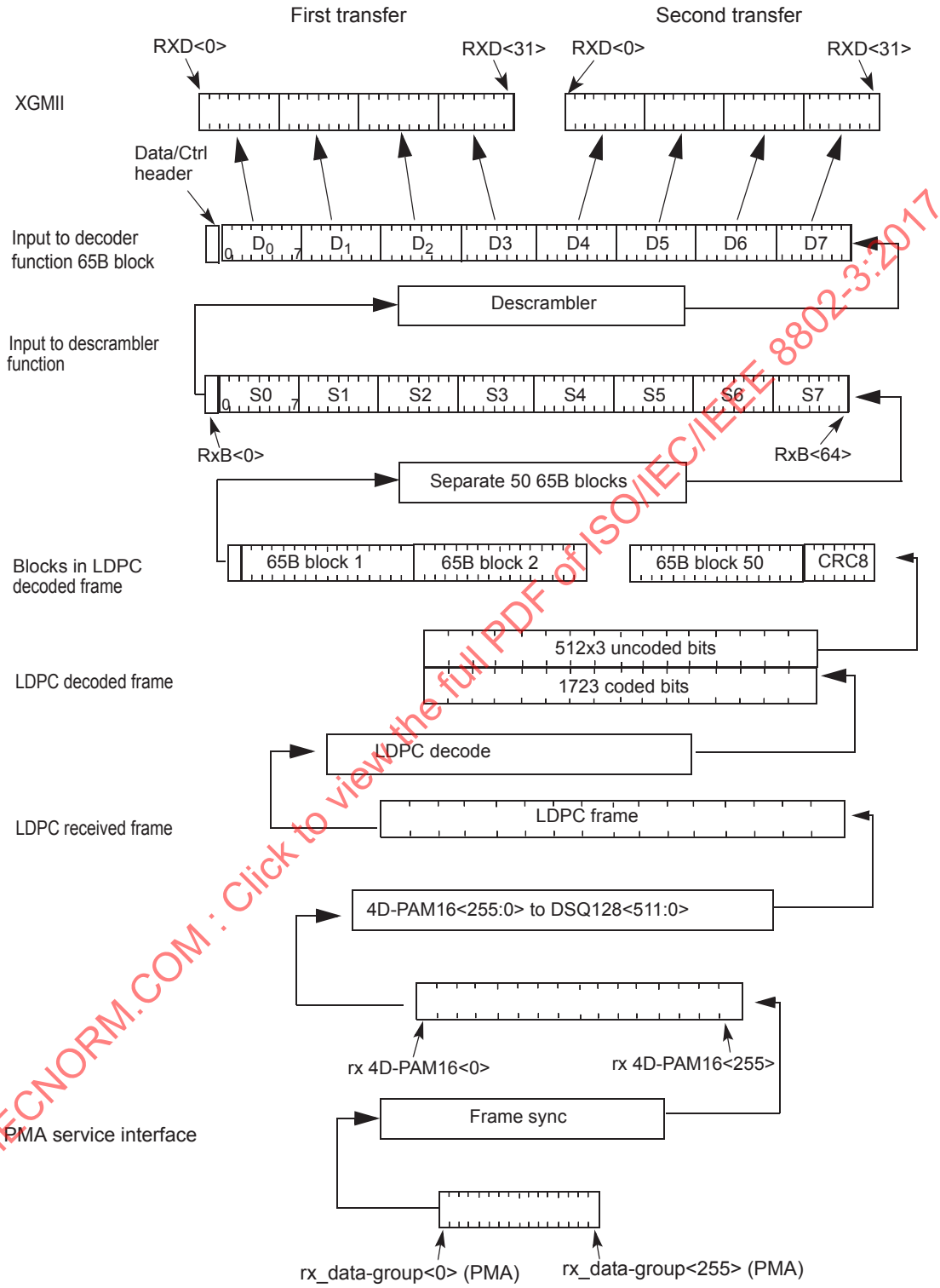

Figure 55–7—PCS Receive bit ordering

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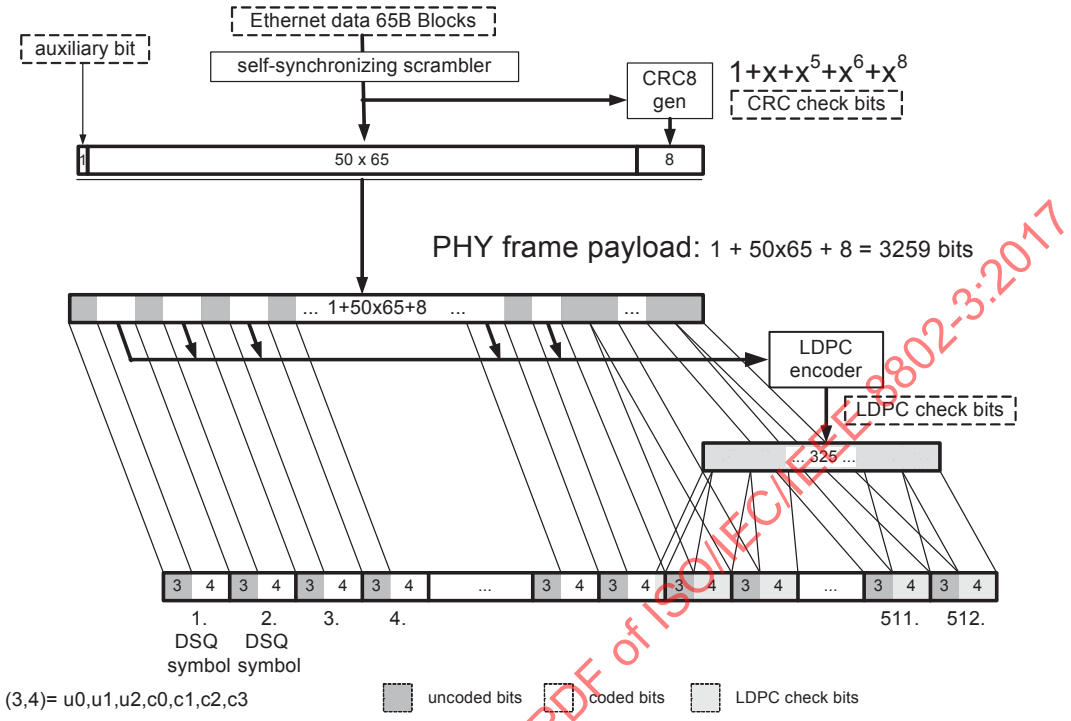

Figure 55–8—PCS detailed transmit bit ordering

Data blocks contain eight data characters. Control blocks begin with an 8-bit block type field that indicates the format of the remainder of the block. For control blocks containing a Start or Terminate character, that character is implied by the block type field. Other control characters are encoded in a 7-bit control code or a 4-bit O Code. Each control block contains eight characters.

The format of the blocks is as shown in Figure 55–9. In the figure, the column labeled Input Data shows, in abbreviated form, the eight characters used to create the 65-bit block. These characters are either data characters or control characters and, when transferred across the XGMII interface, the corresponding TXC or RXC bit is set accordingly. Within the Input Data column, D_0 through D_7 are data octets and are transferred with the corresponding TXC or RXC bit set to zero. All other characters are control octets and are transferred with the corresponding TXC or RXC bit set to one. The single bit fields (thin rectangles with no label in the figure) are sent as zero and ignored upon receipt.

Bits and field positions are shown with the least significant bit on the left. Hexadecimal numbers are shown prepended with '0x', and with the least significant digit on the right. For example the block type field 0x1E is sent as 01111000 representing bits 1 through 8 of the 65-bit block. The least significant bit for each field is placed in the lowest numbered position of the field.

All unused values of block type field[20] are reserved.

[20]The block type field values have been chosen to have a 4-bit Hamming distance between them. The only unused value that maintains the Hamming distance is 0x00.

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55.3.2.2.6 Control codes

The same set of control characters are supported by the XGMII and the 10GBASE-T PCS. The representations of the control characters are the control codes. XGMII encodes a control character into an octet (an 8-bit value). The 10GBASE-T PCS encodes the start and terminate control characters implicitly by the block type field. The 10GBASE-T PCS encodes the ordered set control codes using a combination of the block type field and a 4-bit O code for each ordered set. The 10GBASE-T PCS encodes each of the other control characters into a 7-bit C code).

The control characters and their mappings to 10GBASE-T control codes and XGMII control codes are specified in Table 55–1. All XGMII and 10GBASE-T control code values that do not appear in the table shall not be transmitted and shall be treated as an error if received.

Input Data	data ctrl header	Block Payload							
Bit Position: / Data Block Format:	0	1							64
$D_0\ D_1\ D_2\ D_3/D_4\ D_5\ D_6\ D_7$	0	D_0	D_1	D_2	D_3	D_4	D_5	D_6	D_7
Control Block Formats:		Block							
$C_0\ C_1\ C_2\ C_3/C_4\ C_5\ C_6\ C_7$	1	0x1E	C_0	C_1	C_2	C_3	C_4	C_5	C_6	C_7
$C_0\ C_1\ C_2\ C_3/O_4\ D_5\ D_6\ D_7$	1	0x2D	C_0	C_1	C_2	C_3	O_4	D_5	D_6	D_7
$C_0\ C_1\ C_2\ C_3/S_4\ D_5\ D_6\ D_7$	1	0x33	C_0	C_1	C_2	C_3		D_5	D_6	D_7
$O_0\ D_1\ D_2\ D_3/S_4\ D_5\ D_6\ D_7$	1	0x66	D_1	D_2	D_3	O_0		D_5	D_6	D_7
$O_0\ D_1\ D_2\ D_3/O_4\ D_5\ D_6\ D_7$	1	0x55	D_1	D_2	D_3	O_0	O_4	D_5	D_6	D_7
$S_0\ D_1\ D_2\ D_3/D_4\ D_5\ D_6\ D_7$	1	0x78	D_1	D_2	D_3	D_4		D_5	D_6	D_7
$O_0\ D_1\ D_2\ D_3/C_4\ C_5\ C_6\ C_7$	1	0x4B	D_1	D_2	D_3	O_0	C_4	C_5	C_6	C_7
$T_0\ C_1\ C_2\ C_3/C_4\ C_5\ C_6\ C_7$	1	0x87		C_1	C_2	C_3	C_4	C_5	C_6	C_7
$D_0\ T_1\ C_2\ C_3/C_4\ C_5\ C_6\ C_7$	1	0x99	D_0		C_2	C_3	C_4	C_5	C_6	C_7
$D_0\ D_1\ T_2\ C_3/C_4\ C_5\ C_6\ C_7$	1	0xAA	D_0	D_1		C_3	C_4	C_5	C_6	C_7
$D_0\ D_1\ D_2\ T_3/C_4\ C_5\ C_6\ C_7$	1	0xB4	D_0	D_1	D_2		C_4	C_5	C_6	C_7
$D_0\ D_1\ D_2\ D_3/T_4\ C_5\ C_6\ C_7$	1	0xCC	D_0	D_1	D_2	D_3		C_5	C_6	C_7
$D_0\ D_1\ D_2\ D_3/D_4\ T_5\ C_6\ C_7$	1	0xD2	D_0	D_1	D_2	D_3	D_4		C_6	C_7
$D_0\ D_1\ D_2\ D_3/D_4\ D_5\ T_6\ C_7$	1	0xE1	D_0	D_1	D_2	D_3	D_4	D_5		C_7
$D_0\ D_1\ D_2\ D_3/D_4\ D_5\ D_6\ T_7$	1	0xFF	D_0	D_1	D_2	D_3	D_4	D_5	D_6	

Figure 55–9—64B/65B block formats

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55.3.2.2.7 Ordered sets

Ordered sets are used to extend the ability to send control and status information over the link such as remote fault and local fault status. Ordered sets consist of a control character followed by three data characters. Ordered sets always begin on the first octet of the XGMII. 10 Gigabit Ethernet uses one kind of ordered set: the sequence ordered set (see 46.3.4). The sequence ordered set control character is denoted /Q/. An additional ordered set, the signal ordered set, has been reserved and it begins with another control code. The 4-bit O field encodes the control code. See Table 55–1 for the mappings.

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55.3.2.2.8 Valid and invalid blocks

A block is invalid if any of the following conditions exists:

a) The block type field contains a reserved value.
b) Any control character contains a value not in Table 55–1.
c) Any O code contains a value not in Table 55–1.
d) The set of eight XGMII characters does not have a corresponding block format in Figure 55–9.
e) The block contains the payload of an invalid received PHY frame or the first 64B/65B block following an invalid received PHY frame to account for self-synchronizing scrambler error propagation.

55.3.2.2.9 Idle (/I/)

Idle control characters (/I/) are transmitted when idle control characters are received from the XGMII. Idle characters may be added or deleted by the PCS to adapt between clock rates. /I/ insertion and deletion shall occur in groups of 4. /I/s may be added following idle or ordered sets. They shall not be added while data is being received. When deleting /I/s, the first four characters after a /T/ shall not be deleted.

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Table 55–1—Control codes

Control character	Notation	XGMII control codes	10GBASE-T control codes	10GBASE-T O code	8B/10B code[a]
idle	/I/	0x07	0x00		K28.0 or K28.3 or K28.5 without D20.5[b]
LPI	/LI/	0x06	0x06		K28.0 or K28.3 or K28.5 with D20.5[b]
start	/S/	0xFB	Encoded by block type field		K27.7
terminate	/T/	0xFD	Encoded by block type field		K29.7
error	/E/	0xFE	0x1E		K30.7
Sequence ordered set	/Q/	0x9C	Encoded by block type field plus O code	0x0	K28.4
reserved0	/R/[c]	0x1C	0x2D		K28.0
reserved1		0x3C	0x33		K28.1
reserved2	/A/	0x7C	0x4B		K28.3
reserved3	/K/	0xBC	0x55		K28.5
reserved4		0xDC	0x66		K28.6
reserved5		0xF7	0x78		K23.7
Signal ordered set[d]	/Fsig/	0x5C	Encoded by block type field plus O code	0xF	K28.2

[a]For information only. The 8B/10B code is specified in Clause 36. Usage of the 8B/10B code for 10 Gb/s operation is specified in Clause 48.
[b]Use of idle and LPI ordered sets per 48.2.4.2.
[c]The codes for /A/, /K/, and /R/ are used on the XAUI interface to signal idle. They are not present on the XGMII when no errors have occurred, but certain bit errors cause the XGXS to send them on the XGMII.
[d]Reserved for INCITS T11 Fibre Channel use.

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55.3.2.2.10 LPI (/LI/)

Low power idle (LPI) control characters (/LI/) on the XGMII indicate that the LPI client is requesting operation in the LPI transmit mode. A continuous stream of LPI control characters (/LI/) is used to maintain a link in the LPI transmit mode. Idle control characters (/I/) are used to transition from the LPI transmit mode to the normal mode. EEE compliant PHYs respond to the LPI XGMII control characters using the

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procedure outlined in 55.1.3.3. LPI characters may be added or deleted by the PCS to adapt between clock rates. /LI/ insertion and deletion shall occur in groups of four. /LI/s may be added following low power idle characters. They shall not be added while data is being received.

If EEE is not supported, then /LI/ is not a valid control character.

55.3.2.2.11 Start (/S/)

The start control character (/S/) indicates the start of a packet. This delimiter is only valid on the first octet of the XGMII (TXD<0:7> and RXD<0:7>). Receipt of an /S/ on any other octet of TxD indicates an error. Block type field values implicitly encode an /S/ as the fifth or first character of the block. These are the only characters of a block on which a start can occur.

55.3.2.2.12 Terminate (/T/)

The terminate control character (/T/) indicates the end of a packet. Since packets may be any length, the /T/ can occur on any octet of the XGMII interface and within any character of the block. The location of the /T/ in the block is implicitly encoded in the block type field. A valid end of packet occurs when a block containing a /T/ is followed by a control block that does not contain a /T/.

55.3.2.2.13 ordered set (/O/)

The ordered set control characters (/O/) indicate the start of an ordered set. There are two kinds of ordered sets: the sequence ordered set and the signal ordered set (which is reserved). When it is necessary to designate the control character for the sequence ordered set specifically, /Q/ is used. /O/ is only valid on the first octet of the XGMII. Receipt of an /O/ on any other octet of TXD indicates an error. Block type field values implicitly encode an /O/ as the first or fifth character of the block. The 4-bit O code encodes the specific /O/ character for the ordered set.

Sequence ordered sets may be deleted by the PCS to adapt between clock rates. Such deletion shall only occur when two consecutive sequence ordered sets have been received and shall delete only one of the two. Only Idles may be inserted for clock compensation. Signal ordered sets are not deleted for clock compensation.

55.3.2.2.14 Error (/E/)

The /E/ is sent whenever an /E/ is received. It is also sent when invalid blocks are received. The /E/ allows physical sublayers such as the XGXS and PCS to propagate received errors. See R_BLOCK_TYPE and T_BLOCK_TYPE function definitions in 55.3.6.2.4 for further information.

55.3.2.2.15 Transmit process

The transmit process generates blocks based upon the TXD<31:0> and TXC<3:0> signals received from the XGMII. Two XGMII data transfers are encoded into each block. It takes 256 PMA_UNITDATA transfers to send an LDPC frame of data. Therefore, if the PCS is connected to an XGMII and PMA sublayer where the ratio of their transfer rates is exactly 25:64, then the transmit process does not need to perform rate adaptation. Where the XGMII and PMA sublayer data rates are not synchronized to that ratio, the transmit process needs to insert idles, delete idles, or delete sequence ordered sets to adapt between the rates.

The transmit process generates blocks as specified in the transmit process state diagram. The contents of each block are contained in a vector tx_coded<64:0>, which is passed to the scrambler. tx_coded<0> contains the data/ctrl header and the remainder of the bits contain the block payload.

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55.3.2.2.16 PCS scrambler

The payload of the PCS PHY frame is scrambled with a self-synchronizing scrambler. The scrambler for the MASTER shall produce the same result as the implementation shown in Figure 55–10. This implements the scrambler polynomial:[21]

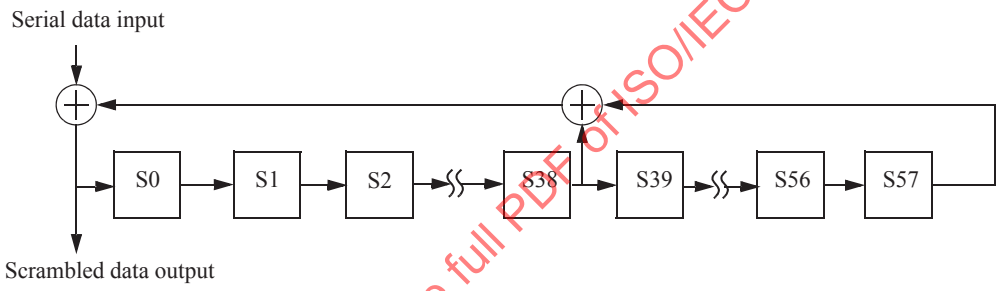
$$G(x) = 1 + x^{39} + x^{58} \quad (55–1)$$

The scrambler for the SLAVE shall produce the same result as the implementation shown in Figure 55–10. This implements the scrambler polynomial:

$$G(x) = 1 + x^{19} + x^{58} \quad (55–2)$$

The initial seed values for the MASTER and SLAVE are left to the implementer. The scrambler is run continuously on all payload bits.

PCS scrambler employed by the MASTER



PCS scrambler employed by the SLAVE

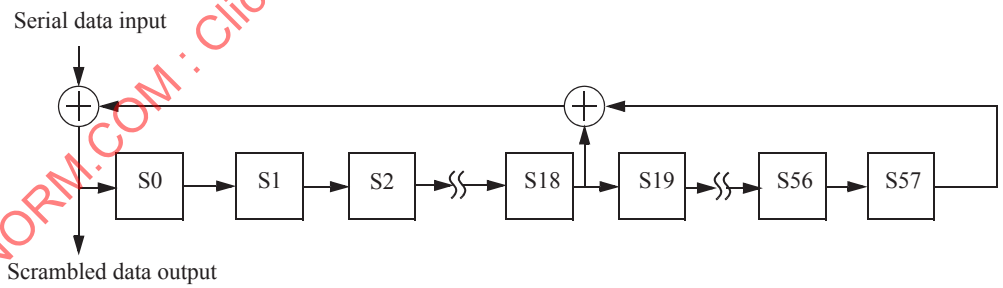


Figure 55–10—MASTER and SLAVE PCS scramblers

[21]The convention here, which considers the most recent bit into the scrambler to be the lowest order term, is consistent with most references and with other scramblers shown in this standard. Some references consider the most recent bit into the scrambler to be the highest order term and would therefore identify this as the inverse of the polynomial in Equation (55–1). In case of doubt, note that the conformance requirement is based on the representation of the scrambler in the figure rather than the polynomial equation.

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55.3.2.2.17 CRC8

The aggregated 50 65B blocks shall be used to calculate the cyclic redundancy check parity bits for each PHY frame. The parity bits are generated by the following CRC8 cyclic generator polynomial:

$$C(x) = 1 + x + x^5 + x^6 + x^8 \quad (55–3)$$

The CRC8 shall produce the same result as the implementation shown in Figure 55–11. In Figure 55–11 the 8 delay elements S0,..., S7, shall be initialized to zero. Afterwards the 50 65B blocks of serial data input are used to compute the CRC8 with the switch connected, which is setting CRCgen in Figure 55–11. After all the 50 65B blocks have been processed, the switch is disconnected (setting CRCout) and the 8 values stored in the delay elements are transmitted in the order illustrated, first S7, followed by S6, and so on until the final value S0.

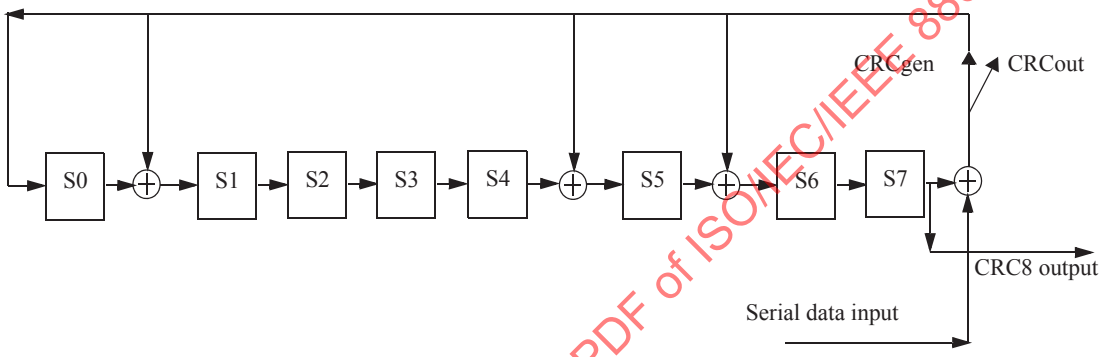

Figure 55–11—CRC8

55.3.2.2.18 LDPC encoder

The resulting payload of scrambled 50 65B blocks, followed by the corresponding 8 bits from the CRC8 and preceded by 1 auxiliary bit results in a total payload of 50 × 65 + 8 +1 = 3259 bits. The use of this bit for vendor-specific communication is outside the scope of this document. For the purposes of this standard it is ignored by the link partner. From the total payload of 3259 bits, 1536 (3 bits for each of the 512 DSQ128 symbols) are uncoded bits and the remaining 1723 shall be encoded by the LDPC(1723, 2048) generator matrix G. G is described in Annex 55A.

The LPDC encoding takes the 1723 bit input code vector $x = [x_0\ x_1\ x_2\ ...\ x_{1722}]$, and shall generate the 2048 bit codeword c represented by the matrix multiplication $c = x \times G$. For both x and c the encoder shall follow the notation described in 55.3.2.2.3 where the LSB (leftmost element of the vectors x and c) is the first bit into the LDPC encoder and the first transmitted bit.

55.3.2.2.19 DSQ128 bit mapping

DSQ128 refers to a two dimensional constellation with 128 possible 2D values, such that the combined 2D symbol carries $\log_2(128)$ or 7 bits. The PHY frame of 1536 uncoded bits and 2048 (LDPC output) coded bits described in Figure 55–6 shall be partitioned into 7-bit groups of (3 uncoded, 4 coded) as described in Figure 55–8. The bit partition is as follows, the first 1290 (3 × 430) uncoded bits are paired with the first 1720 (4 × 430) LDPC input bits. The following 3 uncoded bits are paired with the last 3 LDPC input bits and the first LDPC parity bit. Finally the remaining 243 (3 × 81) uncoded bits are paired with the remaining 324 (4 × 81) LDPC parity bits.

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Each 2D-DSQ128 value has two PAM16 components denoted $PAM16_1$ and $PAM16_2$ respectively. The DSQ128 can be constructed by pruning the 256 values of a 2D-PAM16 where every other point in 2D is discarded (like the black or white squares in a checkerboard). The PAM16 components $PAM16_1$ and $PAM16_2$ can each take any of the values from the set {–15, –13, –11, –9, –7, –5, –3, –1, 1, 3, 5, 7, 9, 11, 13, 15}. The mapping from 7 bits where $u_0\ u_1\ u_2$ denote the 3 uncoded bits and $c_0\ c_1\ c_2\ c_3$ denote the 4 coded bits to the DSQ128 is described by the following four steps (the bits from the scrambler output shall be read LSB first):

Step 1:

$x_{13} = (!u_0)\ \&\ u_2$

$x_{12} = u_0\ \text{XOR}\ u_2$

$x_{11} = c_0$

$x_{10} = c_0\ \text{XOR}\ c_1$

$x_{23} = (u_1\ \&\ u_2)\ \text{OR}\ (u_0\ \&\ !u_1)$

$x_{22} = u_1\ \text{XOR}\ u_2$

$x_{21} = c_2$

$x_{20} = c_2\ \text{XOR}\ c_3$

Step 2:

$x_1 = 8x_{13} + 4x_{12} + 2x_{11} + x_{10}$

$x_2 = 8x_{23} + 4x_{22} + 2x_{21} + x_{20}$

Step 3:

$y_1 = (x_1 + x_2)\ \text{mod16}$

$y_2 = (-x_1 + x_2)\ \text{mod16}$

Step 4:

$PAM16_1 = 2y_1 - 15$

$PAM16_2 = 2y_2 - 15$

where '*n* mod16' for an integer *n*, is defined as the integer value *p* in the range 0 to 15 (both inclusive) such that '$p = n + 16m$', for some integer *m*.

55.3.2.2.20 DSQ128 to 4D-PAM16

The DSQ mapper generates 512 2D-DSQ128 symbols per LDPC frame that are mapped onto 256 4D-PAM16 symbols prior to sending to the PMA via PMA_UNITDATA.request. The mapping of DSQ128 to 4D-PAM16 is illustrated in Figure 55–6. As shown in Figure 55–6, the two PAM16 components of each DSQ128 symbol are mapped onto two consecutive time periods on the same wire pair.

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55.3.2.2.21 65B-LDPC framer

The 65B-LDPC framer adapts between the 65-bit width of the 65B blocks and the 4D-PAM16 width of the PMA. When the transmit channel is operating in normal mode, the 65B-LDPC sends four PAM16 of transmit data at a time via PMA_UNITDATA.request primitives. The PMA_UNITDATA.request primitives are fully packed with bits.

55.3.2.2.22 EEE capability

The optional 10GBASE-T EEE capability allows compliant PHYs to transition to an LPI mode of operation when link utilization is low.

EEE compliant PHYs shall implement the EEE transmit state diagram, shown in Figure 55–20, within the PCS.

When PCS_Reset is asserted or pcs_data_mode is not asserted, the state diagram enters the TX_NORMAL state.

When a complete 64B/65B block of LPI characters is generated by the PCS transmit function, the PHY transmits the sleep signal to indicate to the link partner that it is transitioning to the LPI transmit mode. If the sleep signal begins on an LDPC frame boundary, then it contains 9 full LDPC frames each composed entirely of 64B/65B LDPC-encoded LP_IDLE blocks. If the sleep signal does not begin on an LDPC frame boundary, then it contains one LDPC frame partially composed of LP_IDLE blocks followed by 9 LDPC frames fully composed of LP_IDLE blocks.

Following the transmission of the sleep signal, quiet-refresh signaling begins, as described in 55.3.5.

After the sleep signal is transmitted LPI control characters shall be input to the PCS scrambler continuously until the PCS Transmit Function exits the LPI transmit mode.

While the PMA asserts SEND_N, the lpi_tx_mode variable shall control the transmit signal through the PMA_UNITDATA.request primitive described as follows:

> When the PHY is not in the PCS_Data state, the lpi_tx_mode variable is ignored.
>
> When the lpi_tx_mode variable takes the value NORMAL and the PMA asserts SEND_N, the PCS passes coded data to the PMA via the PMA_UNITDATA.request primitive as described in 55.3.2.2.
>
> When the lpi_tx_mode variable takes the value QUIET and the PMA asserts SEND_N, the PCS passes zeros to the PMA through the PMA_UNITDATA.request primitive.
>
> When the lpi_tx_mode variable takes the value REFRESH_A and the PMA asserts SEND_N, the PCS passes the PMA training signal to the PMA on pair A, to allow both the local and remote PHY to refresh adaptive filters and timing loops. The PCS passes zeros to all other pairs in this condition. REFRESH_B, REFRESH_C and REFRESH_D operate in a analogous manner for the other pairs.
>
> When the lpi_tx_mode variable takes the value ALERT and the PMA asserts SEND_N, the PCS passes the ALERT vector to the PMA.

The quiet-refresh cycle is repeated until codewords other than LP_IDLE are detected at the XGMII. These codewords indicate that the local system is requesting a transition back to the normal operational mode. Following this event, the PMA_UNITDATA.request message is set to the value ALERT. The alert signal is not synchronized with respect to the quiet-refresh cycle but shall be synchronized so that the alert signal from the PMA begins on a LDPC frame boundary.

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The PHY will also transition back to the normal operation mode if an error condition occurs. This error condition is defined as the detection of any characters other than LPI or IDLE at the XGMII.

After the alert signal the PCS completes the transition from LPI mode to normal mode by sending a wake signal containing lpi_wake_time LDPC frames composed of IDLE 64B/65B blocks.

lpi_wake_time is a fixed parameter that is defined as 9 LDPC frames as shown in Table 55–2. The maximum PHY wake time when wake is requested before sleep has been completely transmitted is 7.36 µs (lpi_wake_timer=T_{w_phy} as defined by Clause 78). The maximum PHY wake time when wake is requested after sleep has been completely transmitted is 4.48 µs.

Table 55–2—LPI wake time

lpi_wake_time	lpi_wake_timer when wake starts before sleep signal is complete		lpi_wake_timer when wake starts after sleep signal is complete	
(frames)	(frames)	(µs)	(frames)	(µs)
9	23	7.36	14	4.48

55.3.2.3 PCS Receive function

The PCS Receive function shall conform to the PCS 64B/65B receive state diagram in Figure 55–18 and the PCS Receive bit ordering in Figure 55–7 including compliance with the associated state variables as specified in 55.3.6.

The PCS Receive function accepts received code-groups provided by the PMA Receive function via the parameter rx_symb_vector. The PCS receiver uses knowledge of the encoding rules to correctly align the 65B-LDPC frames. The received 65B-LDPC frames are decoded with error correction; the CRC8 and framing is checked; and the 64B/65B ordered sets are converted to 64-bit data blocks to obtain the signals RXD<31:0> and RXC<3:0> for transmission to the XGMII. Two XGMII data transfers are decoded from each block. Where the XGMII and PMA sublayer data rates are not synchronized to a 25:64 ratio, the receive process inserts idles, delete idles, or delete sequence ordered sets to adapt between rates.

During PMA training mode, PCS Receive checks the received PAM2 framing and signals the reliable acquisition of the descrambler state by setting the parameter scr_status to OK.

When the PCS Synchronization process has obtained synchronization, the LDPC frame error ratio (LFER) monitor process monitors the signal quality asserting hi_lfer if excessive LDPC frame errors are detected (LDPC parity error or CRC8 error). If 40 consecutive LDPC frame errors are detected, the block_lock flag is de-asserted. When block_lock is asserted and hi_lfer is de-asserted, the PCS Receive process continuously accepts blocks. The PCS Receive process monitors these blocks and generates RXD <31:0> and RXC <3:0> on the XGMII.

When the receive channel is in training mode, the PCS Synchronization process continuously monitors PMA_RXSTATUS.indication (loc_rcvr_status). When loc_rcvr_status indicates OK, then the PCS Synchronization process accepts data-units via the PMA_UNITDATA.request primitive. It attains frame and block synchronization based on the PMA training frames and conveys received blocks to the PCS Receive process. The PCS Synchronization process sets the block_lock flag to indicate whether the PCS has obtained synchronization. The PMA training sequence includes 1 bit pattern on pair A every 256 PAM2 symbols, which is aligned with the PCS PHY frame boundary. When the PCS Synchronization process is synchronized to this pattern, block_lock is asserted.

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PHYs with the EEE capability support transition to the LPI mode when the PHY has successfully completed training and pcs_data_mode is TRUE. Transitions to and from the LPI mode are allowed to occur independently in the transmit and receive functions. The PCS receive function is responsible for detecting transitions to and from the LPI receive mode and indicating these transitions using signals defined in 55.2.2.

The link partner signals a transition to the LPI mode of operation by transmitting 9 LDPC frames composed entirely of 64B/65B blocks of /LI/. When blocks of /LI/ are detected at the output of the 64B/65B decoder, rx_lpi_active is asserted by the PCS receive function and the /LI/ character is continuously asserted at the receive XGMII. These frames may be preceded by a frame composed partially of /LI/ characters. After these frames the link partner begins transmitting zeros, and it is recommended that the receiver power down receive circuits to reduce power consumption. The receive function uses LDPC frame counters to maintain synchronization with the remote PHY and receives periodic refresh signals that are used to update coefficients, so that the integrity of adaptive filters and timing loops in the PMA is maintained. LPI signaling is defined in 55.3.5. The quiet-refresh cycle continues until the PMA asserts alert_detect to indicate that the alert signal has been reliably detected. After the alert signal the link partner transmits repeated /I/ characters, representing a wake signal. The PHY receive function sends /I/ to the XGMII for 9 LDPC frame periods and then resumes normal operation.

55.3.2.3.1 Frame and block synchronization

When the receive channel is operating in normal mode, the frame and block synchronization function receives data via 4D-PAM16 PMA_UNITDATA.request primitives. It shall form a 4D-PAM16 stream from the primitives by concatenating requests with the PAM16s of each primitive in order from rx_data-group<0> to rx_data-group<255> (see Figure 55–7). It obtains block_lock to the LDPC frames during the PAM2 training pattern using synchronization bits provided on pair A. The 65-bit blocks are extracted based on their location in the LDPC frame.

55.3.2.3.2 PCS descrambler

The descrambler processes the payload to reverse the effect of the scrambler using the same polynomial. It shall produce the same result as the implementations shown in Figure 55–12 for the MASTER and the SLAVE.

55.3.2.3.3 CRC8 receive function

The PCS Receive function shall check the integrity of the CRC8 parity bits defined in 55.3.2.2.17. If the CRC check fails the PHY frame is invalid.

The PCS Receive function may decode and check the CRC8 parity bits simultaneous to resolving the LDPC error correction function. It is recommended that the PCS receiver not use the CRC8 parity check code to assist the LDPC convergence.

55.3.3 Test-pattern generators

The test-pattern generator mode is provided for enabling joint testing of the local transmitter, the channel and remote receiver. When the transmit PCS is operating in test-pattern mode it shall transmit continuously as illustrated in Figure 55–6, with the input to the scrambler set to zero and the initial condition of the scrambler set to any non-zero value. When the receiver PCS is operating in test-pattern mode it shall receive continuously as illustrated in Figure 55–7. After acquiring the self-synchronizing scrambler state, the output of the received scrambled values should ideally be zero. Any nonzero values correspond to receiver bit errors. This mode is further described as test mode 7 in 55.5.2

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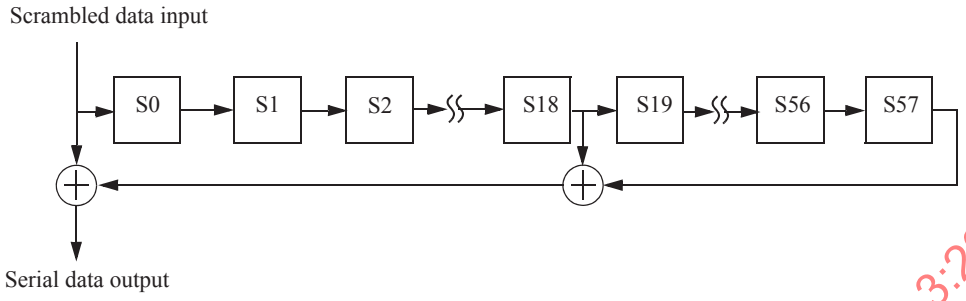
PCS descrambler employed by the MASTER



PCS descrambler employed by the SLAVE

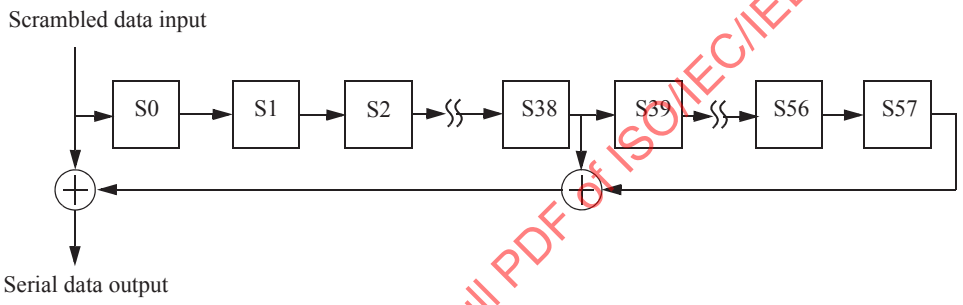


Figure 55–12—MASTER and SLAVE PCS descramblers

55.3.4 PMA training side-stream scrambler polynomials

The PCS Transmit function employs side-stream scrambling for generating 2-level PAM PMA training sequences as shown in Figure 55–13. An implementation of MASTER and SLAVE PHY side-stream scramblers is shown in the "Main PN sequence" box. The bits stored in the shift register delay line at time *n* are denoted by $Scr_n[32:0]$. At each symbol period, the shift register is advanced by one bit, and one new bit represented by $Scr_n[0]$ is generated. The transmitter side-stream scrambler is reset upon execution of the PCS Reset function. If PCS Reset is executed, all bits of the 33-bit vector representing the side-stream scrambler state are arbitrarily set. The initialization of the scrambler state is left to the implementer. In no case shall the scrambler state be initialized to all zeros.

Moreover during Auto-Negotiation each transceiver may request the remote transceiver to reinitialize the values of its scrambler state after every 16384 symbol periods, to generate a periodically repeating pattern with repetition period 16384. The initial 33-bit values of the scrambler state shall be generated by combining 0x39A422 for the 22 MSBs and random value SB10-SB0 from Table 55–15 generated by the local device for the 11 LSBs as shown in Figure 55–13.

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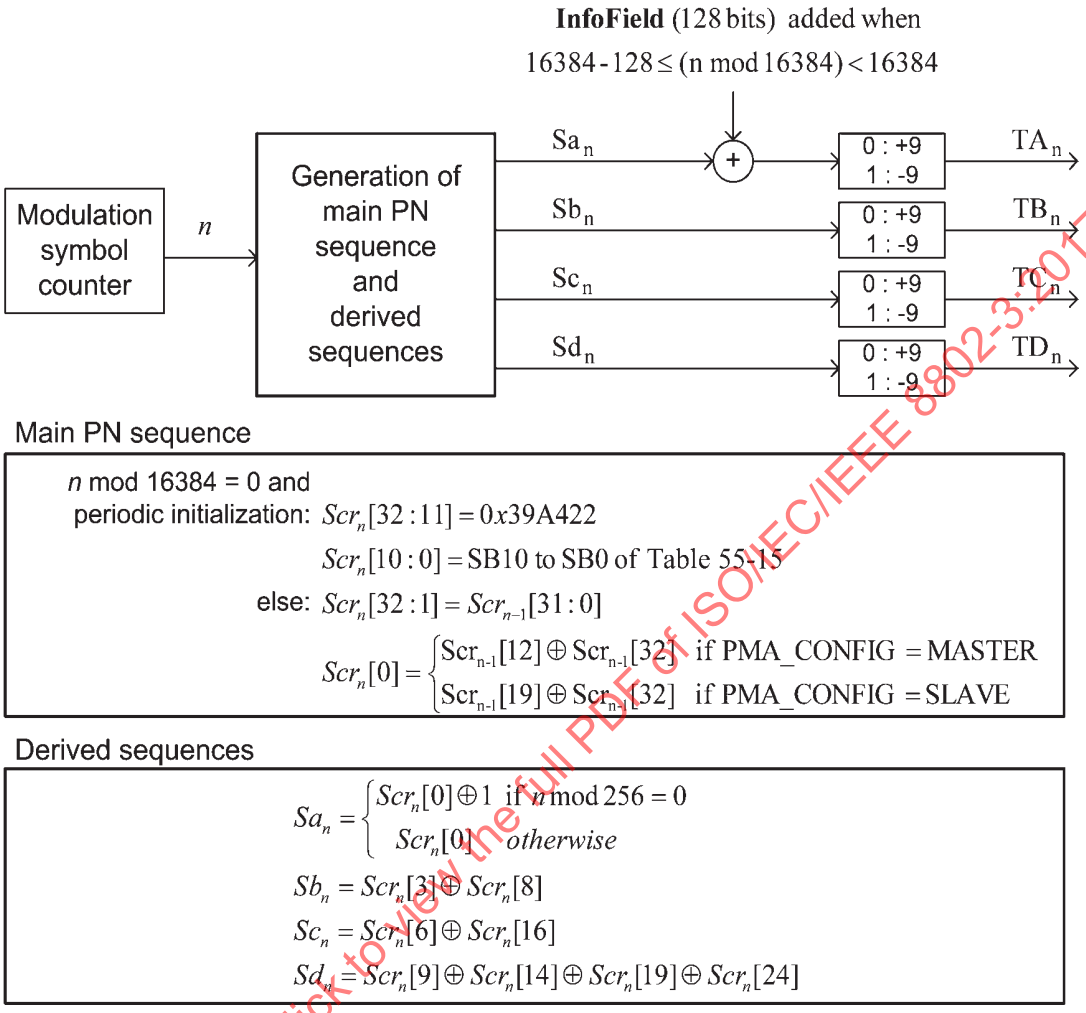

Figure 55–13—A realization of PMA training PAM2 sequences

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55.3.4.1 Generation of bits Sa_n, Sb_n, Sc_n, Sd_n

PMA training signal encoding rules are based on the generation, at time n, of the four bits Sa_n, Sb_n, Sc_n, Sd_n. These four bits are generated in a systematic fashion using the bits in $Scr_n[32:0]$, and an auxiliary generating polynomial. For both MASTER and SLAVE PHYs, they are obtained by the same linear combinations of bits stored in the transmit scrambler shift register delay line. These four bits are derived from elements of the same maximum-length shift register sequence of length $2^{33}–1$ as $Scr_n[0]$, but shifted in time. The associated delays are all large and different so that there is no short-term correlation among the bits Sa_n, Sb_n, Sc_n, Sd_n. The four bits are generated using the bit $Scr_n[0]$ and the equations in Figure 55–13 in the "Derived sequences" box.

55.3.4.2 Generation of 4D symbols TA_n, TB_n, TC_n, TD_n

The four bits Sa_n, Sb_n, Sc_n, Sd_n are mapped to a 4D symbol (TA_n, TB_n, TC_n, TD_n) as shown in Figure 55–13.

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The inversion on pair A at 256 intervals ($n = k \times 256, k = 0, 1, 2, \ldots$) defines the LDPC boundary during data mode. If requested by the link partner, the PCS shall reset the training mode scrambler every 16384 periods aligned with the 256 symbol period inversion on pair A, which corresponds to the time instants $n = m \times 16384, m = 0, 1, 2, \ldots$

Notice that over the repeating time intervals of 16384 and of length 128, $m \times 16384 - 128 \le n < m \times 16384, m = 1, 2, 3, \ldots$, the PMA training pattern in pair A is XOR'ed with the InfoField. Thus, pair A transmits the InfoField, which communicates to the remote transceiver settings of THP and power backoff and other control information.

55.3.4.3 PMA training mode descrambler polynomials

The PHY shall acquire descrambler state synchronization to the PAM2 training sequence and report success through scr_status. For side-stream descrambling, the MASTER PHY shall employ the receiver descrambler generator polynomial $g'_M(x) = 1 + x^{20} + x^{33}$ and the SLAVE PHY shall employ the receiver descrambler generator polynomial $g'_S(x) = 1 + x^{13} + x^{33}$.

55.3.5 LPI signaling

PHYs with EEE capability have transmit and receive functions that can enter and leave the LPI mode independently. The PHY can transition to the LPI mode when the PHY has successfully completed training and pcs_data_mode is TRUE. The transmit function of the PHY initiates a transition to the LPI transmit mode when it generates 64B/65B blocks composed entirely of LPI control characters, as described in 55.3.2.2.22. The transmit function of the link partner signals the transition using the sleep signal. When the transmitter begins to send the sleep signal, it asserts tx_lpi_active and the transmit function enters the LPI transmit mode.

Within the LPI mode PHYs use a repeating quiet-refresh cycle (see Figure 55–14). The first part of this cycle is known as the quiet period and lasts for a time lpi_quiet_time equal to 124 LDPC frame periods. The quiet period is defined in 55.3.5.2. The second part of this cycle is known as the refresh period and lasts for a time lpi_refresh_time equal to 4 LDPC frame periods. The refresh period is defined in 55.3.5.3. A cycle composed of one quiet period and one refresh period is known as a single pair LPI cycle and lasts for a time lpi_qr_time equal to 128 LDPC frame periods. The time taken to complete a quiet-refresh cycle for all four pairs is known as a complete LPI cycle.

lpi_offset, lpi_quiet_time, lpi_refresh_time, lpi_qr_time, and lpi_allpairs_qr_time are timing parameters that are integer multiples of the LDPC frame period. lpi_offset is a fixed value equal to lpi_qr_time/2 that is used to ensure refresh signals are appropriately offset by the link partners.

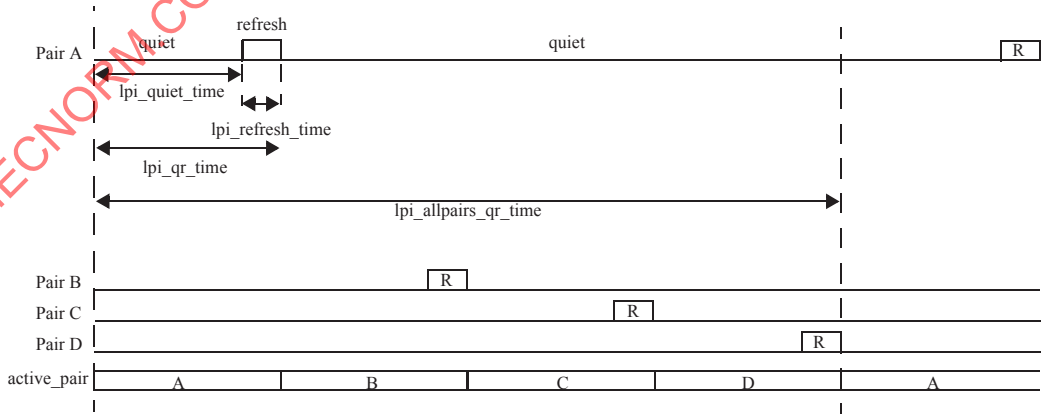

Figure 55–14—Timing periods for LPI signals

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PHYs begin the transition from the LPI receive mode when the alert signal is detected by the PMA as defined in 55.4.2.4.

55.3.5.1 LPI Synchronization

To maximize power savings, maintain link integrity, and ensure interoperability, EEE-capable PHYs must synchronize refresh intervals during the LPI mode. The transition to PCS_Test is used as a fixed timing reference for the link partners. Refresh signaling is derived by counting LDPC frames from the transition to PCS_Test. An EEE-capable PHY shall support loop timing and loop timing shall be enabled on the slave PHY.

In initial training, normal retraining, and fast retraining, with or without the EEE capability being supported, the master and slave signal when they will transition to PCS_Test using the transition counter following the procedure described in 55.4.2.5.14.

A EEE-capable PHY in slave mode is responsible for synchronizing its PMA training frame to the master's PMA training frame during the transition to PMA_Training_Init_S. The slave shall ensure that its PMA training frames are synchronized to the master's PMA training frames within 1 LDPC frame, measured at the slave MDI on pair A. In addition, the slave shall initialize its transition counter so that it transitions to PCS_Test within 1 LDPC frame of the master PHY's transition to PCS_Test, measured at the slave PHY's MDI on pair A. This mechanism ensures that the refresh offset is bounded to a small value at both MDI interfaces, thus ensuring there is no overlap of master and slave signals when both transmit and receive are in the LPI mode.

Following the transition to PCS_Test, the PCS counts transmitted and received LDPC frames, and uses these counters to generate refresh and pair control signals for the transmit and receive functions. The transmitted LDPC frame count is named tx_ldpc_frame_cnt. The received LDPC frame count is named rx_ldpc_frame_cnt.

The master and slave shall derive the active pair and refresh_active signals from the LDPC frame counters as shown in Table 55–3 and Table 55–4.

Table 55–3—Synchronization logic derived from slave signal LDPC frame count

Slave-side variable	Master-side variable	for master u=rx_ldpc_frame_cnt for slave u=tx_ldpc_frame_cnt
tx_refresh_active=true	rx_refresh_active=true	lpi_offset – lpi_refresh_time ≤ mod(u,lpi_qr_time) < lpi_offset
tx_lpi_full_refresh=true	N/A	lpi_offset – lpi_refresh_time = mod(u,lpi_qr_time)
tx_active_pair=PAIR_A	rx_active_pair=PAIR_A	lpi_offset + lpi_qr_time ≤ u < lpi_offset + 2 x lpi_qr_time
tx_active_pair=PAIR_B	rx_active_pair=PAIR_B	lpi_offset + 2 x lpi_qr_time ≤ u < lpi_offset + 3 x lpi_qr_time
tx_active_pair=PAIR_C	rx_active_pair=PAIR_C	lpi_offset + 3 x lpi_qr_time ≤ u < 4 x lpi_qr_time OR 0 ≤ u < lpi_offset
tx_active_pair=PAIR_D	rx_active_pair=PAIR_D	lpi_offset ≤ u < lpi_offset + lpi_qr_time

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Table 55–4—Synchronization logic derived from master signal LDPC frame count

Slave-side variable	Master-side variable	for master v=tx_ldpc_frame_cnt for slave v=rx_ldpc_frame_cnt
rx_refresh_active=true	tx_refresh_active=true	lpi_quiet_time ≤ mod(v,lpi_qr_-time)
N/A	tx_lpi_full_refresh=true	lpi_quiet_time = mod(v,lpi_qr_-time)
rx_active_pair=PAIR_A	tx_active_pair=PAIR_A	0 ≤ v < lpi_qr_time
rx_active_pair=PAIR_B	tx_active_pair=PAIR_B	lpi_qr_time ≤ v < 2 x lpi_qr_time
rx_active_pair=PAIR_C	tx_active_pair=PAIR_C	2 x lpi_qr_time ≤ v < 3 x lpi_qr_-time
rx_active_pair=PAIR_D	tx_active_pair=PAIR_D	3 x lpi_qr_time ≤ v < 4 x lpi_qr_-time

55.3.5.2 Quiet period signaling

During the quiet period the transmitters on all four pairs should be turned off. Average launch power (as measured from 28 LDPC frames after a refresh period to 28 LDPC frames before the next refresh period on the same lane) for each Transmitter shall be less than –41dBm. This requirement does not apply to the periods when the alert signal is transmitted as defined in 55.4.2.2.1.

55.3.5.3 Refresh period signaling

During the LPI mode 10GBASE-T PHYs use staggered, out-of-phase refresh signaling to maximize power savings. Two-level PAM refresh symbols are generated using the PMA side-stream scrambler polynomials described in 55.3.4 and exactly as is shown in Figure 55–13 with the exception that the InfoField consists of a sequence of 128 zeros. The training sequence without periodic reinitialization described in 55.3.4 shall be used during the LPI mode, with the scramblers free-running from PCS Reset. If scrambler reinitialization is used for normal training, it shall be disabled and the scramblers shall begin free-running when the PHY Control state diagram enters the PCS_Test state.

Refresh signals shall be sent using the THP filter as described in 55.4.3.1. At the start of each refresh signal the THP feedback delay line shall be initialized with zeros.

While a transmit function is in the LPI transmit mode only one of the transmit pairs will be active during a refresh period. tx_symb_vector for all transmit pairs that are not active shall be set to zero.

When tx_symb_vector has the value ALERT and the PHY is master, the transmitter on pair A shall be active and all other pairs shall be quiet. When tx_symb_vector has the value ALERT and the PHY is slave, the transmitter on pair C shall be active and all other pairs shall be quiet. If lpi_tx_mode=REFRESH_A on a MASTER PHY or lpi_tx_mode=REFRESH_C on a SLAVE PHY, and tx_symb_vector has the value ALERT, then the alert signaling shall be transmitted in place of the refresh signaling where the signals overlap.

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55.3.6 Detailed functions and state diagrams

55.3.6.1 State diagram conventions

The body of this subclause is comprised of state diagrams, including the associated definitions of variables, constants, and functions. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

The notation used in the state diagrams follows the conventions of 21.5. State diagram timers follow the conventions of 14.2.3.2. The notation ++ after a counter or integer variable indicates that its value is to be incremented.

55.3.6.2 State diagram parameters

55.3.6.2.1 Constants

EBLOCK_R<71:0>
: 72 bit vector to be sent to the XGMII interface containing /E/ in all the eight character locations.

EBLOCK_T<64:0>
: 65 bit vector to be sent to the LDPC encoder containing /E/ in all the eight character locations.

LBLOCK_R<71:0>
: 72 bit vector to be sent to the XGMII interface containing two Local Fault ordered sets. The Local Fault ordered set is defined in 46.3.4.

LBLOCK_T<64:0>
: 65 bit vector to be sent to the LDPC encoder containing two Local Fault ordered sets.

LPBLOCK_R<71:0>
: 72 bit vector to be sent to the XGMII containing /LI/ in all the eight character locations.

LPBLOCK_T<64:0>
: 65 bit vector to be sent to the LDPC encoder containing /LI/ in all the eight character locations.

IBLOCK_R<71:0>
: 72 bit vector to be sent to the XGMII containing /I/ in all the eight character locations.

IBLOCK_T<64:0>
: 65 bit vector to be sent to the LDPC encoder containing /I/ in all the eight character locations.

UBLOCK_R<71:0>
: 72 bit vector to be sent to the XGMII containing two Link Interruption ordered sets. The Link Interruption ordered set is defined in 46.3.4.

55.3.6.2.2 Variables

lfer_test_lf
: Boolean variable that is set true when a new LDPC frame is available for testing and false when LFER_TEST_LF state is entered. A new LDPC frame is available for testing when the Block Sync process has accumulated enough symbols from the PMA to evaluate the next LDPC frame.

block_lock
: Boolean variable that is set true when receiver acquires block delineation.

hi_lfer
: Boolean variable which is asserted true when the lfer_cnt exceeds 16 indicating a bit error ratio > 4×10^{-4}.

pcs_reset
: Boolean variable that controls the resetting of the PCS. It is true whenever a reset is necessary

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including when reset is initiated from the MDIO, during power on, and when the MDIO has put the PCS into low-power mode.

rx_coded<64:0>
: Vector containing the input to the 64B/65B decoder. The format for this vector is shown in Figure 55–9. The leftmost bit in the figure is rx_coded<0> and the rightmost bit is rx_coded<64>.

rx_raw<71:0>
: Vector containing two successive XGMII output transfers. RXC<0> through RXC<3> for the first transfer are taken from rx_raw<0> through rx_raw<3>, respectively. RXC<0> through RXC<3> for the second transfer are taken from rx_raw<4> through rx_raw<7>, respectively. RXD<0> through RXD<31> for the first transfer are taken from rx_raw<8> through rx_raw<39>, respectively. RXD<0> through RXD<31> for the second transfer are taken from rx_raw<40> through rx_raw<71>, respectively.

lf_valid
: Boolean indication that is set true if received LDPC frame is valid. LDPC frame is valid if:
  a. All parity checks of the coded bits are satisfied
  b. CRC8 check is satisfied

tx_coded<64:0>
: Vector containing the output from the 64B/65B encoder. The format for this vector is shown in Figure 55–9. The leftmost bit in the figure is tx_coded<0> and the rightmost bit is tx_coded<64>.

tx_raw<71:0>
: Vector containing two successive XGMII transfers. TXC<0> through TXC<3> for the first transfer are placed in tx_raw<0> through tx_raw<3>, respectively. TXC<0> through TXC<3> for the second transfer are placed in tx_raw<4> through tx_raw<7>, respectively. TXD<0> through TXD<31> for the first transfer are placed in tx_raw<8> through tx_raw<39>, respectively. TXD<0> through TXD<31> for the second transfer are placed in tx_raw<40> through tx_raw<71>, respectively.

The following variables are required for PHYs that support the EEE capability:

tx_lpi_active
: A Boolean variable that is set true when the PHY transmit function is operating in the LPI transmit mode and during transitions to and from the LPI transmit mode (i.e., at any time when the PHY is transmitting sleep, alert, wake, or quiet-refresh signaling). It is set false otherwise.

tx_lpi_qr_active
: A Boolean variable that is set true during the LPI transmit mode, when the PHY is transmitting quiet-refresh signaling. Set false otherwise.

rx_lpi_active
: A Boolean variable that is set true when the PHY receive function is operating in the LPI receive mode and set false otherwise. The LPI receive mode begins when the sleep signal is detected and lasts until the alert signal is detected. When the EEE capability is not supported, rx_lpi_active is set false.

tx_lpi_req
: A Boolean variable that is set true when the LPI client indicates that it is requesting operation in the LPI transmit mode via the XGMII and set false otherwise.

alert_detect
: Indicates that an alert signal from the link partner has been received at the MDI as indicated by PMA_ALERTDETECT.indication(alert_detect).

tx_lpi_alert_active
: A Boolean variable that is set true when the PHY is transmitting ALERT signaling. Set false otherwise.

rx_lpi_wake
: A Boolean variable that is set true when the PHY receiver is in the WAKE state and sending IDLE to the XGMII. Set false otherwise. When the EEE capability is not supported, rx_lpi_wake is set false.

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tx_active_pair
: A variable indicating the transmit active pair during the LPI transmit mode. The variable may take the values PAIR_A, PAIR_B, PAIR_C, PAIR_D. This variable is defined in 55.3.5.1.

lpi_tx_mode
: A variable indicating the signaling to be used from the PCS to the PMA across the PMA_UNITDATA.request (tx_symb_vector) interface.
lpi_tx_mode controls tx_symb_vector only when tx_mode is set to SEND_N.
The variable is set to NORMAL when (!tx_lpi_qr_active * !tx_lpi_alert_active), indicating that the PCS is in the normal mode of operation and will encode code-groups as described in Figure 55–16 and Figure 55–17.
The variable is set to REFRESH_A when (tx_lpi_qr_active * (tx_active_pair==PAIR_A) * tx_refresh active).
The variable is set to REFRESH_B when (tx_lpi_qr_active * (tx_active_pair==PAIR_B) * tx_refresh active).
The variable is set to REFRESH_C when (tx_lpi_qr_active * (tx_active_pair==PAIR_C) * tx_refresh active).
The variable is set to REFRESH_D when (tx_lpi_qr_active * (tx_active_pair==PAIR_D) * tx_refresh active).
The variable is set to QUIET when (tx_lpi_qr_active * (!tx _refresh_active + tx_lpi_initial_quiet))
The variable is set to ALERT when (tx_lpi_alert_active)

tx_refresh_active
: A Boolean value. This variable is set true following the logic described in 55.3.5.1.

tx_lpi_full_refresh
: A Boolean value. This variable is set true following the logic described in 55.3.5.1.

tx_lpi_initial_quiet
: A Boolean value. This variable is set true when the transmit function enters the LPI transmit mode and a partial refresh will be replaced by quiet signaling.

ldpc_frame_done
: A Boolean value. This variable is set true when the final symbol of each LDPC frame is transmitted and is set false otherwise.

The following variable is only required for PHYs that support the fast retrain capability:

fr_sigtype
: If fast retrain is supported, this variable is set based on the value in 1.147.2:1 as follows:
00 IBLOCK_R
01 LBLOCK_R
10 UBLOCK_R
11 Reserved

55.3.6.2.3 Timers

State diagram timers follow the conventions described in 14.2.3.2.

125_ustimer:
: Timer that is triggered every 125 µs +1%, –25%.

The following timers are required for PHYs that support the EEE capability:

lpi_tx_sleep_timer
: This timer defines the time the local transmitter sends the sleep signal to the link partner.

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Values: The condition lpi_tx_sleep_timer_done becomes true upon timer expiration.
Duration: This timer shall have a period equal to 9 LDPC frame periods.

lpi_tx_alert_timer
This timer defines the time the local transmitter transmits the alert signal.
Values: The condition lpi_tx_alert_timer_done becomes true upon timer expiration.
Duration: This timer shall have a period equal to 4 LDPC frame periods.

lpi_tx_wake_timer:
This timer defines the time the local transmitter transmits the wake signal.
Values: The condition lpi_tx_wake_timer_done becomes true upon timer expiration.
Duration: This timer shall have a period equal to lpi_wake_time LDPC frame periods.

lpi_rx_wake_timer:
This timer defines the time the receiver sends IDLE blocks to the XGMII after the alert signal is detected.
Values: The condition lpi_rx_wake_timer_done becomes true upon timer expiration.
Duration: This timer shall have a period equal to lpi_wake_time LDPC frame periods.

55.3.6.2.4 Functions

DECODE(rx_symb_vector<64:0>)
In the PCS Receive process, this function takes as its argument 65-bit rx_coded<64:0> from the LDPC decoder and decodes the 65B-LDPC bit vector returning a vector rx_raw<71:0>, which is sent to the XGMII. The DECODE function shall decode the block based on code specified in 55.3.2.2.2.

ENCODE(tx_raw<71:0>)
Encodes the 72-bit vector received from the XGMII, returning 65 bit vector tx_coded. The ENCODE function shall encode the block as specified in 55.3.2.2.2.

R_BLOCK_TYPE = {C, S, T, D, E, I, LI, LII}
When the EEE capability is not supported, this function classifies each 65 bit rx_coded vector as belonging to one of the five types {C, S, T, D, E} depending on its contents.
When the EEE capability is supported, this function classifies each 65 bit rx_coded vector as belonging to the eight types depending on its contents. A vector may simultaneously belong to the C and I types when it contains eight valid control characters that are all /I/, but in every other case the vector belongs to only one type.
Values: C; The vector contains a data/ctrl header of 1 and one of the following:
a) A block type field of 0x1E and eight valid control characters other than /E/ and /LI/;
b) A block type field of 0x2D or 0x4B, a valid O code, and four valid control characters;
c) A block type field of 0x55 and two valid O codes.

S; The vector contains a data/ctrl header of 1 and one of the following:
a) A block type field of 0x33 and four valid control characters;
b) A block type field of 0x66 and a valid O code;
c) A block type field of 0x78.

T; The vector contains a data/ctrl header of 1, a block type field of 0x87, 0x99, 0xAA, 0xB4, 0xCC, 0xD2, 0xE1 or 0xFF and all control characters are valid.

D; The vector contains a data/ctrl header of 0.

I; If the optional EEE capability is supported, then the I type is a special case of the C type where the vector contains a data/ctrl header of 1, a block type field of 0x1e, and eight control characters of /I/.

LI: If the optional EEE capability is supported, then the LI type occurs when the vector contains a data/ctrl header of 1, a block type field of 0x1e, and eight control characters of /LI/.

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LII: If the optional EEE capability is supported, then the LII type occurs when the vector contains a data/ctrl header of 1, a block type field of 0x1E, and one of the following:
a) four control characters of /LI/ followed by four control characters of /I/;
b) four control characters of /I/ followed by four control characters of /LI/
E; The vector does not meet the criteria for any other value.

A valid control character is one containing a 10GBASE-T control code specified in Table 55–1. A valid O code is one containing an O code specified in Table 55–1.

R_TYPE(rx_coded<64:0>)
Returns the R_BLOCK_TYPE of the rx_coded<64:0> bit vector.

R_TYPE_NEXT
Prescient end of packet check function. It returns the R_BLOCK_TYPE of the rx_coded vector immediately following the current rx_coded vector.

T_BLOCK_TYPE = {C, S, T, D, E, I, LI, LII}
When the EEE capability is not supported, this function classifies each 72-bit tx_raw vector as belonging to one of the five types {C, S, T, D, E} depending on its contents.
When the EEE capability is supported, this function classifies each 72-bit tx_raw vector as belonging to the eight types depending on its contents. A vector may simultaneously belong to the C and I types when it contains eight valid control characters that are all /I/, but in every other case the vector belongs to only one type.
Values: C; The vector contains one of the following:
a) eight valid control characters other than /O/, /S/, /T/, /E/, and /LI/;
b) one valid ordered set and four valid control characters other than /O/, /S/ and /T/;
c) two valid ordered sets.
S; The vector contains an /S/ in its first or fifth character, any characters before the S character are valid control characters other than /O/, /S/ and /T/ or form a valid ordered set, and all characters following the /S/ are data characters.
T; The vector contains a /T/ in one of its characters, all characters before the /T/ are data characters, and all characters following the /T/ are valid control characters other than /O/, /S/ and /T/.
D; The vector contains eight data characters.
I; If the optional EEE capability is supported, then the I type is a special case of the C type where the vector contains eight control characters of /I/.
LI: If the optional EEE capability is supported, then the LI type occurs when the vector contains eight control characters of /LI/.
LII: If the optional EEE capability is supported, then the LII type occurs when the vector contains one of the following:
a) four control characters of /LI/ followed by four control characters of /I/;
b) four control characters of /I/ followed by four control characters of /LI/.
E; The vector does not meet the criteria for any other value.

A tx_raw character is a control character if its associated TXC bit is asserted. A valid control character is one containing an XGMII control code specified in Table 55–1. A valid ordered set consists of a valid /O/ character in the first or fifth characters and data characters in the three characters following the /O/. A valid /O/ is any character with a value for O code in Table 55–1.

T_TYPE(tx_raw<71:0>)
Returns the T_BLOCK_TYPE of the tx_raw<71:0> bit vector.

T_TYPE_NEXT
Prescient end of packet check function. It returns the FRAME_TYPE of the tx_raw vector immediately following the current tx_raw vector.

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55.3.6.2.5 Counters

lfer_cnt
: Count up to a maximum of 16 of the number of invalid LDPC frames within the current 125 μs period.

The following counters are required for PHYs that support the EEE capability:

tx_ldpc_frame_cnt
: An integer value that counts transmit LDPC frame periods. The counter is reset when the first symbol of the first LDPC frame crosses the MDI on pair A in the transmit direction after normal training or fast retraining. It is incremented after the last symbol of each transmitted LDPC frame. tx_ldpc_frame_cnt is reset to 0 when tx_ldpc_frame_cnt = lpi_qr_time x 4.

rx_ldpc_frame_cnt
: An integer value that counts receive LDPC frame periods. The counter is reset when the first symbol of the first LDPC frame crosses the MDI on pair A in the receive direction after normal training or fast retraining. It is incremented after the last symbol of each received LDPC frame. rx_ldpc_frame_cnt is reset to 0 when rx_ldpc_frame_cnt = lpi_qr_time x 4.

lpi_rxw_err_cnt
: An integer value that counts the number of receive wake on error conditions. lpi_rxw_err_cnt is reset to zero during PCS_Test. The counter is reflected in register 3.22 (see 45.2.3.10).

55.3.6.3 Messages

PMA_UNITDATA.indication (rx_symb_vector)
: A signal sent by PMA Receive indicating that a vector of four symbols is available in rx_symb_vector. (See 55.2.2.4.)

PMA_UNITDATA.request (tx_symb_vector)
: A signal sent to PMA Transmit indicating that a vector of four PAM16 symbols is available tx_symb_vector. (See 55.2.2.3.)

PCS_status
: Indicates whether the PCS is in a fully operational state. (See 55.3.7.1.)

55.3.6.4 State diagrams

The LFER Monitor state diagram shown in Figure 55–15 monitors the received signal for high LDPC frame error ratio.

The 64B/65B Transmit state diagram shown in Figure 55–16 controls the encoding of 65B transmitted blocks. It makes exactly one transition for each 65B transmit block processed. Though the Transmit state diagram sends Local Fault ordered sets when reset is asserted, the scrambler and 65B-LDPC may not be operational during reset. Thus, the Local Fault ordered sets may not appear on the PMA service interface.

The 64B/65B Receive state diagram shown in Figure 55–18 controls the decoding of 65B received blocks. It makes exactly one transition for each receive block processed except for the transition from RX_WE to RX_E, which occurs immediately after the RX_WE processes are complete.

The PCS shall perform the functions of LFER Monitor, Transmit, and Receive as specified in these state diagrams. The PCS shall not perform the LFER Monitor function during LPI receive operation from the time that the PCS 64B/65B Receiver enters the state RX_L, until the state RX_W is exited.

Transitions surrounded by dashed rectangles indicate requirements for 10GBASE-T EEE-capable implementations.

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55.3.7 PCS management

The following objects apply to PCS management. If an MDIO Interface is provided (see Clause 45), they are accessed via that interface. If not, it is recommended that an equivalent access be provided.

55.3.7.1 Status

PCS_status:
: Indicates whether the PCS is in a fully operational state. It is only true if block_lock is true and hi_lfer is false. This status is reflected in MDIO register 3.32.12. A latch low view of this status is reflected in MDIO register 3.1.2 and a latch high of the inverse of this status, Receive fault, is reflected in MDIO register 3.8.10.

block_lock:
: Indicates the state of the block_lock variable. This status is reflected in MDIO register 3.32.0. A latch low view of this status is reflected in MDIO register 3.33.15.

hi_lfer:
: Indicates the state of the hi_lfer variable. This status is reflected in MDIO register 3.32.1. A latch high view of this status is reflected in MDIO register 3.33.14.

Rx LPI indication:
: For EEE capability, this variable indicates the current state of the receive LPI function. This flag is set to TRUE (register bit set to one) when the PCS 64B/65B Receive state diagram (Figure 55–19) is in the RX_L or RX_W states. This status is reflected in MDIO register 3.1.8. A latch high view of this status is reflected in MDIO register 3.1.10 (Rx LPI received).

Tx LPI indication
: For EEE capability, this variable indicates the current state of the transmit LPI function. This flag is set to TRUE (register bit set to one) when the PCS 64B/65B Transmit state diagram (Figure 55–17) is in the TX_L or TX_W states. This status is reflected in MDIO register 3.1.9. A latch high view of this status is reflected in MDIO register 3.1.11 (Tx LPI received).

55.3.7.2 Counters

The following counters are reset to zero upon read and upon reset of the PCS. When they reach all ones, they stop counting. Their purpose is to help monitor the quality of the link.

lfer_count:
: 6-bit counter that counts each time LFER_BAD_LF state is entered. This counter is reflected in MDIO register bits 3.33.13:8. The counter is reset when register 3.33 is read by management. Note that this counter counts a maximum of 16 counts per 125 µs since the LFER_BAD_LF can be entered a maximum of 16 times per 125 µs window.

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errored_block_count:
8-bit counter. When the receiver is in normal mode, errored_block_count counts once for each time RX_E state is entered. This counter is reflected in MDIO register bits 3.33.7:0

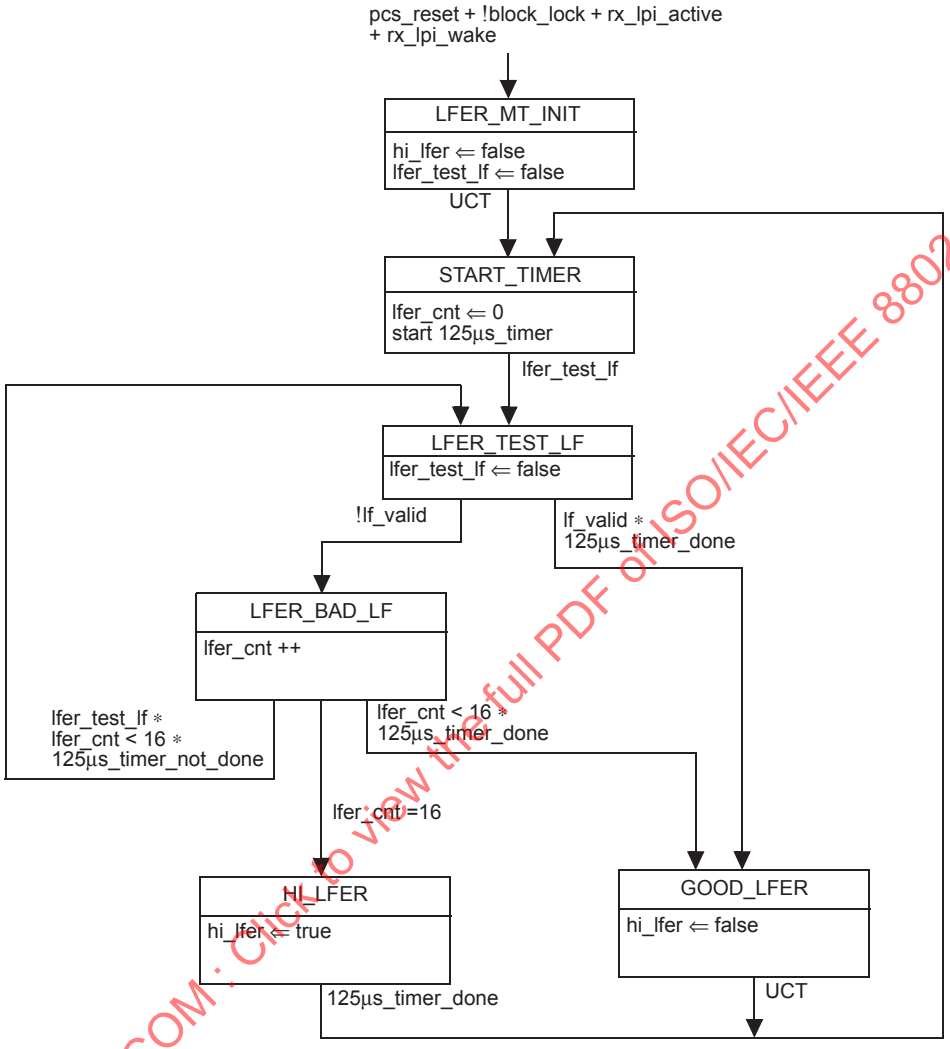

Figure 55–15—LFER monitor state diagram

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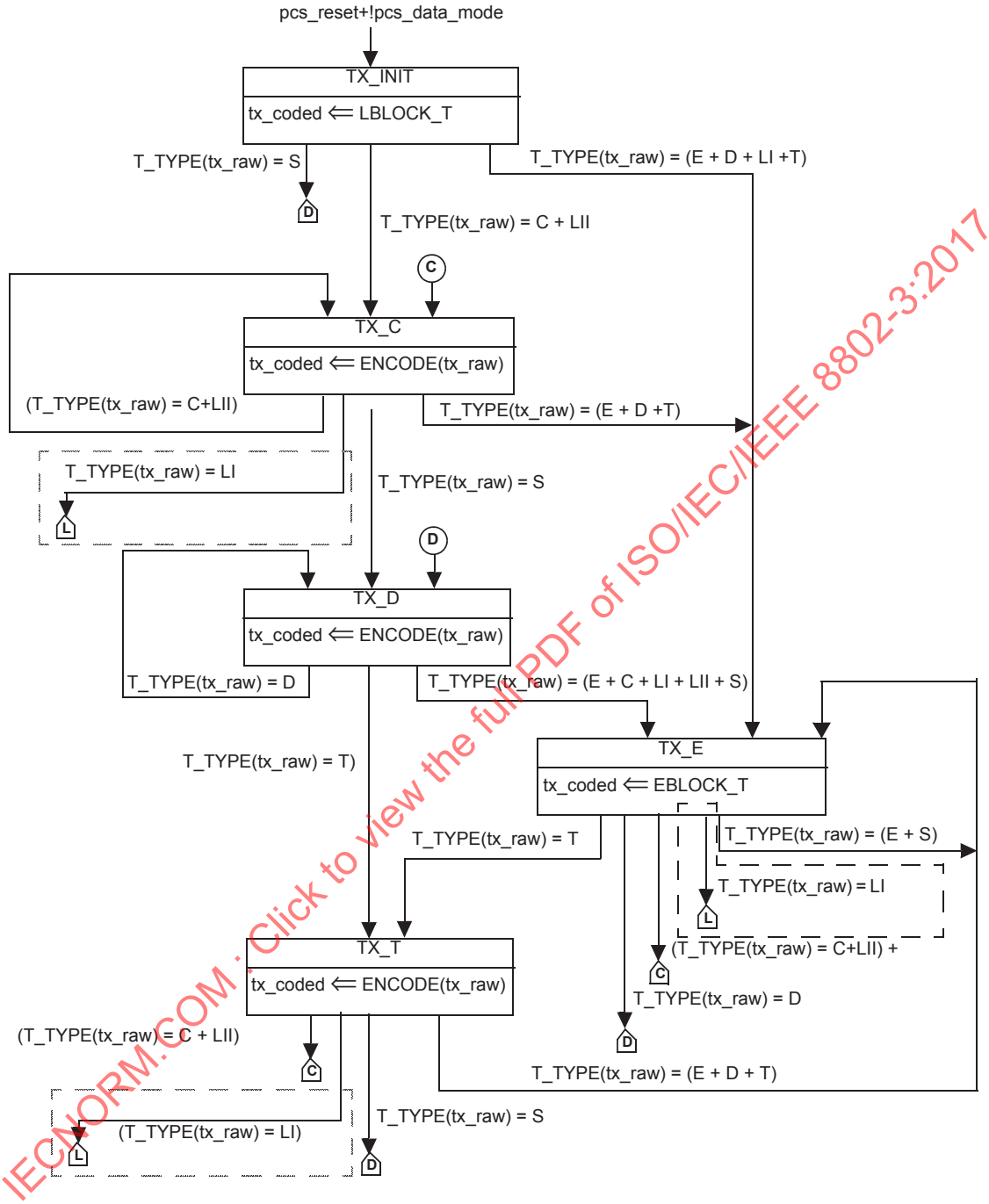

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NOTE—Transitions inside dashed boxes are only required for the EEE capability.

Figure 55–16—PCS 64B/65B Transmit state diagram, part a

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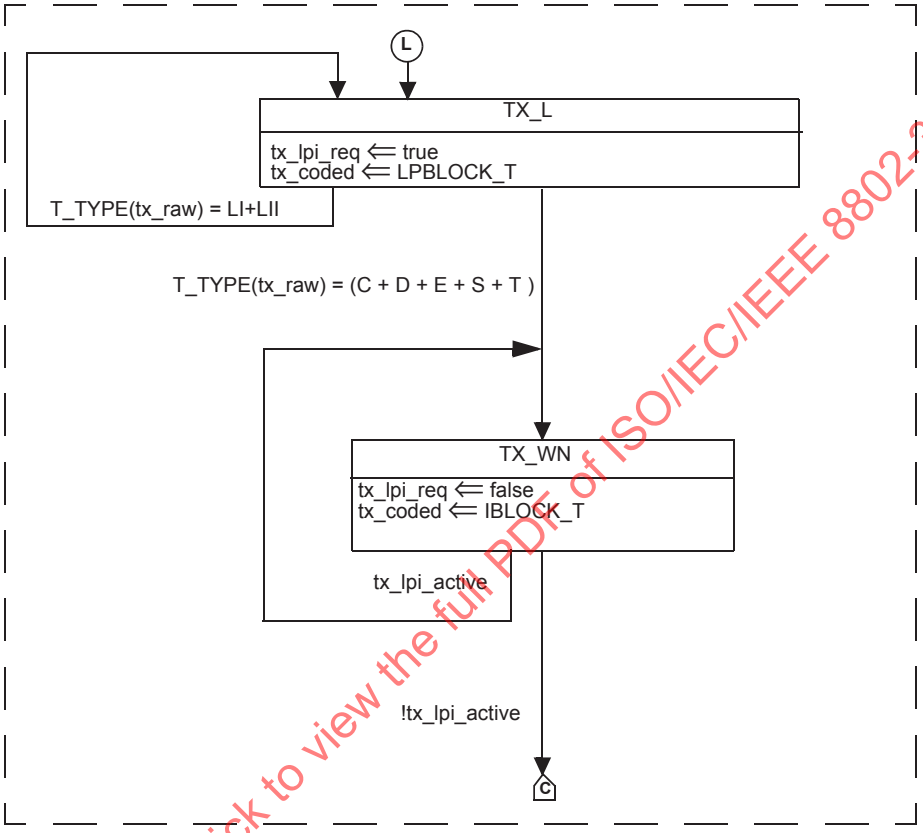

NOTE—This figure is mandatory for PHYs with the EEE capability.

Figure 55–17—PCS 64B/65B Transmit state diagram, part b

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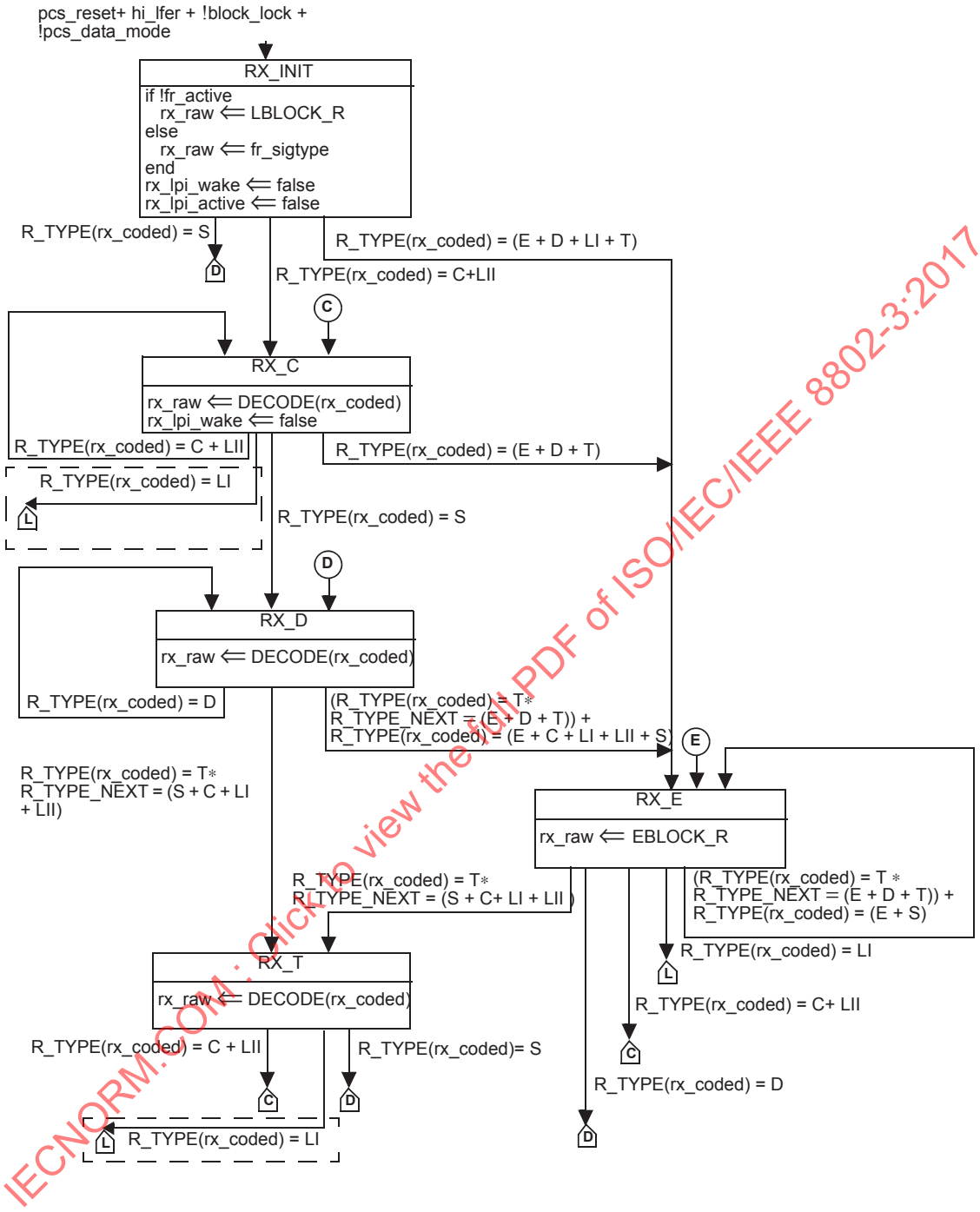

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NOTE—Signals and functions shown with dashed lines are only required for the EEE capability.

Figure 55–18—PCS 64B/65B Receive state diagram, part a

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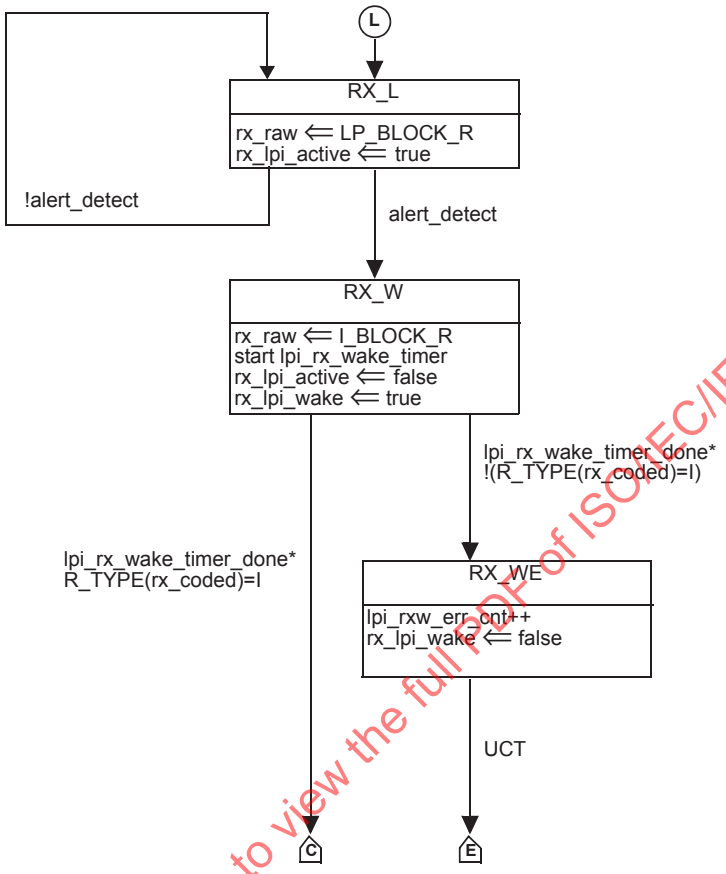

NOTE—This figure is mandatory for PHYs with the EEE capability.

Figure 55–19—PCS 64B/65B Receive state diagram, part b

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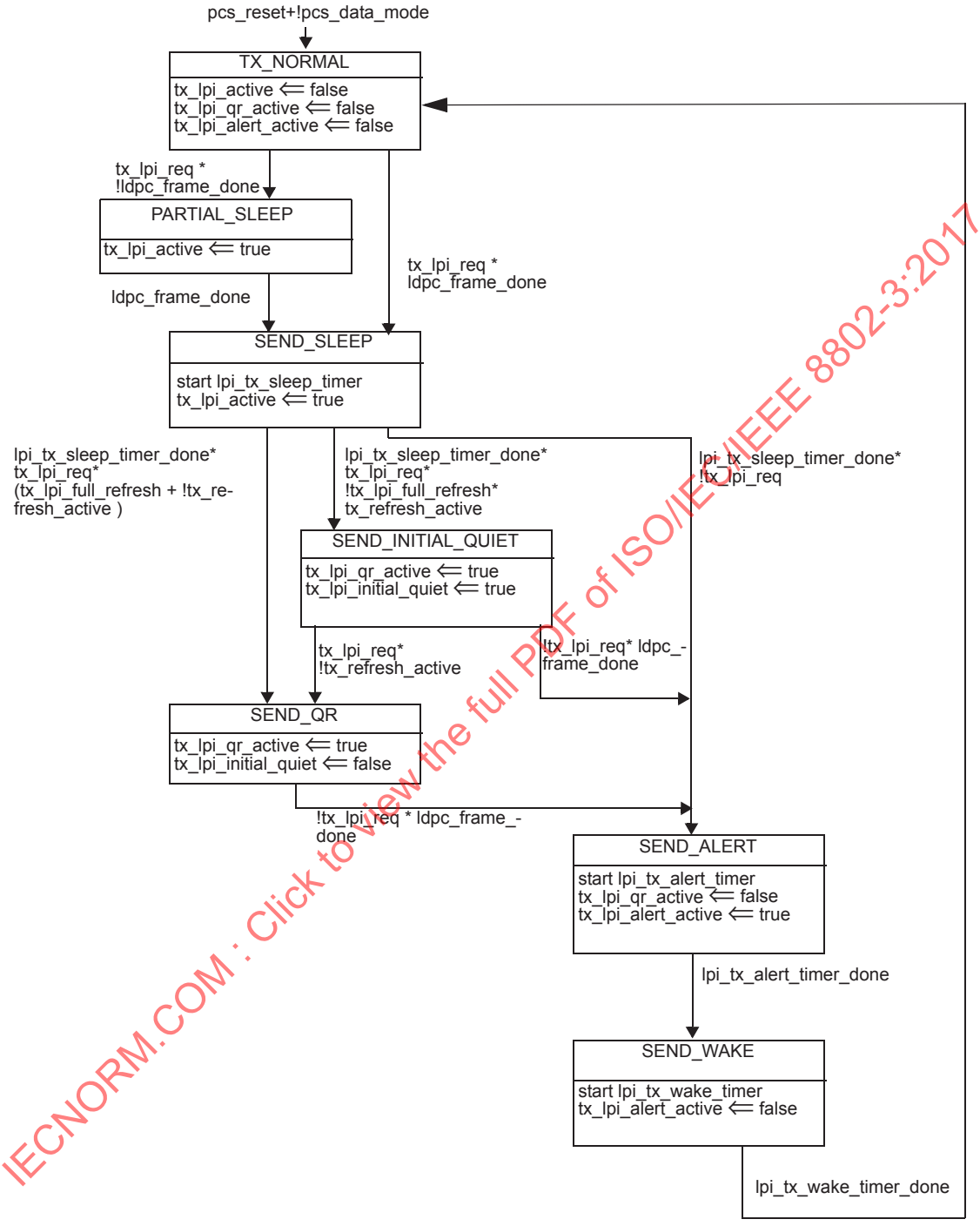

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NOTE—This figure is mandatory for PHYs with the EEE capability.

Figure 55–20—EEE transmit state diagram

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55.3.7.3 Loopback

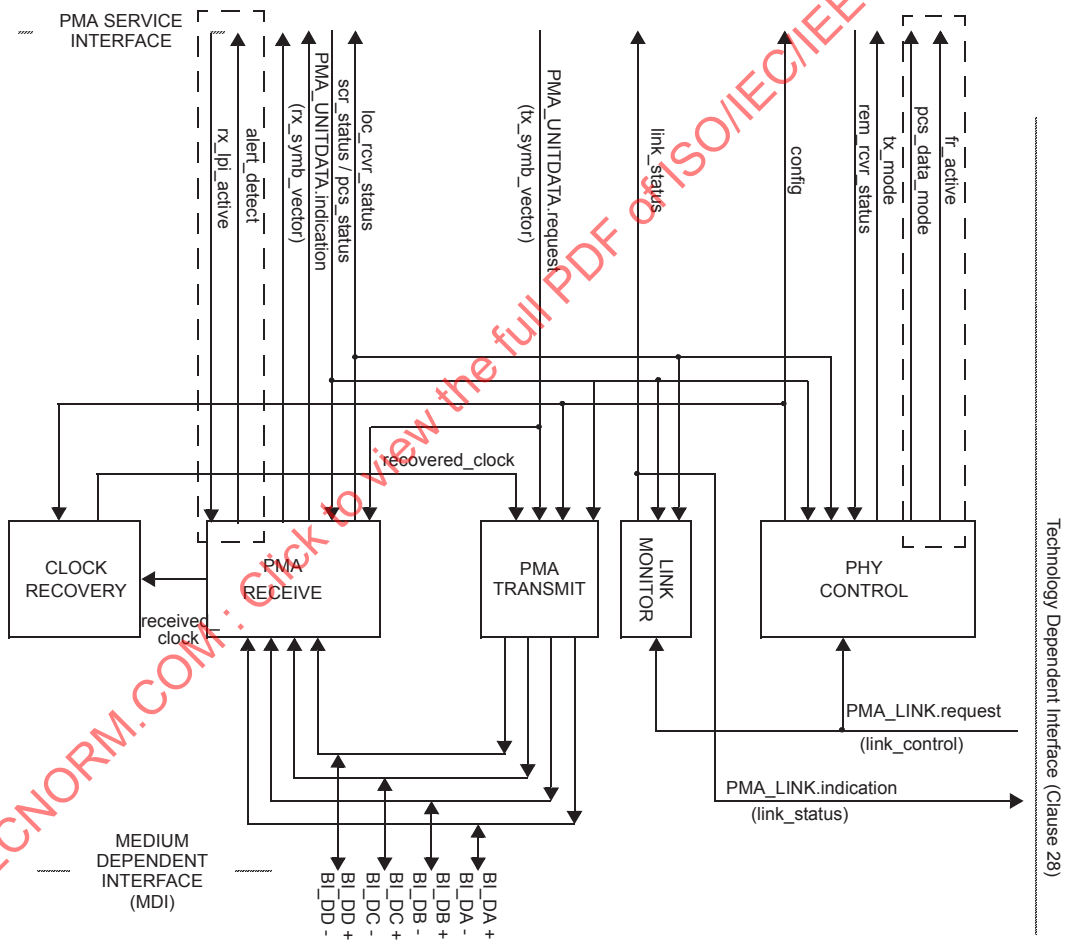
The PCS shall be placed in loopback mode when the loopback bit in MDIO register 3.0.14 is set to a one. In this mode, the PCS shall accept data on the transmit path from the XGMII and return it on the receive path to the XGMII. In addition, the PCS shall transmit a continuous stream of 65B-LDPC encoded 4D-PAM16 symbols to the PMA sublayer, and shall ignore all data presented to it by the PMA sublayer.

55.4 Physical Medium Attachment (PMA) sublayer

55.4.1 PMA functional specifications

The PMA couples messages from a PMA service interface specified in 55.2.2 to the 10GBASE-T baseband medium, specified in 55.7.

The interface between PMA and the baseband medium is the Medium Dependent Interface (MDI), which is specified in 55.8.



NOTE 1—The recovered_clock arc is shown to indicate delivery of the recovered clock signal back to PMA TRANSMIT for loop timing.

NOTE 2—pcs_data_mode is required only for the EEE or fast retrain capabilities alert_detect and rx_lpi_active are only required for the EEE capability fr_active is only required for the fast retrain capability

Figure 55–21— PMA reference diagram

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55.4.2 PMA functions

The PMA sublayer comprises one PMA Reset function and five simultaneous and asynchronous operating functions. The PMA operating functions are PHY Control, PMA Transmit, PMA Receive, Link Monitor, and Clock Recovery. All operating functions are started immediately after the successful completion of the PMA Reset function.

The PMA reference diagram, Figure 55–21, shows how the operating functions relate to the messages of the PMA Service interface and the signals of the MDI. Connections from the management interface, comprising the signals MDC and MDIO, to other layers are pervasive and are not shown in Figure 55–21.

55.4.2.1 PMA Reset function

The PMA Reset function shall be executed whenever one of the two following conditions occur:

a) Power on (see 55.3.6.2.2)
b) The receipt of a request for reset from the management entity

All state diagrams take the open-ended pma_reset branch upon execution of PMA Reset. The reference diagrams do not explicitly show the PMA Reset function.

55.4.2.2 PMA Transmit function

The PMA Transmit function comprises four synchronous transmitters to generate four pulse-amplitude modulated signals on each of the four pairs BI_DA, BI_DB, BI_DC, and BI_DD. While send_fail is FALSE and ALERT is not indicated by tx_symb_vector, PMA Transmit shall continuously transmit onto the MDI pulses modulated by the symbols given by tx_symb_vector[BI_DA], tx_symb_vector[BI_DB], tx_symb_vector[BI_DC], and tx_symb_vector[BI_DD], respectively after processing with the THP, optional transmit filtering, digital to analog conversion (DAC) and subsequent analog filtering. When ALERT is indicated by tx_symb_vector, the alert signal is transmitted as specified in 55.4.2.2.1. When send_fail is TRUE, the link failure signal is transmitted as specified in 55.4.2.2.2. The four transmitters shall be driven by the same transmit clock, TX_TCLK. The signals generated by PMA Transmit shall follow the mathematical description given in 55.4.3.1, and shall comply with the electrical specifications given in 55.5.

When the PMA_CONFIG.indication parameter config is MASTER, for both normal and LPI operation, the PMA Transmit function shall source TX_TCLK from a local clock source while meeting the transmit jitter requirements of 55.5.3.3. The MASTER/SLAVE relationship may include loop timing. If loop timing is implemented and the PMA_CONFIG.indication parameter config is SLAVE, the PMA Transmit function shall source TX_TCLK from the recovered clock of 55.4.2.8 while meeting the jitter requirements of 55.5.3.3. If loop timing is not implemented, the SLAVE PHY transmit clocking is identical to the MASTER PHY transmit clocking. An EEE-capable PHY shall operate with loop timing when configured as SLAVE.

The PMA Transmit fault function is optional. The faults detected by this function are implementation specific. If the MDIO interface is implemented, then this function shall be mapped to the transmit fault bit as specified in 45.2.1.7.4.

EEE-capable PHYs shall implement a PMA Transmit function that generates the alert signal as defined in 55.4.2.2.1. PHYs that support the fast retrain capability shall implement a PMA Transmit function that generates the link failure signal as defined in 55.4.2.2.2. If ALERT is indicated by tx_symb_vector at the same time as send_fail is TRUE, then link failure signaling is transmitted.

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55.4.2.2.1 Alert signal

PHYs that support the optional EEE capability will transmit the following PAM2 sequence when the PMA_UNITDATA.request parameter is set to ALERT. The alert signal is sent for a total of 4 LDPC frame periods and begins on a LDPC frame boundary. The alert signal is transmitted without THP filtering. The alert signal is transmitted on pair A when the PHY operates as a MASTER. The alert signal is transmitted on pair C when the PHY operates as a SLAVE. All other pairs transmit quiet as described in 55.3.5.

When the PMA_CONFIG.indication(config) is MASTER the alert signal is composed of 7 repetitions of the following 128 symbol PAM2 sequence, followed by 128 zero symbols.

xpr_master =

9 9 -9 -9 -9 -9 -9 -9 9 9 -9 -9 9 9 9 9

9 9 9 9 -9 -9 9 9 9 9 -9 -9 9 9 -9 -9

-9 -9 -9 -9 -9 -9 9 9 -9 -9 -9 -9 -9 -9 9 9

-9 -9 -9 -9 -9 -9 -9 -9 9 9 -9 -9 9 9 -9 -9

-9 -9 9 9 9 9 9 9 9 9 9 9 -9 -9 -9 -9

9 9 -9 -9 -9 -9 9 9 9 9 -9 -9 9 9 -9 -9

-9 -9 -9 -9 -9 -9 -9 -9 9 9 9 9 -9 -9 9 9

9 9 -9 -9 9 9 -9 -9 9 9 9 9 -9 -9 -9 -9

When the PMA_CONFIG.indication(config) is SLAVE the alert signal is composed of 7 repetitions of the following 128 symbol PAM2 sequence, followed by 128 zero symbols.

xpr_slave =

-9 -9 -9 -9 9 9 9 9 -9 -9 9 9 -9 -9 9 9

9 9 -9 -9 9 9 9 9 -9 -9 -9 -9 -9 -9 -9 -9

-9 -9 9 9 -9 -9 9 9 9 9 -9 -9 -9 -9 9 9

-9 -9 -9 -9 9 9 9 9 9 9 9 9 9 9 -9 -9

-9 -9 9 9 -9 -9 9 9 -9 -9 -9 -9 -9 -9 -9 -9

9 9 -9 -9 -9 -9 -9 -9 9 9 -9 -9 -9 -9 -9 -9

-9 -9 9 9 -9 -9 9 9 9 9 -9 -9 9 9 9 9

9 9 9 9 -9 -9 9 9 -9 -9 -9 -9 -9 -9 9 9

The alert signal is followed by a wake signal composed of repeated IDLE characters encoded using the 64B/65B encoding technique. At the start of the wake signal all THP feedback delay lines are initialized with zeros.

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55.4.2.2.2 Link failure signal

PHYs that support the fast retrain capability transmit the link failure signal under the control of the Fast Retrain state diagram. The link failure signal indicates to the link partner that a link failure has been detected and that the link partners should begin the fast retrain procedure.

The link failure signal is sent for 4 LDPC frames and begins on a LDPC frame boundary. The link failure signal is transmitted without THP filtering. The link failure signal is transmitted on pair A when the PHY operates as a MASTER. The link failure signal is transmitted on pair C when the PHY operates as a SLAVE. All other pairs transmit quiet as described in 55.3.5.

When the PMA_CONFIG.indication(config) is MASTER, the link failure signal is composed of 7 repetitions of the following 128 symbol PAM2 sequence, followed by 128 zero symbols.

xfr_master = xpr_master × (−1)

When the PMA_CONFIG.indication(config) is SLAVE the link failure signal is composed of 7 repetitions of the following 128 symbol PAM2 sequence, followed by 128 zero symbols.

xfr_slave = xpr_slave × (−1)

55.4.2.3 PMA transmit disable function

55.4.2.3.1 Global PMA transmit disable function

The Global_PMA_transmit_disable function allows all of the transmitters to be disabled, when either.

a) When a Global_PMA_transmit_disable variable is set to TRUE, this function shall turn off all of the transmitters so that the each transmitter Average Launch Power of the OFF Transmitter is less than –53 dBm.
b) If a PMA_transmit_fault is detected, then the PMA may set the Global_PMA_transmit_disable to TRUE, turning off the transmitter on each pair.

55.4.2.3.2 PMA pair by pair transmit disable function

The PMA_transmit_disable function allows the transmitters on each pair to be selectively disabled.

When a PMA_transmit_disable_N variable is set to TRUE, this function shall turn off the transmitter associated with that variable so that the transmitter Average Launch Power of the OFF Transmitter is less than –53 dBm.

55.4.2.3.3 PMA MDIO function mapping

The MDIO capability described in Clause 45 defines several variables that provide control and status information for and about the PMA. Mapping of MDIO control variables to PMA control variables is shown in Table 55–5. Mapping of MDIO status variables to PMA status variables is shown in Table 55–6.

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Table 55–5—MDIO/PMA control variable mapping

MDIO control variable	PMA register name	Register/bit number	PMA control variable
Reset	Control register 1	1.0.15	PMA_reset
Global transmit disable	Transmit disable register	1.9.0	Global_PMA_transmit_disable
Transmit disable pair D	Transmit disable register	1.9.4	PMA_transmit_disable_D
Transmit disable pair C	Transmit disable register	1.9.3	PMA_transmit_disable_C
Transmit disable pair B	Transmit disable register	1.9.2	PMA_transmit_disable_B
Transmit disable pair A	Transmit disable register	1.9.1	PMA_transmit_disable_A

Table 55–6—MDIO/PMA status variable mapping

MDIO status variable	PMA register name	Register/bit number	PMA status variable
Fault	Status register 1	1.1.7	PMA_fault
Transmit fault	Status register 2	1.8.11	PMA_transmit_fault
Receive fault	Status register 2	1.8.10	PMA_receive_fault

55.4.2.4 PMA Receive function

The PMA Receive function comprises four independent receivers for pulse-amplitude modulated signals on each of the four pairs BI_DA, BI_DB, BI_DC, and BI_DD. PMA Receive contains the circuits necessary to both detect symbol sequences from the signals received at the MDI over receive pairs BI_DA, BI_DB, BI_DC, and BI_DD and to present these sequences to the PCS Receive function. The signals received at the MDI are described mathematically in 55.4.3.2. The PMA translates the signals received on pairs BI_DA, BI_DB, BI_DC, and BI_DB into the PMA_UNITDATA.indication parameter rx_symb_vector. The quality of these symbols shall allow LFER of less than 3.2×10^{-9} after LDPC decoding, over a channel meeting the requirements of 55.7. The receiver shall correct for differential delay variations of up to 50 ns across the wire-pairs. The delay skew is removed by computing the relative received delay of the four known transmit patterns described in 55.3.4.

To achieve the indicated performance, it is highly recommended that PMA Receive include the functions of signal equalization, echo and crosstalk cancellation. The sequence of code-groups assigned to tx_symb_vector is needed to perform echo and self near-end crosstalk cancellation.

The PMA Receive function uses the scr_status parameter and the state of the equalization, cancellation, estimation, and LPI functions to determine the quality of the receiver performance, and generates the loc_rcvr_status variable accordingly. The precise algorithm for generation of loc_rcvr_status is implementation dependent.

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The receiver uses the sequence of symbols during the training sequence to detect and correct for pair swaps and crossovers. The receiver pairs BI_DA, BI_DB, BI_DC, and BI_DD may be connected in any manner described in 55.4.4 to the corresponding transmit pairs. The receiver also detects and corrects for polarity mismatches on any pairs and corrects for differential delay variations across the wire-pairs.

The PMA Receive fault function is optional. The PMA Receive fault function is the logical OR of the link_status = FAIL and any implementation specific fault. If the MDIO interface is implemented, then this function shall contribute to the receive fault bit specified in 45.2.1.7.5.

PMA receive functions that support the optional EEE capability shall generate alert_detect when the alert signal is detected at the receiver. The PMA receive function asserts alert_detect after the entire alert signal (3.5 LDPC frame periods of the xpr_master or xpr_slave sequence and 0.5 frames of silence) has been detected. The alert signal is specified in 55.4.2.2.1. The criterion used to generate alert_detect is left to the implementer.

PHYs that support the fast retrain capability shall set link_fail_detect to TRUE when the link failure signal is reliably detected at the receiver. The PMA receive function asserts link_fail_detect after the entire link failure signal (3.5 LDPC frame periods of the xfr_master or xfr_slave sequence and 0.5 frames of silence) has been detected. The link failure signal is specified in 55.4.2.2.2. The criterion used to generate link_fail_detect is left to the implementer. It is highly recommended that the generation of link_fail_detect is qualified with repeated errored frames at the LDPC decoder output.

55.4.2.5 PHY Control function

PHY Control generates the control actions that are needed to bring the PHY into a mode of operation during which frames can be exchanged with the link partner. PHY Control shall comply with the state diagram description given in Figure 55–28.

During PMA training (includes PMA_Training_Init_M, PMA_Training_Init_S, PMA_PBO_Exch, PMA_Coeff_Exch, and PMA_Fine_Adjust states in Figure 55–28), PHY Control information is exchanged between link partners with a 16 octet InfoField, which is XOR'ed with the last 128 bits of the PMA 16384 PAM2 frame on pair A (see Figure 55–13). The InfoField is also denoted IF. The link partner is not required to decode every IF transmitted but is required to decode IFs at a rate that enables the correct actions to timer expiration times, transition counter values, etc. described in Figure 55–28, Figure 55–29, and Figure 55–30.

The 16 octet InfoField shall include the fields in 55.4.2.5.2 through 55.4.2.5.13, also shown in the overview Figure 55–22, and the more detailed Figure 55–23, Figure 55–24, and Figure 55–25.

Start of Frame Delimiter 0xBBA70000	3 Transmitter Settings	Message Field	SNR Margin	Message Field Dependent	Message Field Dependent	CRC16
4 octets	3 octets	1 octet	4 bits	1.5 octets	4 octets	2 octets

Figure 55–22—InfoField format

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Start of Frame Delimiter 0xBBA70000	3 Transmitter Settings	Message Field	SNR Margin	Reser-ved	Transition Counter	Reser-ved	Vendor Specific	CRC16
4 octets	3 octets	1 octet	4 bits	2 bits	10 bits	2 octets	2 octets	2 octets

Figure 55–23—InfoField transition counter format

Start of Frame Delimiter 0xBBA70000	3 Transmitter Settings	Message Field	SNR Margin	Coefficient Exchange	Coefficient Field	CRC16
4 octets	3 octets	1 octet	4 bits	1.5 octets	4 octets	2 octets

Figure 55–24—InfoField coefficient exchange format

Start of Frame Delimiter 0xBBA70000	3 Transmitter Settings	Message Field	SNR Margin	Reserved	Reserved	Vendor Specific	CRC16
4 octets	3 octets	1 octet	4 bits	1.5 octets	2 octets	2 octets	2 octets

Figure 55–25—InfoField not transition counter and not coefficient exchange format

55.4.2.5.1 Infofield notation

For all the InfoField notation below, Reserved<bit location> represents any unused values and shall be set to zero and ignored by the link partner. For all PBO InfoField values below, the PBO<6:4> are unsigned 3-bit values 000, 001, 010, 011, 100, 101, 110, and 111 shall indicate power backoffs of 0 dB, 2 dB, 4 dB, 6 dB, 8 dB, 10 dB, 12 dB, and 14 dB respectively. The InfoField is transmitted following the notation described in 55.3.2.2.3 where the LSB of each octet is sent first and the octets are sent in increasing number order (that is, the LSB of Oct1 is sent first).

55.4.2.5.2 Start of Frame Delimiter

The start of Frame Delimiter consist of 4 octets [Oct1<7:0>, Oct2<7:0>, Oct3<7:0>, Oct4<7:0>] and shall use the hexadecimal value 0xBBA70000. 0xBB corresponds to Oct1<7:0> and so forth.

55.4.2.5.3 Current transmitter settings

Current transmitter setting (1 octet). Represented by the octet Oct5{Valid<7>, PBO<6:4>, Reserved<3:0>} and shown in Figure 55–26. Used to announce the current fixed PBO setting during PMA_Training_Init_M, PMA_Training_Init_S and PMA_PBO_Exch, and the current programmable PBO setting during PMA_Coeff_Exch. For every other state this octet is set to zero and ignored by the link partner. The bit Valid shall be set to one if the corresponding octet information is valid and shall be set to zero if it the octet information is not valid. If Valid is set to zero, the octet is ignored by the link partner.

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Single transmitter setting detail (one for current, next or requested)

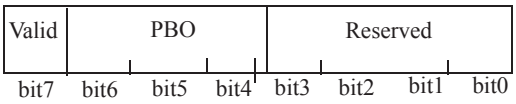

Figure 55–26—InfoField transmitter setting format

55.4.2.5.4 Next transmitter settings

Next transmitter setting (1 octet). Represented by the octet Oct6{Valid<7>, PBO<6:4>, Reserved<3:0>} and shown in Figure 55–26. Used to announce the next programmable PBO setting during PMA_PBO_Exch that takes effect upon entering PMA_Coeff_Exch state. For every other state, this octet is set to zero and ignored by the link partner. The bit Valid shall be set to one if the corresponding octet information is valid and shall be set to zero if it the octet information is not valid. If Valid is set to zero, the octet is ignored by the link partner.

55.4.2.5.5 Requested transmitter settings

Requested remote transmitter setting (1 octet). Represented by the octet Oct7{Valid<7>, PBO<6:4>, Reserved<3:0>} and shown in Figure 55–26. Used to request the remote transmitter programmable PBO setting during PMA_PBO_Exch that takes effect upon entering PMA_Coeff_Exch state. For every other state, this octet is set to zero and ignored by the link partner. The bit Valid shall be set to one if the corresponding octet information is valid and shall be set to zero if it the octet information is not valid. If Valid is set to zero, the octet is ignored by the link partner.

55.4.2.5.6 Message Field

Message Field (1 octet). For the MASTER, this field is represented by the octet Oct8{PMA_state<7:6>, loc_rcvr_status<5>, en_slave_tx<4>, trans_to_Coeff_Exch<3>, Coeff_exchange<2>, trans_to_Fine_Adjust<1>, trans_to_PCS_Test<0>}. For the SLAVE, this field is represented by the octet Oct8{PMA_state<7:6>, loc_rcvr_status<5>, timing_lock_OK<4>, trans_to_Coeff_Exch<3>, Coeff_exchange<2>, trans_to_Fine_Adjust <1>, trans_to_PCS_Test<0>}.

The two state-indicator bits PMA_state<7:6> shall communicate the state of the transmitting transceiver to the link partner. PMA_state<7:6>=00 indicates PMA_Training_Init_M or PMA_Training_Init_S, PMA_state<7:6>=01 indicates PMA_PBO_Exch, PMA_state<7:6>=10 indicates PMA_Coeff_Exch, and PMA_state<7:6>=11 indicates PMA_Fine_Adjust.

All possible Message Field settings are listed in Table 55–7 for the MASTER and Table 55–8 for the SLAVE. Any other value shall not be transmitted and shall be ignored at the receiver. The Message Field setting for the first transmitted PMA frame shall be the first row of Table 55–7 for the MASTER and the first row of Table 55–8 for the SLAVE. Moreover, for a given Message Field setting, the following Message Field setting shall be the same Message Field setting or the Message Field setting corresponding to a row below the current setting. When loc_rcvr_status=OK the InfoField variable is set to loc_rcvr_status<5>=1 and set to 0 otherwise.

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Table 55–7—InfoField message field valid MASTER settings

PMA_state<7:6>	loc_rcvr_ status	en_slave_tx	trans_to_ Coeff_Exch	Coeff_ exchange	trans_to_ Fine_Adjust	trans_to_ PCS_test
00	0	0	0	0	0	0
00	0	1	0	0	0	0
01	0	1	0	0	0	0
01	0	1	1	0	0	0
10	0	1	0	0	0	0
10	0	1	0	1	0	0
10	0	1	0	0	0	0
10	0	1	0	0	1	0
11	0/1	1	0	0	0	0
11	1	1	0	0	0	1

Table 55–8—InfoField message field valid SLAVE settings

PMA_state<7:6>	loc_rcvr_ status	timing_lock _OK	trans_to_ Coeff_Exch	Coeff_ exchange	trans_to_ Fine_Adjust	trans_to_ PCS_test
00	0	0	0	0	0	0
00	0	0/1	0	0	0	0
01	0	1	0	0	0	0
01	0	1	1	0	0	0
10	0	0/1	0	0	0	0
10	0	1	0	1	0	0
10	0	1	0	0	0	0
10	0	1	0	0	1	0
11	0	0/1	0	0	0	0
11	0/1	1	0	0	0	0
11	1	1	0	0	0	1

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55.4.2.5.7 SNR_margin

SNR_margin (4 bits). Represented by the half octet Oct9<7:4>, which reports received decision point SNR margin in 1/2 dB steps. SNR_margin is relative to the SNR required for reception of LDPC-coded DSQ128 at an LDPC frame error ratio of less than 3.2×10^{-9}. The SNR_margin<7:4> 4-bit values, 0010, 0011, 0100, 0101, 0110, 0111, 1000, 1001, 1010, 1011, 1100, 1101, 1110 shall indicate the decision point SNR margin

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values of –1.5, –1, –0.5, 0, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5 dB respectively. The value 0001 shall indicate a margin of –2 dB or less, and the value 1111 shall indicate 5 dB or more. Finally the value 0000 shall indicate that the SNR margin value is unknown.

55.4.2.5.8 Transition counter

Transition counter (10 bits). Represented by the 1.25 octets [Oct9<1:0>, Oct10<7:0>]. When configured as Transition counter (Coeff_exchange<2>=0 and a transition is announced to PMA_Coeff_Exch, PMA_Fine_Adjust or PCS_Test) this field is used as a 10 bit counter that counts the number of remaining frames until the next transition (PMA_Coeff_Exch, PMA_Fine_Adjust, PCS_Test).

55.4.2.5.9 Coefficient exchange handshake

Coefficient exchange handshake (12 bits). Represented by the 1.5 octets [Oct9<3:0>, Oct10<7:0>]. If Coeff_exchange<2>=1, this field is configured as a Coefficient exchange handshake and is used as a handshake control channel during programmable THP coefficient exchange. The details of the coefficient exchange are described in 55.4.2.5.14.

55.4.2.5.10 Reserved Fields

All InfoField fields denoted Reserved in Figure 55–23, Figure 55–24, and Figure 55–25 are reserved for future use. This includes octets Oct11 and Oct12 when Coeff_exchange<2>=0, Oct9<3:2> when transition counter is announced and [Oct9<3:0>, Oct10<7:0>] when no transition is announced and no coefficients are exchanged.

55.4.2.5.11 Vendor-specific field

If Coeff_exchange<2>=0 octets, Oct13 and Oct14 are vendor-specific fields. If during Auto-Negotiation both transceivers agree on the use of the two vendor-specific octets, they may be used as a PHY communication channel; otherwise they are set to zero and ignored by the link partner. Represented by the 2 octets [Oct13<7:0>, Oct14<7:0>].

55.4.2.5.12 Coefficient Field

Coefficient Field (4 octets). Represented by the octets [Oct11<7:0>, Oct12<7:0>, Oct13<7:0>, Oct14<7:0>]. When Coeff_exchange<2>=1, this field is used to exchange programmable THP coefficients. It transmits four 8-bit THP coefficients out of the total of 64 (16 coefficients over each of the 4 pairs). The order is pair A, coefficients 0:3, followed by coefficients 4:7, followed by 8:11 and 12:15. For all cases the first coefficient (indices 0, 4, 8 and 12) is mapped to Oct11, the second coefficient (indices 1, 5, 9, 13) is mapped to Oct12 and so on. The same coefficient order is followed to transmit the coefficients for pair B, followed by pair C, and finally pair D. The details of the coefficient exchange are described in 55.4.2.5.14.

55.4.2.5.13 CRC16

CRC16 (2 octets). Shall implement the CRC16 polynomial $(x+1)(x^{15}+x+1)$ of the previous 10 octets, Oct5<7:0>, Oct6<7:0>, Oct7<7:0>, Oct8<7:0>, Oct9<7:0>, Oct10<7:0>, Oct11<7:0>, Oct12<7:0>, Oct13<7:0>, and Oct14<7:0>. The CRC16 shall produce the same result as the implementation shown in Figure 55–27. In Figure 55–27 the 16 delay elements S0,..., S15, shall be initialized to zero. Afterwards Oct5 through Oct14 are used to compute the CRC16 with the switch connected, which is setting CRCgen in Figure 55–27. After all the 10 octets have been processed, the switch is disconnected (setting CRCout) and the 16 values stored in the delay elements are transmitted in the order illustrated, first S15, followed by S14, and so on, until the final value S0.

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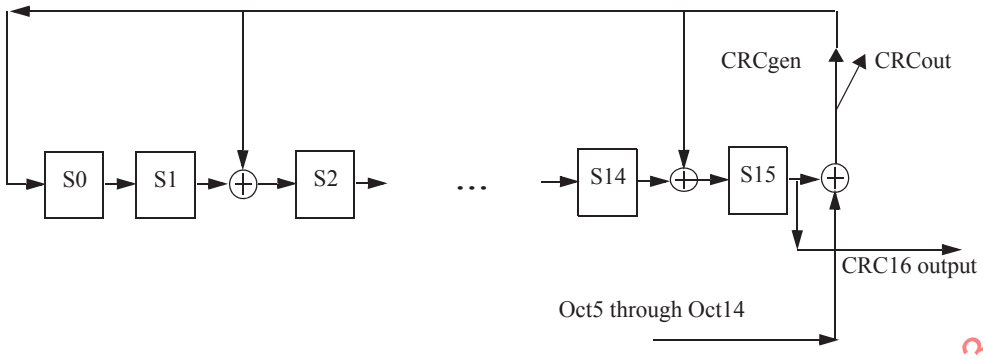

Figure 55–27—CRC16

55.4.2.5.14 Startup sequence

The startup sequence shall comply with the state diagram description given in Figure 55–28 and the transition counter state diagrams Figure 55–29 and Figure 55–30.

During Auto-Negotiation, PHY Control is in the DISABLE_10GBASE-T_TRANSMITTER state and the transmitters are disabled. During normal training, prior to enabling the transmitter, the THP coefficients are set to zero.

When the Auto-Negotiation process asserts link_control=ENABLE, PHY Control enters the INIT_MAXWAIT_TIMER state. Upon entering this state, the maxwait_timer is started and PHY Control enters the SILENT state, which starts the minwait_timer and forces transmission of zeros by setting tx_mode=SEND_Z.

In MASTER mode, after expiration of the minwait_timer, PHY Control transitions to the PMA_Training_Init_M state.

Upon entering the PMA_Training_Init_M and PMA_Training_Init_S states, the PHY Control forces transmission into the training mode by asserting tx_mode=SEND_T, which includes the transmission of InfoFields.

Upon entering state PMA_Training_Init_M, the MASTER starts transmission with a fixed transmit power level, PBO=4 (corresponding to a power backoff of 8 dB). The PBO variable is communicated to the link partner via the current transmitter octet of the InfoField.

Initially the MASTER is not ready for the SLAVE to respond and sets en_slave_tx=0, which is communicated to the link partner via the InfoField. After the MASTER has sufficiently converged the necessary circuitry, the MASTER must set en_slave_tx=1 to allow the SLAVE to transition to PMA_Training_Init_S.

In SLAVE mode, PHY Control transitions to the PMA_Training_Init_S state only after the SLAVE PHY acquires timing, converges its equalizers, acquires its descrambler state and sets loc_SNR_margin=OK. The SLAVE shall respond using the fixed PBO transmit power level, PBO=4 (corresponding to a power backoff of 8 dB). For PHYs with the EEE capability, further requirements for this transition are described in 55.3.5.1.

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While in states PMA_Training_Init_S, PMA_PBO_Exch, or PMA_Coeff_Exch, whenever a SLAVE operating in loop timing mode loses the MASTER timing reference (for example, after transmit power level transitions) it sets timing_lock_OK=0, which is communicated to the link partner via the InfoField. Otherwise, timing_lock_OK is set to one.

In MASTER mode, PHY Control enters the PMA_PBO_Exch state after loc_SNR_margin=OK and in SLAVE mode PHY Control enters the PMA_PBO_Exch state after the loc_SNR_margin=OK and minwait_timer expires. In the PMA_PBO_Exch state, after the MASTER has computed the final desired programmable PBO level, it shall request a PBO change using the requested transmitter setting in the InfoField (octet 7). In SLAVE mode, after the MASTER has requested the desired PBO level, the SLAVE shall request a desired PBO level that is within two levels (within 4 dB) of the requested MASTER PBO level.

Following PBO exchange for both transceivers, each PHY shall announce the next PBO setting using the next transmitter setting (octet 6). Afterwards, each PHY announces a transition to the PMA_Coeff_Exch state using the trans_to_Coeff_Exch=1 and transition_count as described in 55.4.5.1. MASTER initiates the transition to PMA_Coeff_Exch count with the trans_to_Coeff_Exch=1 flag and a transition counter value of 2^9 (10 ms). The SLAVE responds prior to the MASTER transition counter reaching 2^6 (1 ms) by setting trans_to_Coeff_Exch=1 flag and a transition counter value matching the MASTER. The PMA frame after each transceiver transition_count reaches zero, the PHYs shall enter the PMA_Coeff_Exch state and enable the requested PBO. Therefore, both PHYs will enter the PMA_Coeff_Exch state within one PMA frame.

While both MASTER and SLAVE are in state PMA_Coeff_Exch, when either end has computed the programmable THP settings, the programmable THP coefficient exchange process can begin, using the 1.5 octet Coefficient exchange handshake and the 4 octet Coefficient Field as follows:

a) During PMA_Coeff_Exch each PHY begins a coefficient exchange by setting the Coeff_Exchange flag to 1 in the Message Field.
b) During coefficient exchange, the transition counter bits are used as the Coefficient Exchange Handshake
    1) Oct9{Reserved<3:0>}: unused
    2) Coefficient Pair Received, Oct10<7:6>: 01 for local transmitter pair A, 10 for B, 11 for C and 00 for D (default). This is the handshake to tell the remote unit the last coefficients received.
    3) Coefficient Group Received, Oct10<5:4>: 01 for coefficients 0:3, 10 for 4:7, 11 for 8:11 and 00 for 12:15 (default). This is the handshake to tell the remote unit the last coefficients received.
    4) Coefficient Pair Sent, Oct10<3:2>: 01 for remote transmitter pair A, 10 for B, 11 for C and 00 for D (default). This is the handshake to tell the remote unit the current coefficients being sent.
    5) Coefficient Group Sent, Oct10<1:0>: 01 for 0:3, 10 for 4:7, 11 for 8:11 and 00 for 12:15 (default). This is the handshake to tell the remote unit the current coefficients being sent.
c) The Coefficient Field is used to send 4 8-bit coefficients in each frame designated by the Coefficient Pair Sent and Coefficient Group Sent bits. The coefficient format is:
    1) 8 bits per coefficient. Use one octet per coefficient in twos complement notation
    2) Coefficient range is –2.0 to 1.984375 in steps of 0.015625
    3) The sign of the coefficients shall be consistent with Equation (55–4)
d) Each PHY begins the exchange by sending pair A coefficients 0:3 with Coefficient Pair Sent=01 and Coefficient Group Sent=01.
e) The remote unit acknowledges by setting Coefficient Pair Received=01 and Coefficient Group Received=01.
f) Following each acknowledgement, the PHY increments through the Coefficient Group and then Coefficient Pair settings until Coefficient Pair Sent=00 and Coefficient Group Sent=00 and Coefficient Pair Received=00 and Coefficient Group Received=00. At this time, coefficient exchange is done and both PHYs set Coeff_Exchange=0.

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Following coefficient exchange for both transceivers, each PHY announces a transition to the PMA_Fine_Adjust state (trans_to_Fine_Adjust=1) and starts the transition_count as described in 55.4.5.1. During the first PMA frame after the transition_count reaches zero, the PHYs enter the PMA_Fine_Adjust state and enable the THP precoders with the requested coefficients. At the closure of the THP feedback loop, the initial state of the THP feedback filters shall be the last 16 symbols from the state PMA_Coeff_Exch.

The THP coefficients and PBO setting may not be changed during PMA_Fine_Adjust. The final convergence of the adaptive filter parameters is completed in the PMA_Fine_Adjust state.

After the PHY completes successful training and establishes proper receiver operations, PCS Transmit conveys this information to the link partner via transmission of the parameter InfoField value loc_rcvr_status. The link partner's value for loc_rcvr_status is stored in the local device parameter rem_rcvr status. When the condition loc_rcvr_status=OK and rem_rcvr_status=OK is satisfied, each PHY announces a transition to the PCS_Test state (trans_to_PCS_Test=1) and start the transition counter as described in 55.4.5.1. For PHYs with the EEE capability, further requirements for this transition are described in 55.3.5.1.

The normal mode of operation corresponds to the PCS_Data state, where PHY Control asserts tx_mode=SEND_N and transmission of data over the link can take place.

PHY Control may force the transmit scrambler state to be initialized to an arbitrary value by requesting the execution of the PCS Reset function defined in 55.3.2.1.

The operation of the maxwait_timer requires that the PHY complete the startup sequence from state SILENT to PMA_Fine_Adjust in the PHY Control state diagram (Figure 55–28) in less than 2000 ms to avoid link_status being changed to FAIL by the Link Monitor state diagram (Figure 55–31). To ensure interoperability the timing in Table 55–9 should be observed.

After reaching the PCS_Data state PHYs with the EEE capability can transition to the LPI receive mode under the control of the link partner and to the LPI transmit mode under control of the local LPI client.

Table 55–9—Recommended startup sequence timing

Master	Recommended maximum time (ms)	Recommended average time (ms)	Slave
SILENT plus (PMA_Training_Init_M state AND en_slave_tx = 0)	350	315	SILENT
(PMA_Training_Init_M state AND en_slave_tx = 1) plus PMA_PBO_Exch state	480	432	PMA_Training_Init_S state plus PMA_PBO_Exch state
PMA_Coeff_Exch state	100	90	PMA_Coeff_Exch state with timing_lock_OK=0
	520	468	Total for PMA Coeff Exch state
PMA_Fine_Adjust state	650	585	PMA_Fine_Adjust state
Total	2000	1800	

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55.4.2.5.15 Fast retrain function

PHYs that support the fast retrain capability shall implement the fast retrain state diagram shown in Figure 55–33. PHYs may request a fast retrain by setting the variable loc_fr_req to TRUE. This causes the transmission of an easily-detected link failure signal specified in 55.4.2.2.2. After completing the link failure signal the PHY shall transition to the PMA_Coeff_Exch state, keep its THP turned on with its previously exchanged coefficients, and send PAM2 signaling within a time period equivalent to 9 LDPC frame periods.

After the detection of the link failure signal, a PHY shall transition to the PMA_Coeff_Exch state and respond with PAM2 signaling within a time period equivalent to 9 LDPC frame periods after receiving the link failure signal.

The PAM2 symbols are generated using the PMA sidestream scrambler polynomials shown in Figure 55–13. The training sequence without periodic re-initialization described in 55.3.4 shall be used during fast retraining, with the scramblers free-running from PCS Reset. If scrambler re-initialization is used for normal training, it shall be disabled and the scramblers shall begin free-running when the PHY Control state diagram enters the PCS_Test state and the variable fr_active is FALSE.

Note that reliable traffic on the transmitter may be interrupted when the local receiver requests a fast retrain.

Following the link failure signal, the two link partners transition back to the PMA_Coeff_Exch state and follow the training procedure described in 55.4.2.5.14, with the exception that the initial infofield countdown values are reduced as indicated in Figure 55–29 and Figure 55–30.

To ensure interoperability the training times in Table 55–10 should be observed during the fast retrain.

Table 55–10—Recommended fast retrain sequence timing

State	Recommended maximum time (ms)
PMA_Coeff_Exch state	20
PMA_Fine_Adjust state	10

55.4.2.6 Link Monitor function

Link Monitor determines the status of the underlying receive channel and communicates it via the variable link_status. Failure of the underlying receive channel typically causes the PMA's clients to suspend normal operation.

The Link Monitor function shall comply with the state diagram of Figure 55–31.

Upon power on, reset, or release from power down, the Auto-Negotiation algorithm sets link_control=SCAN_FOR_CARRIER and, during this period, sends fast link pulses to signal its presence to a remote station. If the presence of a remote station is sensed through reception of fast link pulses, the Auto-Negotiation algorithm sets link_control=DISABLE and exchanges Auto-Negotiation information with the remote station. During this period, link_status=FAIL is asserted. If the presence of a remote 10GBASE-T station is established, the Auto-Negotiation algorithm permits full operation by setting link_control=ENABLE. As soon as reliable transmission is achieved, the variable link_status=OK is asserted, upon which further PHY operations can take place.

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55.4.2.7 Refresh Monitor function

The Refresh monitor is required for PHYs that support the EEE capability. The Refresh monitor operates when the PHY is in the LPI receive mode. The Refresh monitor shall comply with the state diagram of Figure 55–19. The function forces a link retrain if a refresh signal is not reliably detected within a moving time window equivalent to 50 complete LPI cycles (nominally equal to 8.192 ms), when the PHY is in the lower power receive mode.

55.4.2.8 Clock Recovery function

The Clock Recovery function couples to all four receive pairs. It may provide independent clock phases for sampling the signals on each of the four pairs.

The Clock Recovery function shall provide clocks suitable for signal sampling on each line so that the LDPC FER indicated in 55.4.2.4 is achieved. The received clock signal should be stable and ready for use when training has been completed (loc_rcvr_status=OK). The received clock signal is supplied to the PMA Transmit function by received_clock.

55.4.3 MDI

Communication through the MDI is summarized in 55.4.3.1 and 55.4.3.2.

55.4.3.1 MDI signals transmitted by the PHY

The symbols to be transmitted by the PMA on the four pairs BI_DA, BI_DB, BI_DC, and BI_DD are denoted by tx_symb_vector[BI_DA], tx_symb_vector[BI_DB], tx_symb_vector[BI_DC], and tx_symb_vector[BI_DD], respectively. The modulation scheme used over each pair is PAM16. PMA Transmit generates a pulse-amplitude modulated signal on each pair in the following form:

$$x_n = M(a_n - \sum_{k=1}^{16} x_{n-k}c_k) = a_n + 32m_n - \sum_{k=1}^{16} x_{n-k}c_k \quad (55\text{–}4)$$

$$s(t) = \sum_{n=0}^{\infty} x_n h_T(t - nT) \quad (55\text{–}5)$$

In Equation (55–4), a_n is the PAM16 modulation symbol from the set {–15, –13, –11, –9, –7, –5, –3, –1, 1, 3, 5, 7, 9, 11, 13, 15} to be transmitted at time nT. Each of the 16 THP coefficients c_1, c_2,..., c_{16} per wire pair is represented in two's complement form by 8 bits described in 55.4.2.5. The nonlinear THP operation given by $M(\alpha) = (\alpha + 16) mod 32 - 16$ corresponds to changing the modulation symbol a_n to an augmented modulation symbol $\tilde{a}_n = a_n + 32m_n$ with the integer m_n chosen such that the THP output lies in the interval $-16 \le x_n < 16$. Equation (55–5)describes the convolution of the THP output signals with the transmitter symbol response $h_T(t)$ to obtain the transmit signal $s(t)$ at the MDI. The values of the programmable THP coefficients are exchanged in the InfoField during PMA_Coeff_Exch. The THP filter coefficients shall be fixed after startup.

The nominal power (denoted Ptx) and the symbol response of the PMA transmitted signal $s(t)$, shall comply with the electrical specifications given in 55.5. When the link segment does not experience the maximum insertion loss (IL), each transceiver indicates to the link partner that the link partner PMA Transmit signal shall be reduced in increments of 2 dB. The minimum power backoff level requested shall comply with the power backoff schedule in Table 55–11. If a given receiver has sufficient decision point SNR margin, it may choose to request from the link partner larger power backoff (up to 14 dB) than shown in Table 55–11. Additionally, the Slave shall select a PBO level as described in the PMA_PBO_Exch state of 55.4.2.5.14. The PMA Transmit shall be capable of eight power backoff settings in approximately 2 dB

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steps. The difference between each consecutive power setting shall be 2 ± 0.25 dB, and each step shall be centered at 2 × *n* dB (*n* = 0 to 7) reduction from nominal, with a maximum error of ± 1 dB.

The received signal power at the MDI, *P* (dBm), in Table 55–11, should be the estimate of the average received power across all four pairs from the remote transmitter when the link partner PMA Transmit is at nominal power (after accounting for local transmitter power). If the remote transmitter is not at nominal power during the measurement, the estimate of the received power should be incremented by the amount of power backoff of the link partner transmitter during the measurement. Nominal power refers to the transmit power without any power backoff and is specified in 55.5.3.4. The estimate of the received signal power is stored in registers 1.141 to 1.144 as described in 45.2.1. The values in the length, *L* (m), column in Table 55–11 are for reference only (not required for power backoff evaluation) and have been computed using the scaled insertion loss equation in 55.7.

Table 55–11—Power backoff schedule

Received signal power at MDI, *P* (dBm)	Length *L*(m) (reference)	Minimum power backoff (dB)
$-1.1 < P$	$0 \le L < 35$	10
$-2.3 < P \le -1.1$	$35 \le L < 45$	8
$-3.3 < P \le -2.3$	$45 \le L < 55$	6
$-4.2 < P \le -3.3$	$55 \le L < 65$	4
$-5.0 < P \le -4.2$	$65 \le L < 75$	2
$P \le -5.0$	$75 \le L$	0

55.4.3.2 Signals received at the MDI

Signals received at the MDI can be expressed for each pair as pulse-amplitude modulated signals that are corrupted by noise as follows:

$$r(t) = \sum_{n=0}^{\infty} \tilde{a}_n h_R(t - nT) + w(t) \qquad (55\text{–}6)$$

In Equation (55–6), $\tilde{a}_n$ are the augmented PAM16 modulation symbols described in 55.4.3.1, $h_R(t)$ denotes the symbol response of the overall channel from the THP precoder to the MDI at the receiver and $w(t)$ represents the contribution of various noise sources including uncancelled crosstalk. The four signals received on pairs BI_DA, BI_DB, BI_DC, and BI_DD are processed within the PMA Receive function to yield the received symbols rx_symb_vector.

55.4.4 Automatic MDI/MDI-X configuration

Automatic MDI/MDI-X configuration is intended to eliminate the need for crossover cables between similar devices. Automatic MDI/MDI-X configuration is required for 10GBASE-T devices and shall comply with 40.4.4.1 and 40.4.4.2.

Having established MDI/MDI-X configuration, the receiver shall detect and correct for several configurations of pair swaps and crossovers and arbitrary polarity swaps. The receiver pairs BI_DA, BI_DB,

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BI_DC, and BI_DD might be connected to the corresponding transmit pairs in any of the following ways with arbitrary polarity:

a) No crossover
b) A/B crossover only
c) C/D crossover only
d) A/B crossover and C/D crossover

For EEE-capable PHYs, the MDI/MDIX function configuration shall apply to refresh and alert signaling. For PHYs with the fast retrain capability, the MDI/MDIX function configuration shall apply to link failure signaling.

55.4.5 State variables

55.4.5.1 State diagram variables

coeff_exchange_done
: This variable reports that both transceivers have received the corresponding coefficients from the link partner.
Values: TRUE: The coefficient exchange has completed.
FALSE: The coefficient exchange has not completed.

config
: The PMA shall generate this variable continuously and pass it to the PCS via the PMA_CONFIG.indication primitive.
Values: MASTER or SLAVE

link_control
: This variable is defined in 28.2.6.2.

link_status
: The link_status parameter set by PMA Link Monitor and passed to the PCS via the PMA_LINK.indication primitive.
Values: OK or FAIL

loc_rcvr_status
: Variable set by the PMA Receive function to indicate correct or incorrect operation of the receive link for the local PHY.
Values: OK: The receive link for the local PHY is operating reliably.
NOT_OK: Operation of the receive link for the local PHY is unreliable.

loc_SNR_margin
: This variable reports whether the local device has sufficient SNR margin to continue to the next state. The criterion for setting the parameter loc_SNR_margin is left to the implementer.
Values: OK: The local device has sufficient SNR margin.
NOT_OK: The local device does not have sufficient SNR margin.

master_transition_counter
: This variable reports the current value of the MASTER's transition counter reported in the InfoField defined in 55.4.2.5.
Values: 0 to 2^9

MessageField_IF
: This variable reports that a receiver has successfully received and decoded the InfoField

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from the remote device. This variable takes on the value contained in the Message Field. If the Message Field cannot be decoded or no explicit action is outstanding the value Null is returned.
Values: trans_to_Coeff_Exch, trans_to_Fine_Adjust, trans_to_PCS_Test or Null

PBO

PBO is a variable that can take any integer value from 0 to 7 and indicates the power backoff level. Denoting Ptx as the maximum nominal power, the PBO values are:
Values: 0, 1, 2, 3, 4, 5, 6, 7, which correspond to transmit power levels of *Ptx*, *Ptx*–2 dB, *Ptx*–4 dB, *Ptx*–6 dB, *Ptx*–8 dB, *Ptx*–10 dB, *Ptx*–12 dB, *Ptx*–14 dB respectively

PBO_next

PBO_next is a variable that can take any integer value from 0 to 7 and indicates the next power backoff level to be used at the local transmitter. The value is taken from the fixed set of values during PMA_Training_Init_M and PMA_Training_Init_S as described in 55.4.2.5. The value is taken from the decoded value of the link partner InfoField during PMA_PBO_Exch
Values: 0, 1, 2, 3, 4, 5, 6, 7, which correspond to transmit power levels of *Ptx*, *Ptx*–2 dB, *Ptx*–4 dB, *Ptx*–6 dB, *Ptx*–8 dB, *Ptx*–10 dB, *Ptx*–12 dB, *Ptx*–14 dB respectively

PBO_tx

PBO_tx is a variable that can take any integer value from 0 to 7 and indicates the power backoff level currently used at the local transmitter.
Values: 0, 1, 2, 3, 4, 5, 6, 7, which correspond to transmit power levels of *Ptx*, *Ptx*–2 dB, *Ptx*–4 dB, *Ptx*–6 dB, *Ptx*–8 dB, *Ptx*–10 dB, *Ptx*–12 dB, *Ptx*–14 dB respectively

PBO_exchange_done

This variable reports that both transceivers have received the corresponding PBO levels from the link partner.
Values: TRUE: The PBO exchange has completed.
FALSE: The PBO exchange has not completed.

pma_reset

Allows reset of the PHY Control and Link Monitor state diagrams.
Values: ON or OFF

rem_rcvr_status

Variable set by the PCS Receive function to indicate whether correct operation of the receive link for the remote PHY is detected or not.
Values: OK: The receive link for the remote PHY is operating reliably.
NOT_OK: Reliable operation of the receive link for the remote PHY is not detected.

THP_next

THP is a variable that contains sixteen 8-bit values and describes the next transmitter setting of the THP coefficients. It refers to the programmable THP coefficients selected during coefficient exchange described in 55.4.2.5.
Values: 16 coefficients of 8-bit values each. Range is –2.0 to 1.984375 in steps of 0.015625

THP_tx

THP is a variable that contains sixteen 8-bit values and describes the current transmitter setting of the THP coefficients. It refers to the programmable THP coefficients selected during

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coefficient exchange described in 55.4.2.5.
Values: 16 coefficients of 8-bit values each. Range is –2.0 to 1.984375 in steps of 0.015625

trans_to_Coeff_Exch
Message field variable defined in 55.4.2.5 that flags a transition by the local device to the PMA_Coeff_Exch state.
Values: 1: The local device transitions to the PMA_Coeff_Exch state on expiration of the transition counter.
0: The local device does not transition to the PMA_Coeff_Exch state.

trans_to_Fine_Adjust
Message field variable defined in 55.4.2.5 that flags a transition by the local device to the PMA_Fine_Adjust state.
Values: 1: The local device transitions to the PMA_Fine_Adjust state on expiration of the transition counter.
0: The local device does not transition to the PMA_Fine_Adjust state.

trans_to_PCS_Test
Message field variable defined in 55.4.2.5 that flags a transition by the local device to the PCS_test state.
Values: 1: The local device transitions to the PCS_test state on expiration of the transition counter.
0: The local device does not transition to the PCS_test state.

transition_count
This variable reports the value of the transition counter contained in the InfoField sent to the remote device. Transition_count must comply with the state diagram description given in 55.4.6.2. When the message field contains a flag for a state transition, the transition counter denotes the remaining number of InfoField until the next state transition. MASTER initiates the transition to PMA_Coeff_Exch count with the trans_to_Coeff_Exch=1 flag and a counter value of 2^9 (10 ms). The SLAVE responds prior to the counter reaching 2^6 (6 ms) with the same flag and a count value matching the MASTER. Then both PHY's transition to PMA_Coeff_Exch within one PMA frame. The same sequence is performed in the transition to PMA_Fine_Adjust state and PCS_Test state using the trans_to_Fine_Adjust=1 and trans_to_PCS_Test=1 flags respectively. In EEE-capable PHYs, synchronization of the PMA frames is tightly controlled as described in 55.3.5.1. When the message field does not contain a flag for a state transition, the transition counter is set to zero and ignored by the receiver.
Values: 0 to 2^9

tx_mode
PCS Transmit sends code-groups according to the value assumed by this variable.
Values: SEND_N: This value is continuously asserted when transmission of sequences of code-groups representing a XGMII data stream take place.

SEND_T: This value is continuously asserted when transmission of sequences of code-groups representing the sequences of code-groups (TA_n, TB_n, TC_n, TD_n) defined in 55.3.4.2 is to take place.

SEND_Z: This value is asserted when transmission of zero code-groups is to take place.

The following variables are required only for PHYs that support the EEE capability:

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lpi_refresh_detect
: Set TRUE when the receiver has reliably detected refresh signaling and FALSE otherwise. The exact criteria left to the implementer.

pcs_data_mode
: Generated by the PMA PHY Control function and indicates whether or not the local PHY may transition its PCS state diagrams out of their initialization states. The current value of the pcs_data_mode is passed to the PCS via the PMA_PCSDATAMODE.indicate primitive. In the absence of the optional EEE and fast retrain capabilities, the PHY operates as if the value of this variable is TRUE.

mtc
: mtc is the transition count for a MASTER PHY during normal training and fast retraining. mtc shall be equal to 2^9 for normal training and 2^5 for fast retrain.

stc
: stc is the transition count for a SLAVE PHY during normal training and fast retraining. stc shall be equal to 2^6 for normal training and 2^4 for fast retrain.

The following six variables are required only for PHYs that support the fast retrain capability:

fr_enable
: This variable is set to TRUE if 1.147.0 is set to 1 and fast retrain is supported. The variable is set to FALSE otherwise.

loc_fr_req
: Set TRUE when the receiver has detected a link failure condition and is requesting a fast retrain; set FALSE otherwise.

loc_fr_detect
: Set TRUE when the receiver has reliably detected the link failure signal. It is highly recommended that loc_fr_detect is qualified with the reception of errored blocks at the LDPC decoder output. Set FALSE when the link failure signal is not detected.

send_link_fail
: When TRUE indicates that the PMA should send the link failure signal. When FALSE the variable has no effect.

fr_active
: Set TRUE when the PHY is performing a fast retrain and set FALSE otherwise.

fast_retrain_flag
: Set TRUE after the PHY generates or detects a link failure signal and set FALSE otherwise.

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55.4.5.2 Timers

All timers operate in the manner described in 14.2.3.2.

maxwait_timer
: A timer used to limit the amount of time during which a receiver dwells in the SILENT and TRAINING states. The timer shall expire 2000 ms ± 10 ms after being started. This timer is used jointly in the PHY Control and Link Monitor state diagrams. The

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maxwait_timer is tested by the Link Monitor to force link_status to be set to FAIL if the timer expires and loc_rcvr_status is NOT_OK. See Figure 55–28 and Figure 55–31.

minwait_timer
: A timer used to determine the minimum amount of time the PHY Control stays in the SILENT, PMA_Training_Init_S, PCS_Test and PCS_Data states. The timer shall expire 1 ms ± 0.1 ms after being started.

The following timer is required only for PHYs that support the EEE capability:

lpi_refresh_rx_timer
: This timer is used to monitor link quality during the LPI receive mode. If the PHY does not reliably detect reliable refresh signaling before this timer expires then a full retrain is performed.
Values: The condition lpi_refresh_rx_timer_done becomes true upon timer expiration.
Duration: This timer shall have a period equal to 50 complete quiet-refresh signal periods, equivalent to 8.192 ms.

The following two timers are required only for PHYs that support the fast retrain capability:

link_fail_sig_timer
: Determines the period of time the PHY sends the link failure signal.
Values: The condition link_fail_sig_timer_done becomes true upon timer expiration.
Duration: This timer shall have a period equal to 4 LDPC frame periods.

fr_maxwait_timer
: Determines the period of time the PHY has to transition its PCS Control State to PCS_Test following a fast retrain before the fast retrain is aborted and a full retrain performed.
Values: The condition fr_maxwait_timer_done becomes true upon timer expiration.
Duration: This timer shall have a period equal to 30 ms.

55.4.5.3 Functions

Exchange_Final_PBO
: This function transmits and receives the final PBO settings using the InfoField as described in 55.4.2.5.

Exchange_THP_Coefficients
: This function compiles and sends to the link partner and receives from the link partner the desired programmable THP coefficients using the InfoField as described in 55.4.2.5.

55.4.5.4 Counters

The following two counters are required only for PHYs that support the fast retrain capability:

fr_tx_counter
: Counts the number of times the PHY initiates a fast link retrain by transmitting the link failure signal. This counter is reflected in MDIO register 1.147.10:6 specified in 45.2.1.79.2.

fr_rx_counter
: Counts the number of times the PHY begins a fast link retrain in response to the detection of link failure signaling from the link partner. This counter is reflected in MDIO register 1.147.15:11 specified in 45.2.1.79.1.

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55.4.6 State diagrams

55.4.6.1 PHY Control state diagram

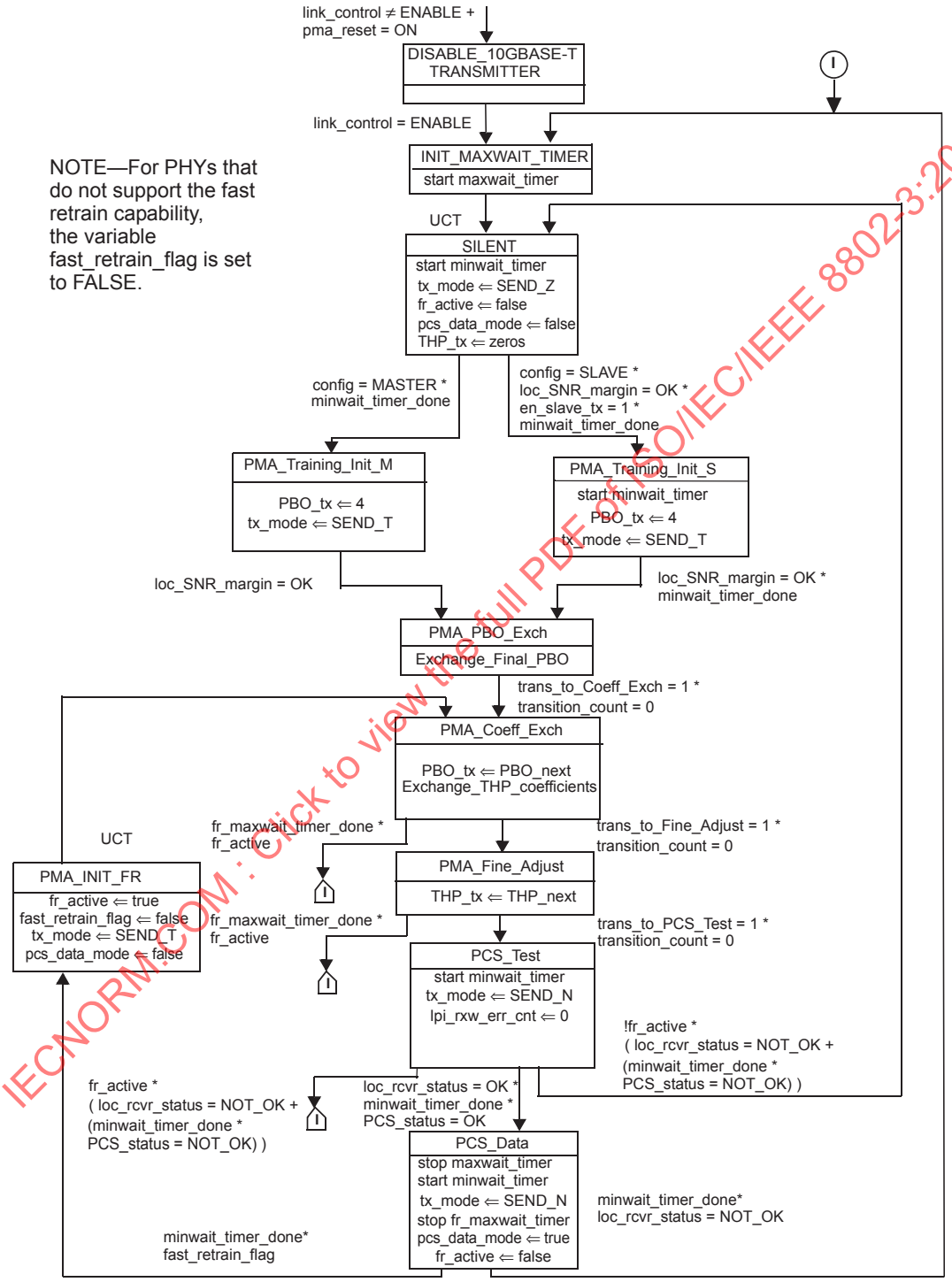

Figure 55–28—PHY Control state diagram

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55.4.6.2 Transition counter state diagrams

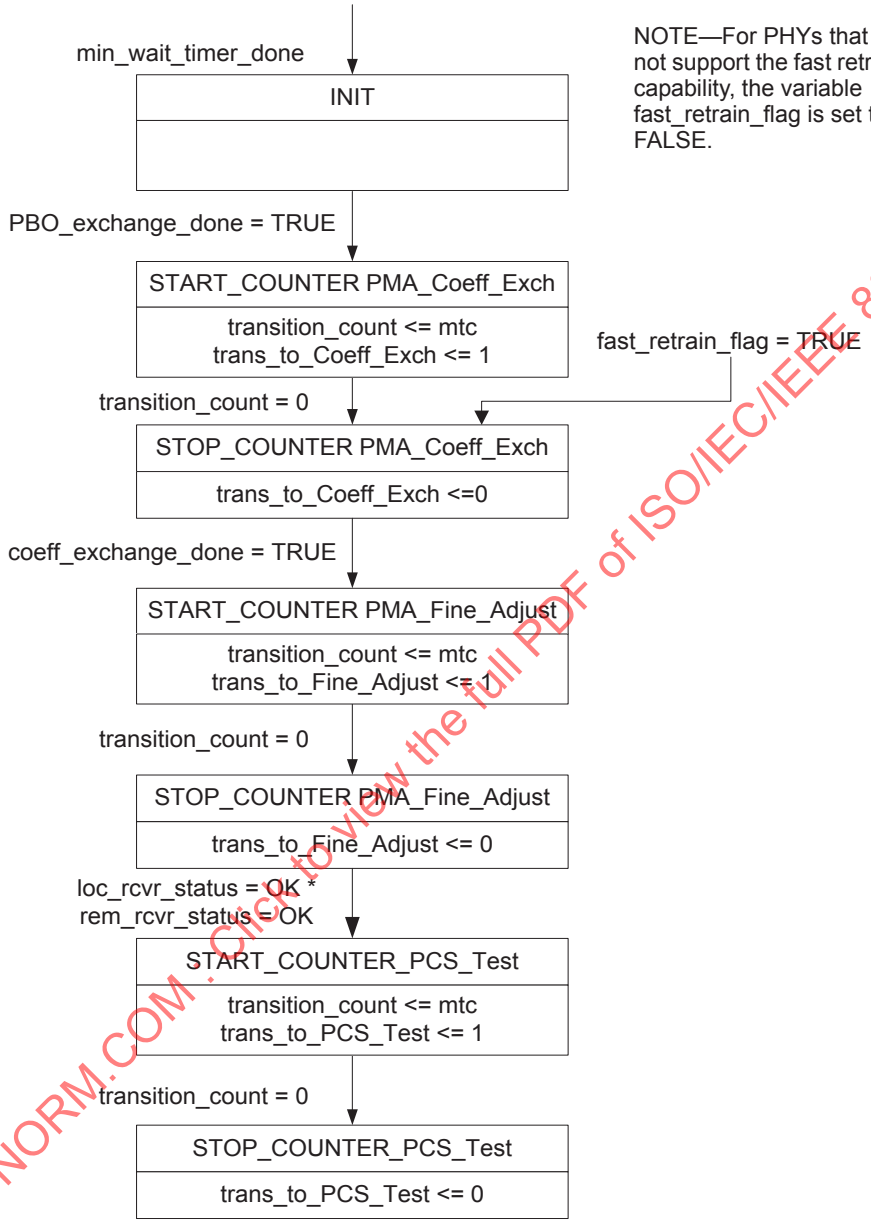

Figure 55–29—MASTER transition counter state diagram

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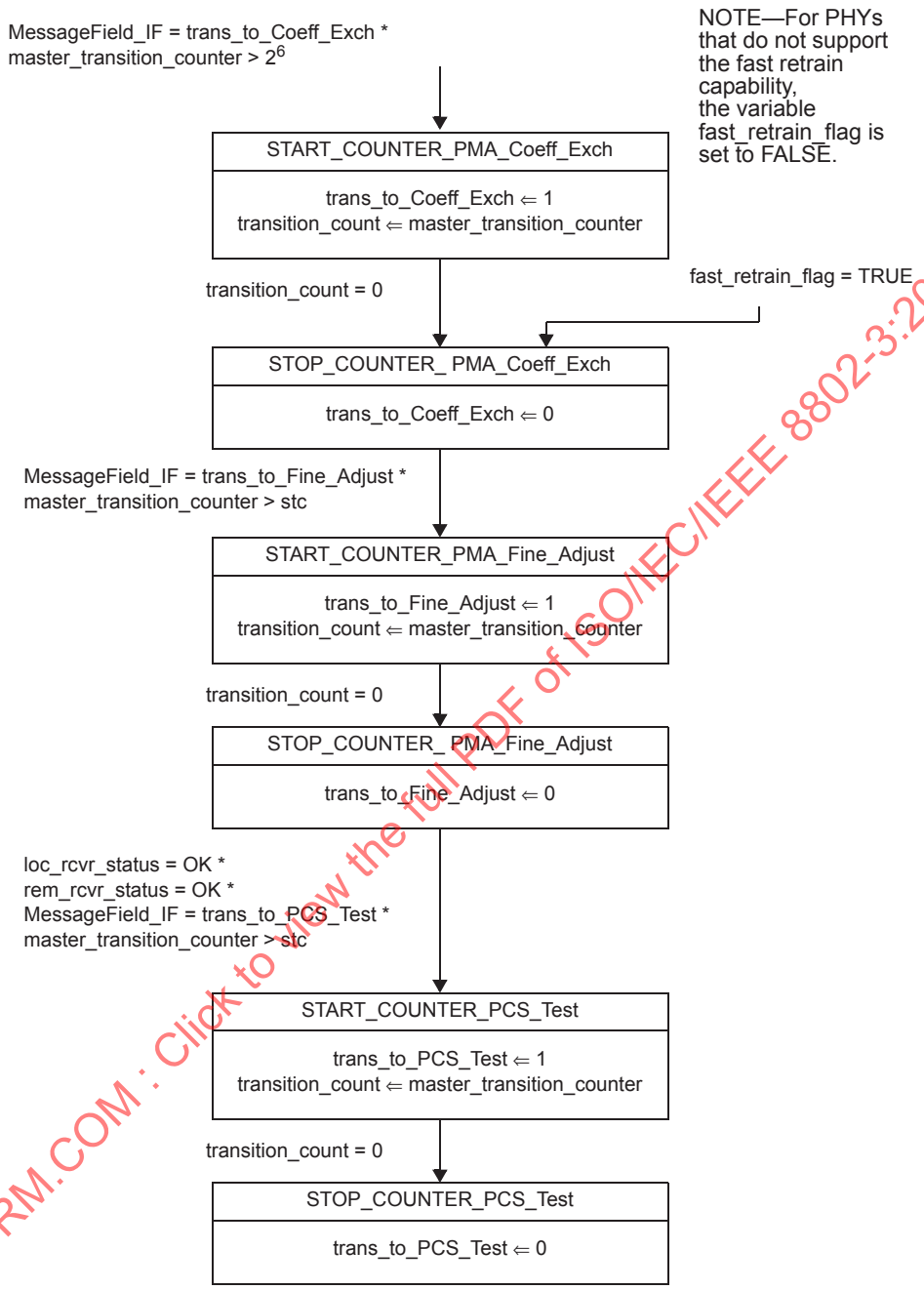

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Figure 55–30—SLAVE transition counter state diagram

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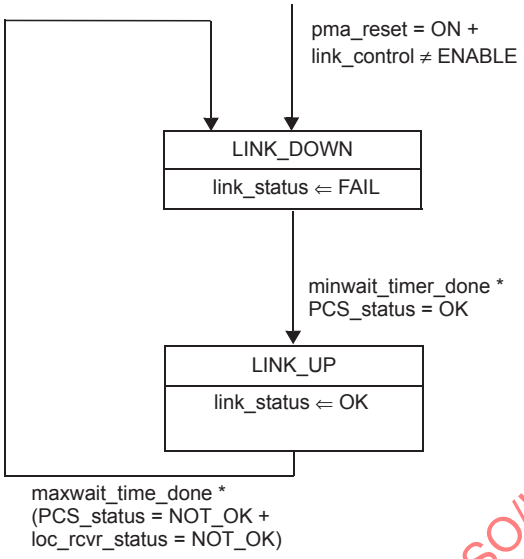
55.4.6.3 Link Monitor state diagram



NOTE 1—maxwait_timer is started in PHY Control state diagram (see Figure 55–28).
NOTE 2—The variables link_control and link_status are designated as link_control_10GigT and link_status_10GigT, respectively, by the Auto-Negotiation Arbitration state diagram (Figure 28–16).

Figure 55–31—Link Monitor state diagram

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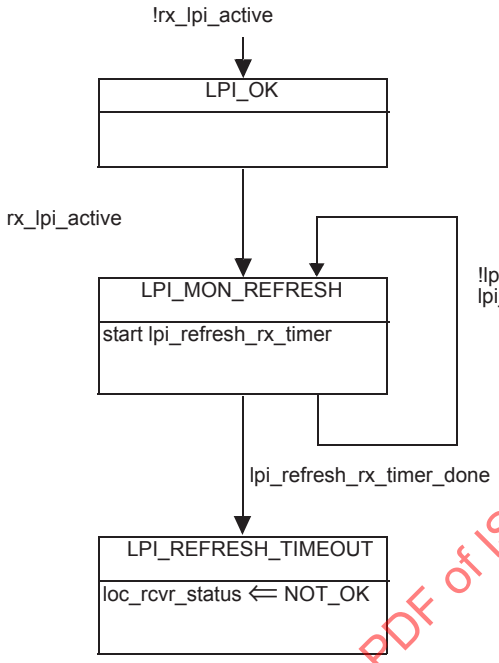
55.4.6.4 EEE Refresh monitor state diagram



NOTE—This state diagram is only required when the PHY supports the EEE capability.

Figure 55–32—EEE Refresh monitor state diagram

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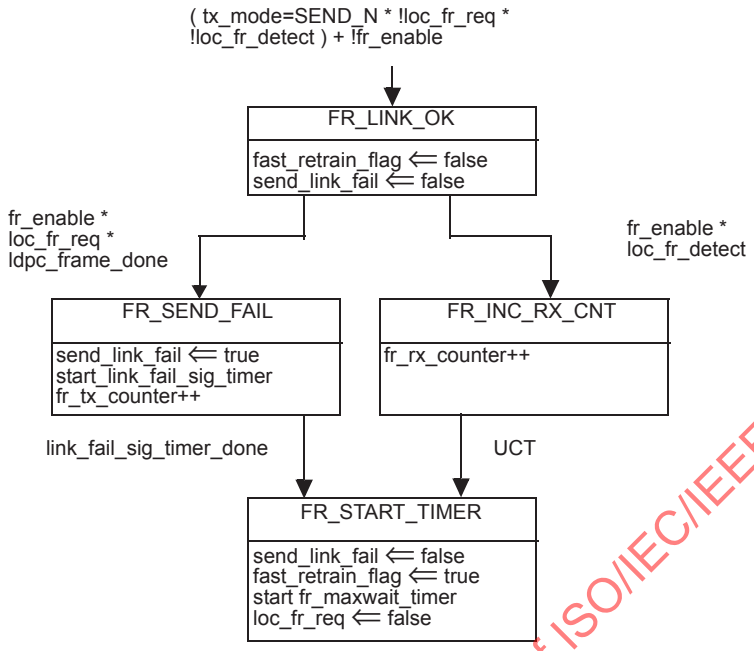
55.4.6.5 Fast retrain state diagram



NOTE—This state diagram is only required when the PHY supports the fast retrain capability.

Figure 55–33—Fast retrain control state diagram

55.5 PMA electrical specifications

This subclause defines the electrical characteristics of the PMA and specifies PMA-to-MDI interface tests.

Common-mode tests use the common-mode return point as a reference.

55.5.1 Isolation requirement

The PHY shall provide electrical isolation between the port device circuits, including frame ground (if any) and all MDI leads. This electrical isolation shall withstand at least one of the following electrical strength tests:

a) 1500 V rms at 50 Hz to 60 Hz for 60 s, applied as specified in Section 5.2.2 of IEC 60950-1:2001.
b) 2250 V dc for 60 s, applied as specified in Section 5.2.2 of IEC 60950-1:2001.
c) A sequence of ten 2400 V impulses of alternating polarity, applied at intervals of not less than 1 s. The shape of the impulses is 1.2/50 µs (1.2 µs virtual front time, 50 µs virtual time or half value), as defined in Annex N of IEC 60950-1:2001.

There shall be no insulation breakdown, as defined in Section 5.2.2 of IEC 60950-1:2001, during the test. The resistance after the test shall be at least 2 MΩ, measured at 500 V dc.

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55.5.2 Test modes

The test modes described below shall be provided to allow for testing of the transmitter waveform, transmitter distortion, transmitted jitter, transmitter droop and BER testing.

For a PHY with an MDIO management interface, these modes shall be enabled by setting bits 1.132.15:13 (10GBASE-T test mode register) of the MDIO Management register set as shown in Table 55–12. These test modes shall only change the data symbols provided to the transmitter circuitry and shall not alter the electrical and jitter characteristics of the transmitter and receiver from those of normal (non-test mode) operation. PHYs without a MDIO shall provide a means to enable these modes for conformance testing.

Table 55–12—MDIO management register settings for test modes

1.132.15	1.132.14	1.132.13	Mode
0	0	0	Normal operation.
0	0	1	Test mode 1—Setting of MASTER transmitter required by SLAVE for transmit jitter test in SLAVE mode.
0	1	0	Test mode 2—Transmit jitter test in MASTER mode.
0	1	1	Test mode 3—Transmit jitter test in SLAVE mode (if loop timing is supported).
1	0	0	Test mode 4—Transmit distortion test.
1	0	1	Test mode 5—Normal operation with no power backoff. This is for the PSD mask and power level test.
1	1	0	Test mode 6—Transmitter droop test mode.
1	1	1	Test mode 7—Pseudo random test mode for BER Monitor.

Test mode 1 is a mode provided for enabling testing of timing jitter on a SLAVE transmitter. When test mode 1 is enabled, the PHY shall transmit the PMA training pattern (PRBS 33) continually from all four transmitters with the THP turned off, with no power backoff and with the transmitted symbols timed from its local clock source.

Test mode 2 is for transmitter jitter testing when transmitter is in MASTER timing mode. When test mode 2 is enabled, the PHY shall transmit {Two +16 symbols followed by two –16 symbols} continually from all four transmitters with the THP turned off, with no power backoff and with the transmitted symbols timed from its local clock source. The transmitter output is a 200 MHz signal.

Test mode 3 is optional for a PHY that does not support loop timing. When test mode 3 is enabled on a PHY that supports loop timing, the PHY shall transmit, with THP turned off, the data symbol sequence {two +16 symbols followed by two –16 symbols} repeatedly on pair D with the symbols timed from its recovered receive data clock in SLAVE timing mode. A PHY that supports loop timing operates in test mode 3 when there is no input signal on pair D. The transmitter output is a 200 MHz signal on pair D and shall be silence on pairs A, B, and C.

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Test mode 4 is for transmitter linearity testing. When test mode 4 is enabled, the PHY shall transmit, with the THP turned off, transmitted symbols, timed from a transmit clock (as specified in 55.5.3.5) in the MASTER timing mode, defined by the bits1.132.12:10 and Table 55–13.

Table 55–13—MDIO management register settings for transmit frequencies in Test mode 4

1.132.12	1.132.11	1.132.10	Output waveform frequencies in MHz
			Two tone frequency pairs
0	0	0	Reserved
0	1	1	Reserved
1	1	1	Reserved
0	0	1	(800/1024) × 47, (800/1024) × 53
0	1	0	(800/1024) × 101, (800/1024) × 103
1	0	0	(800/1024) × 179, (800/1024) × 181
1	0	1	(800/1024) × 277, (800/1024) × 281
1	1	0	(800/1024) × 397, (800/1024) × 401

The peak-to-peak levels used in this test shall correspond to the ± 16 symbol levels and the relative amplitudes of the tones in a two-tone pair shall be within 0.5 dB of each other.

Test mode 5 is for checking whether the transmitter is compliant with the transmit PSD mask and the transmit power level. When test mode 5 is enabled, the PHY shall transmit as in normal operation but with the power backoff disabled.

Test mode 6 is for testing transmitter droop. When test mode 6 is enabled, the PHY shall transmit the following sequence of data symbols A_n, B_n, C_n, D_n, of 55.4.3.1 continually from all four transmitters, with the THP turned off:

{One hundred twenty eight +16 followed by one hundred twenty eight –16 symbols}.

Test mode 7 is for enabling measurement of the bit error ratio of the link including the LDPC encoder/decoder, the transmit and receive analog front ends of the PHY and a cable connecting two PHYs. This mode reuses the 10GBASE-T PCS scrambler and is defined in detail in 55.3.3.

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55.5.2.1 Test fixtures

The following fixtures (illustrated by Figure 55–34, Figure 55–35, and Figure 55–36), or their functional equivalents, can be used for measuring the transmitter specifications described in 55.5.3.

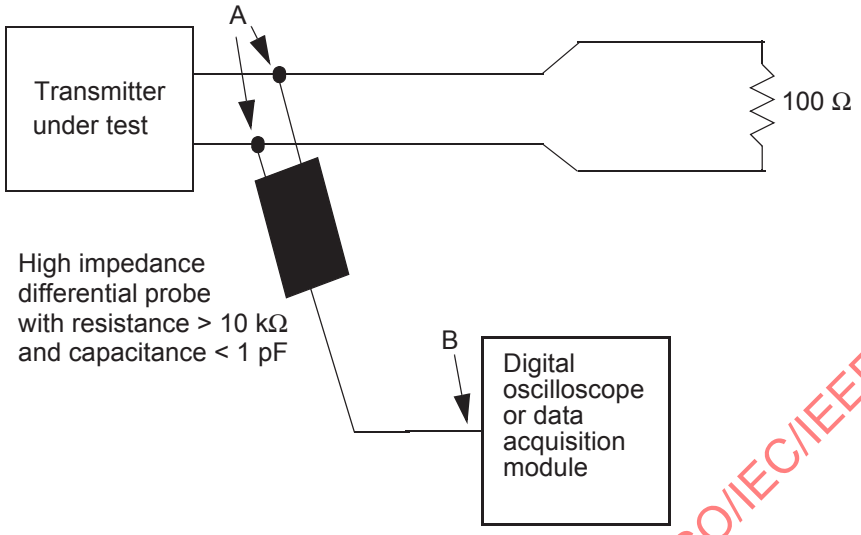

Figure 55–34—Transmitter test fixture 1 for transmitter droop measurement

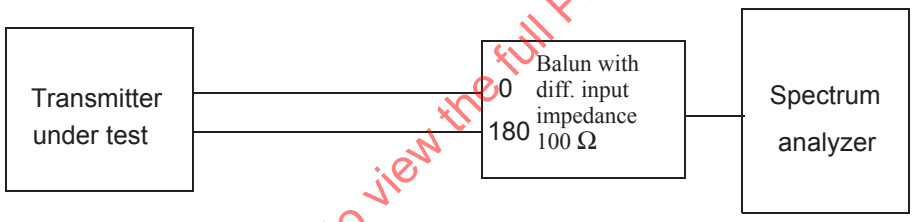

Figure 55–35—Transmitter test fixture 2 for linearity measurement, power spectral density measurement and transmit power level measurement

The high impedance probe shown in Figure 55–34 in transmitter test fixture 1 has resistance > 10 kΩ and capacitance < 1 pF over the frequency range of 1 MHz to 400 MHz. Figure 55–35 includes a power summer or balun device to couple the 100 Ω differential output of the transmitter to the 50 Ω single-ended input typically found in a spectrum analyzer input. The center frequency (f_c) of the band pass filter show in Figure 55–36 is 200 MHz ± 200 kHz and the band pass filter noise bandwidth (B_n) is 2 MHz ± 200 kHz.

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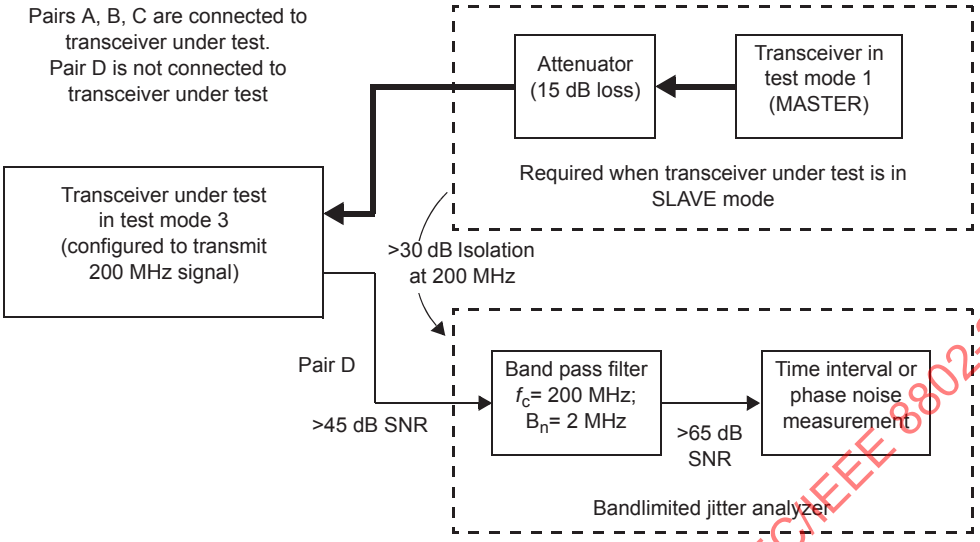

Figure 55–36—Transmitter test fixture 3 for transmitter jitter measurement

55.5.3 Transmitter electrical specifications

The PMA provides the Transmit function specified in 55.4.2.2 in accordance with the electrical specifications of this clause. The PMA shall operate with AC-coupling to the MDI.

Where a load is not specified, the transmitter shall meet the requirements of this clause with a 100 Ω resistive differential load connected to each transmitter output.

55.5.3.1 Maximum output droop

With the transmitter in test mode 6 and using the transmitter test fixture 1, the magnitude of both the positive and negative droop shall be less than 10%, measured with respect to an initial value at 10 ns after the zero crossing and a final value at 90 ns after the zero crossing.

55.5.3.2 Transmitter linearity.

When in test mode 4 and observing the spectrum of the differential signal output at the MDI using transmitter test fixture 2, for each pair, with no intervening cable, the transmitter linearity mask is defined as follows:

The SFDR of the transmitter, with dual tone inputs as specified in test mode 4, shall meet the requirement that:

$$\mathrm{SFDR} \geq \quad 2.5 + \ \min\{52,\ 58 - 20 \times \log_{10}(f/25)\} \tag{55–7}$$

where f is the maximum frequency of the two test tones in MHz and SFDR is the ratio in dB of the minimum RMS value of either input tone to the RMS value of the worst intermodulation product in the frequency range of 1 MHz to 400 MHz.

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This specification on transmit linearity is derived from the requirement for interoperability with the far-end device.

55.5.3.3 Transmitter timing jitter

When in test mode 2, the PHY transmits {two +16 symbols followed by two –16 symbols} continually with the THP turned off and with no power backoff. In this mode, the transmitter output should be a 200 MHz signal and the RMS period jitter measured at the PHY MDI output shall be less than 5.5 ps. The RMS period jitter is measured as per the test configuration shown in Figure 55–36 over an integration time interval of 1 ms ± 10%.

For a PHY that can operate in loop timing mode, the SLAVE mode RMS period jitter test shall be run using the test configuration shown in Figure 55–36. For this test, the MASTER PHY is in test mode 1 and the SLAVE PHY is in test mode 3. The MASTER is transmitting the PMA training pattern (PRBS 33) to the SLAVE PHY on pairs A, B, and C. The SLAVE PHY is in loop timing mode, synchronizing its transmit clock to the signals received from the MASTER PHY on pairs A, B, and C. In this configuration, the transmitter output on pair D should be a 200 MHz signal and the RMS period jitter measured at the SLAVE PHY MDI output shall be less than 5.5 ps. The RMS period jitter is measured over an integration time interval of 1 ms ± 10%.

RMS period jitter over an integration time interval of 1 ms ± 10% is defined as the root mean square period difference from the average period ($T - T_{avg}$), accumulated over a sample size of 200 000 ± 20 000:

$$\text{RMS period jitter} = \sqrt{\frac{\sum[(T - T_{avg})^2]}{\text{Sample size}}} \tag{55–8}$$

55.5.3.4 Transmitter power spectral density (PSD) and power level

In test mode 5 (normal operation with no power backoff), the transmit power shall be in the range 3.2 dBm to 5.2 dBm and the power spectral density of the transmitter, measured into a 100 Ω, load using the test fixture shown in Figure 55–35 shall be between the upper and lower masks specified in Equation (55–9) and Equation (55–10). The masks are shown graphically in Figure 55–37.

$$\text{Upper PSD}\ (f) \leq \begin{cases} -78.5\ \text{dBm/Hz} & 0 < f \leq 70 \\ -78.5 - \left(\dfrac{f-70}{80}\right)\text{dBm/Hz} & 70 < f \leq 150 \\ -79.5 - \left(\dfrac{f-150}{58}\right)\text{dBm/Hz} & 150 < f \leq 730 \\ -79.5 - \left(\dfrac{f-330}{40}\right)\text{dBm/Hz} & 730 < f \leq 1790 \\ -116\ \text{dBm/Hz} & 1790 < f \leq 3000 \end{cases} \tag{55–9}$$

and

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$$\text{Lower PSD}\ (f) \geq \begin{cases} -83\ \text{dBm/Hz} & 5 \leq f \leq 50 \\ -83 - \left(\dfrac{f-50}{50}\right)\text{dBm/Hz} & 50 < f \leq 200 \\ -86 - \left(\dfrac{f-200}{25}\right)\text{dBm/Hz} & 200 < f \leq 400 \end{cases} \quad (55\text{–}10)$$

where f is in MHz.

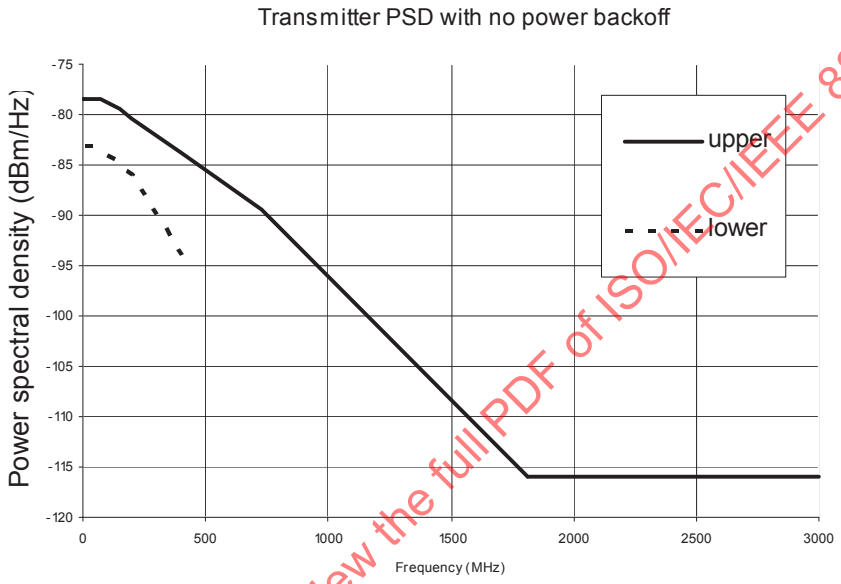

Figure 55–37—Transmitter power spectral density mask

55.5.3.5 Transmit clock frequency

The symbol transmission rate on each pair of the MASTER PHY shall be within the range 800 MHz ± 50 ppm.

When the transmitter is in the LPI transmit mode or when the receiver is in the LPI receive mode the transmitter clock short-term rate of frequency variation shall be less than 0.1 ppm/second. The short-term frequency variation limit shall also apply when switching to and from the LPI mode.

55.5.4 Receiver electrical specifications

The PMA provides the Receive function specified in 55.4.2.4 in accordance with the electrical specifications of this clause using patch cabling and interconnecting hardware that is within the limits specified in 55.7.

55.5.4.1 Receiver differential input signals

Differential signals received at the MDI that were transmitted from a remote transmitter within the specifications of 55.5.3 and have passed through a link specified in 55.7 are received with a BER less than

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10^{-12} and sent to the PCS after link reset completion. This specification shall be satisfied by a frame error ratio less than 9.6×10^{-9} for 800 octet frames with minimum IPG or greater than 799 octet IPG.

55.5.4.2 Receiver frequency tolerance

The receive feature shall properly receive incoming data, per the requirements of 55.5.4.1, with a symbol rate within the range 800 MHz ± 50 ppm.

55.5.4.3 Common-mode noise rejection

This specification is provided to limit the sensitivity of the PMA receiver to common-mode noise from the cabling system. Common-mode noise generally results when the cabling system is subjected to electromagnetic fields.

The common-mode noise can be simulated using the cable clamp test defined in 40.6.1.3.3. A 6 dBm sine wave signal from 80 MHz to 1000 MHz can be used to simulate an external electromagnetic field. Operational requirements of the transceiver during the test are determined by the manufacturer. A system integrating a 10GBASE-T PHY may perform this test.

55.5.4.4 Alien crosstalk noise rejection

While receiving data from a transmitter compliant with specifications in 55.5.3, through a 100 m link segment compliant with the specifications in 55.7, a receiver shall operate with an Ethernet frame error ratio less than 9.6×10^{-9} for 800 octet frames with either a minimum IPG or greater than 799 octet IPG with four noise sources at the specified levels representing alien crosstalk, one connected to each of the four pairs. Independent noise sources should be injected into each MDI inputs using couplers that do not significantly alter the link segment characteristics. Each noise source shall have a flat noise spectrum, with 3 dB bandwidth at least 10 MHz to 400 MHz and a power spectral density such that at the MDI port of the device under test the power spectral density of the injected noise is –141.9 dBm/Hz. A flat noise source is chosen to model the sum of all alien noise sources. See Figure 55–38.

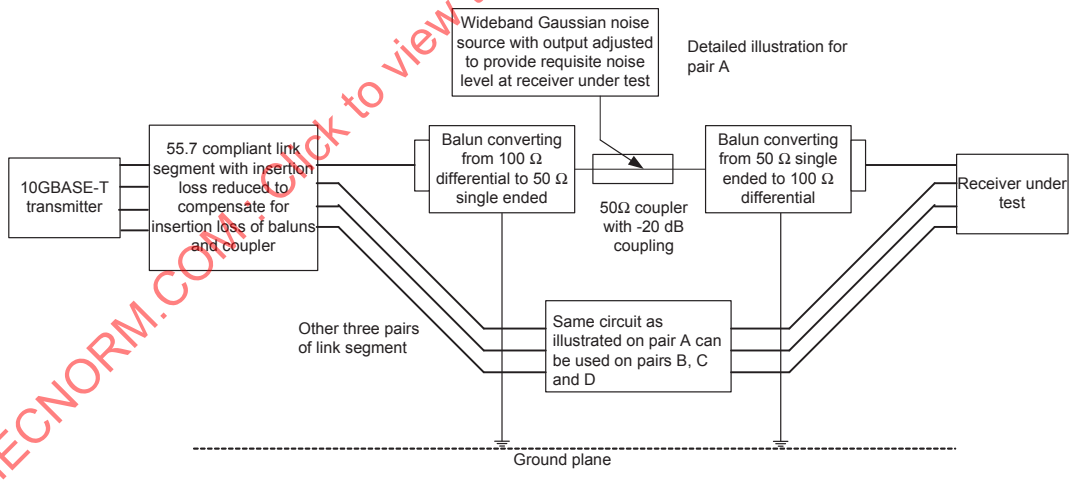

Figure 55–38—Alien crosstalk noise rejection test

The structure shown for injecting the noise in Figure 55–38 is illustrative and alternative approaches are possible. The loss of the coupling structure shown in Figure 55–38, which consists of two baluns and a coupler, is approximately 2.5 dB. The overall insertion loss of the link segment together with the insertion loss of the coupling structure should be adjusted to match the insertion loss specified in 55.7.2.1 to within ± 0.5 dB. This can be achieved by shortening the cable by approximately 5 m. The balun-coupler-balun

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structure shown in Figure 55–38 can be replaced by resistively coupling a balanced noise source to the twisted pair using 500 Ω resistors. In either case, calibration of the test setup is required to confirm the overall insertion loss and the injected noise power at the MDI of the receiver under test.

55.5.4.5 Short reach mode link test

In short reach mode (indicating operation over a short reach channel) while receiving data from a transmitter compliant with specifications in 55.5.3 (whether or not in short reach mode), through both short reach test channels, a receiver shall operate with a frame error ratio less than 9.6×10^{-9} for 800 octet frames with minimum IPG or greater than 799 octet IPG (e.g., operate with a BER less than 10^{-12}).

The PHY short reach register setting 1.131.0 indicates whether the PHY is operating in the short reach mode.

55.5.4.5.1 Short reach test channels

One short reach test channel specification is consistent with the transmission characteristics of a cabling link of 30 m consisting of two connectors, 10 m of cable cord, and a horizontal cable distance of 20 m, that meets the ISO/IEC 11801 Category 7 component specifications.

One short reach test channel specification is consistent with the transmission characteristics of a cabling link of 30 m consisting of two connectors, 10 m of cable cord, and a horizontal cable distance of 20 m that meets the Category 6A component specifications.

55.6 Management interfaces

10GBASE-T makes extensive use of the management functions that may be provided by the MDIO (Clause 45), and the communication and self-configuration functions provided by Auto-Negotiation (Clause 28). Additional Auto-Negotiation requirements are set forth within this subclause.

55.6.1 Support for Auto-Negotiation

All 10GBASE-T PHYs shall provide support for Auto-Negotiation (Clause 28) and shall be capable of operating as MASTER or SLAVE. All 10GBASE-T PHYs shall provide support for Extended Next Pages as defined in 28.2.3.4.2 and shall support and use optimized FLP Burst to FLP burst timing as defined in 28.2.1.1.1, and nlp_link_test_min_timer and link_fail_inhibit_timer as defined in 28.3.2.

Auto-Negotiation is performed as part of the initial set-up of the link, and allows the PHYs at each end to advertise their capabilities (speed, PHY type, half or full duplex) and to automatically select the operating mode for communication on the link. Auto-Negotiation signaling is used for the following primary purposes for 10GBASE-T:

a) To negotiate that the PHY is capable of supporting 10GBASE-T transmission.
b) To determine the MASTER-SLAVE relationship between the PHYs at each end of the link.
c) To determine whether the local PHY performs PMA training pattern reset.
d) To determine whether the local PHY supports the EEE capability.
e) To determine whether the local PHY supports the fast retrain capability.

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55.6.1.1 10GBASE-T use of registers during Auto-Negotiation

A 10GBASE-T PHY shall use the management register definitions and values specified in Table 55–14.

Table 55–14—10GBASE-T registers

Register	Bit	Name	Description	Type [a]
7.0	7.0.15:0	AN control register	Defined in 45.2.7.1	R/W
7.1	7.1.15:0	AN status register	Defined in 45.2.7.2	RO
7.2, 7.3	7.2.15:0, 7.3.15:0	AN device identifier registers	Defined in 45.2.7.3	R/W
7.5, 7.6	7.5.15:0, 7.6.15:0	AN devices in package registers	Defined in 45.2.7.4	R/W
7.14, 7.15	7.14.15:0, 7.15.15:0	AN package identifier registers	Defined in 45.2.7.5	R/W
7.16	7.16.15:0	AN advertisement register	Defined in 45.2.7.6	R/W
7.19	7.19.15:0	AN LP Base Page ability register	Defined in 45.2.7.7	RO
7.22, 7.23, 7.24	7.22.15:0, 7.23.15:0, 7.24.15:0	AN XNP transmit register	Defined in 45.2.7.8	R/W
7.25, 7.26, 7.27	7.25.15:0, 7.26.15:0, 7.27.15:0	AN LP XNP ability register	Defined in 45.2.7.9	RO
7.32	7.32.15:0	10GBASE-T AN control register	Defined in 45.2.7.10	R/W
7.33	7.33.15:0	10GBASE-T AN status register	Defined in 45.2.7.11	RO

[a] R/W = Read/Write, RO = Read only

55.6.1.2 10GBASE-T Auto-Negotiation page use

10GBASE-T PHYs shall exchange a 10GBASE-T and 1000BASE-T formatted Extended Next Page, as specified in Table 55–15, immediately following the exchange of the Base Page.

Note that the Acknowledge 2 bit is not utilized and has no meaning when used for the 10GBASE-T message page exchange.

Table 55–15—10GBASE-T Base and Next Pages bit assignments

Bit	Name	Description
Base Page		
D15	Next Page	Defined in 28.2.1.2.6
D14	Acknowledge	Defined in 28.2.1.2.5
D13	Remote Fault	Defined in 28.2.1.2.4
D12	Extended Next Page	Defined in 28.2.1.2.3
D11:D5	Technology Ability Field	Defined in 28.2.1.2.2
D4:D0	Selector Field	Defined in 28.2.1.2.1
Extended Next Page (Message Code Field and Flags Field)		
M10:M0	Next Page message code	Defined in Annex 28C
T	Toggle	Defined in 28.2.3.4.7

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Table 55–15—10GBASE-T Base and Next Pages bit assignments *(continued)*

Bit	Name	Description
Ack2	Acknowledge 2	Defined in 28.2.3.4.6
MP	Message Page	Defined in 28.2.3.4.5
Ack	Acknowledge	Defined in 28.2.3.4.4
NP	Next Page	Defined in 28.2.3.4
Extended Next Page (Unformatted Message Code Field)		
U31:U25	Reserved, transmit as 0	
U24	10GBASE-T EEE (1 = Advertise EEE capability for 10GBASE-T 0 = Do not advertise EEE capability for 10GBASE-T)	Defined in 45.2.7.13.10
U23	1000BASE-T EEE (1 = Advertise EEE capability for 1000BASE-T 0 = Do not advertise EEE capability for 1000BASE-T)	Defined in 45.2.7.13.11
U22	100BASE-TX EEE (1 = Advertise EEE capability for100BASE-TX 0 = Do not advertise EEE capability for 100BASE-TX)	Defined in 45.2.7.13.12
U21	Reserved	
U20	LD PMA training reset request (1 = Local Device requests that Link Partner reset PMA training PRBS every frame 0 = Local Device requests that Link Partner run PMA training PRBS continuously)	Defined in 45.2.7.10.5
U19	Fast retrain ability (1 = Advertise PHY as supporting fast retrain 0 = Advertise PHY as not supporting fast retrain)	Defined in 45.2.7.10.6
U18	PHY short reach mode (1 = PHY of Local Device is operating in short reach mode 0 = PHY of Local Device is operating in normal mode)	Defined in 45.2.1.64.2
U17	LD loop timing ability (1 = Advertise PHY as capable of loop timing and 0 = do not advertise PHY as capable of loop timing)	Defined in 45.2.7.10.7
U16	10GBASE-T ability (1 = support of 10GBASE-T and 0 = no support)	Defined in 45.2.7.10.4
U15	1000BASE-T half duplex (1 = half duplex and 0 = no half duplex)	
U14	1000BASE-T full duplex (1 = full duplex and 0 = no full duplex)	
U13	Port type bit (1 = multiport device and 0 = single-port device)	Defined in 45.2.7.10.3
U12	10GBASE-T MASTER-SLAVE config value (1 = MASTER and 0 = SLAVE) This bit is ignored if 7.32.15 =0.	Defined in 45.2.7.10.1
U11	10GBASE-T MASTER-SLAVE manual config enable (1 = manual configuration enable) This bit is intended to be used for manual selection in a particular MASTER-SLAVE mode and is to be used in conjunction with bit 7.32.14.	Defined in 45.2.7.10.2
U10	MASTER-SLAVE seed Bit 10 (SB10) (MSB)	
U9	MASTER-SLAVE seed Bit 9 (SB9)	

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Table 55–15—10GBASE-T Base and Next Pages bit assignments *(continued)*

Bit	Name	Description
U8	MASTER-SLAVE seed Bit 8 (SB8)	
U7	MASTER-SLAVE seed Bit 7 (SB7)	
U6	MASTER-SLAVE seed Bit 6 (SB6)	
U5	MASTER-SLAVE seed Bit 5 (SB5)	
U4	MASTER-SLAVE seed Bit 4 (SB4)	
U3	MASTER-SLAVE seed Bit 3 (SB3)	
U2	MASTER-SLAVE seed Bit 2 (SB2)	
U1	MASTER-SLAVE seed Bit 1 (SB1)	
U0	MASTER-SLAVE seed Bit 0 (SB0)	

55.6.1.3 Sending Next Pages

Implementers who do not wish to send additional Next Pages (i.e., Next Pages in addition to those required to perform PHY configuration as defined in this clause) can use Auto-Negotiation as defined in Clause 28.

55.6.2 MASTER-SLAVE configuration resolution

Since both PHYs that share a link segment are capable of being MASTER or SLAVE, a prioritization scheme exists to ensure that the correct mode is chosen. The MASTER-SLAVE relationship shall be determined during Auto-Negotiation using Table 55–16 with the 10GBASE-T Technology Ability Next Page bit values specified in Table 55–15 and information received from the link partner. This process is conducted at the entrance to the FLP LINK GOOD CHECK state shown in the Arbitration state diagram (Figure 28–18.)

The following four equations are used to determine these relationships:

manual_MASTER = U11 * U12
manual_SLAVE = U11 * !U12
single-port device = !U11 * !U13
multiport device = !U11 * U13

where

U11 is bit 11 of 10GBASE-T/1000BASE-T Technology message code,
U12 is bit 12 of 10GBASE-T/1000BASE-T Technology message code,
U13 is bit 13 of 10GBASE-T/1000BASE-T Technology message code (see Table 55–15).

A 10GBASE-T PHY is capable of operating either as the MASTER or SLAVE. In the scenario of a link between a single-port device and a multiport device, the preferred relationship is for the multiport device to be the MASTER PHY and the single-port device to be the SLAVE. However, other topologies may result in contention. The resolution function of Table 55–16 is defined to handle any relationship conflicts.

In the instance when both link partners support the optional loop timing mode, or both link partners do not support the loop timing mode, as designated by bit U17, the resolution shown in Table 55–16 shall be used.

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When only one link partner supports loop timing, the device that supports loop timing shall be forced to SLAVE and the other device shall be forced to MASTER.

Table 55–16—10GBASE-T MASTER-SLAVE configuration resolution table

Local device type	Remote device type	Local device resolution	Remote device resolution
single-port device	multiport device	SLAVE	MASTER
single-port device	manual_MASTER	SLAVE	MASTER
manual_SLAVE	manual_MASTER	SLAVE	MASTER
manual_SLAVE	multiport device	SLAVE	MASTER
multiport device	manual_MASTER	SLAVE	MASTER
manual_SLAVE	single-port device	SLAVE	MASTER
multiport device	single-port device	MASTER	SLAVE
multiport device	manual_SLAVE	MASTER	SLAVE
manual_MASTER	manual_SLAVE	MASTER	SLAVE
manual_MASTER	single-port device	MASTER	SLAVE
single-port device	manual_SLAVE	MASTER	SLAVE
manual_MASTER	multiport device	MASTER	SLAVE
multiport device	multiport device	The device with the higher seed value is configured as MASTER, otherwise SLAVE.	The device with the higher seed value is configured as MASTER, otherwise SLAVE.
single-port device	single-port device	The device with the higher seed value is configured as MASTER, otherwise SLAVE	The device with the higher seed value is configured as MASTER, otherwise SLAVE.
manual_SLAVE	manual_SLAVE	MASTER-SLAVE configuration fault	MASTER-SLAVE configuration fault
manual_MASTER	manual_MASTER	MASTER-SLAVE configuration fault	MASTER-SLAVE configuration fault

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A 10GBASE-T multiport device has higher priority than a single-port device to become the MASTER. In the case where both devices are of the same type, e.g., both devices are multiport devices and both devices have the same loop timing support, the device with the higher MASTER-SLAVE seed bits (SB0...SB10), where SB10 is the MSB, shall become the MASTER and the device with the lower seed value shall become the SLAVE. In case both devices have the same seed value, both should assert link_status_10GigT=FAIL (as defined in 28.3.1) to force a new cycle through Auto-Negotiation. Successful completion of the MASTER-SLAVE resolution shall be treated as MASTER-SLAVE configuration resolution complete.

The method of generating a random or pseudorandom seed is left to the implementer. The generated random seeds should belong to a sequence of independent, identically distributed integer numbers with a uniform distribution in the range of 0 to 2^{11}– 2. The algorithm used to generate the integer should be designed to minimize the correlation between the number generated by any two devices at any given time. A seed counter shall be provided to track the number of seed attempts. The seed counter shall be set to zero at start-up and shall be incremented each time a seed is generated. When MASTER-SLAVE resolution is complete,

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the seed counter shall be reset to 0 and bit 7.33.15 shall be set to zero. A MASTER-SLAVE resolution fault shall be declared if resolution is not reached after the generation of seven seeds.

The MASTER-SLAVE manual configuration enable bit (control register bit 7.32.15) and the MASTER-SLAVE config value bit (control register bit 7.32.14) are used to manually set a device to become the MASTER or the SLAVE. In case both devices are manually set to become the MASTER or the SLAVE, this condition shall be flagged as a MASTER-SLAVE configuration fault condition; thus the MASTER-SLAVE configuration fault bit (status register bit 7.33.15) shall be set to logical one. In the situation where one link partner supports loop timing and the other does not, a MASTER-SLAVE configuration fault bit (status register bit 7.33.15) shall be set to one if the link partner with loop timing support is manually set to MASTER or the link partner with no loop timing support is manually set to SLAVE. The MASTER-SLAVE configuration fault condition shall be treated as MASTER-SLAVE configuration resolution complete and link_status_10GigT shall be set to FAIL, because the MASTER-SLAVE relationship was not resolved. This forces a new cycle through Auto-Negotiation after the link_fail_inhibit_timer has expired. Determination of MASTER-SLAVE values occur on the entrance to the FLP LINK GOOD CHECK state (Figure 28–18) when the highest common denominator (HCD) technology is 10GBASE-T. The resulting MASTER-SLAVE value is used by the 10GBASE-T PHY Control (55.4.2.5).

If MASTER-SLAVE manual configuration is disabled (bit 7.32.15 is set to 0) and the local device detects that both the local device and the remote device are of the same type (either multiport device or single-port device and identical loop timing support) and that both have generated the same random seed, it generates and transmits a new random seed for MASTER-SLAVE negotiation by setting link_status to FAIL and cycling through the Auto-Negotiation process again.

The MASTER-SLAVE configuration process returns one of the three following outcomes:

a) *Successful:* Bit 7.33.15 of the 10GBASE-T status register is set to logical zero and bit 7.33.14 is set to logical one for MASTER resolution or to logical zero for SLAVE resolution. 10GBASE-T returns control to Auto-Negotiation (at the entrance to the FLP LINK GOOD CHECK state in Figure 28–18) and passes the value MASTER or SLAVE to PMA_CONFIG.indicate (see 55.2.2.2).
b) *Unsuccessful:* link_status_10GigT is set to FAIL and Auto-Negotiation restarts (see Figure 28–18).
c) *Fault detected:* Bit 7.33.15 of the 10GBASE-T status register is set to logical one to indicate that a configuration fault has been detected. This bit also is set when seven attempts to configure the MASTER-SLAVE relationship via the seed method have failed. When a fault is detected, link_status_10GigT is set to FAIL, causing Auto-Negotiation to cycle through again.

NOTE—MASTER-SLAVE arbitration only occurs if 10GBASE-T or 1000BASE-T is selected as the highest common denominator.

55.7 Link segment characteristics

10GBASE-T is designed to operate over ISO/IEC 11801 Class E or Class F 4-pair balanced cabling that meets the additional requirements specified in this subclause. Each of the four pairs supports an effective data rate of 2500 Mb/s in each direction simultaneously. The term “link segment” used in this clause refers to four twisted-pairs operating in full duplex. Specifications for a link segment apply equally to each of the four twisted-pairs. All implementations of the balanced cabling link segment specification shall be compatible at the MDI. It is recommended that the guidelines in TIA TSB-155-A, ISO/IEC TR 24750, ANSI/TIA-568-C.2, and ISO/IEC 11801:2002/Amendment 1 be considered before the installation of 10GBASE-T equipment for any cabling system.

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55.7.1 Cabling system characteristics

The cabling system used to support 10GBASE-T requires 4 pairs of ISO/IEC 11801 Class E or Class F balanced cabling with a nominal impedance of 100 Ω. Operation on other classes of cabling may be supported if the link segment meets the requirements of 55.7.

Additionally:

a) 10GBASE-T uses a star topology with Class E or Class F balanced cabling used to connect PHY entities.
b) 10GBASE-T is an ISO/IEC 11801 Class E and Class F application with the additional transmission requirements specified in this subclause. The ISO/IEC 11801 cabling limit calculation minimums apply to the link segment specifications. Mitigation practices may be required—see Annex 55B.

55.7.2 Link segment transmission parameters

A link segment consisting of up to 100 m of Class E or up to 100 m of Class F that meets the transmission parameters of this subclause provides a reliable medium. The transmission parameters of the link segment include insertion loss, delay parameters, nominal impedance, NEXT loss, ELFEXT, and return loss. In addition, the requirements for the alien crosstalk coupled "between" link segments is specified.

Table 55–17 lists the supported cabling types and distances.

Table 55–17— Cabling types and distances

Cabling	Supported link segment distances	Cabling references
Class E / Category 6	55 m to 100 m[a]	ISO/IEC TR 24750 / TIA TSB-155-A
Class E / Category 6: unscreened	55 m	ISO/IEC TR 24750 / TIA TSB-155-A
Class E / Category 6: screened	100 m	ISO/IEC TR 24750 / TIA TSB-155-A
Class F	100 m	ISO/IEC TR 24750
Class E_A / Category 6A	100 m	ISO/IEC 11801:2002/Amendment 1 / ANSI/TIA-568-C.2
Class F_A	100 m	ISO/IEC 11801:2002 Amendment 1

[a]Supported link segments up to 100 m shall meet the alien crosstalk to insertion loss requirements specified in 55.7.3.1.2 and 55.7.3.2.2.

The link segment transmission parameters of insertion loss and ELFEXT specified are ISO/IEC 11801 Class E specifications extended by extrapolating the formulas to a frequency up to 500 MHz with appropriate adjustments for length when applicable as specified in ISO/IEC TR 24750 and TIA TSB-155-A. The link segment transmission parameters of NEXT loss, MDNEXT loss, and return loss specified are ISO/IEC 11801 Class E specifications extended beyond 250 MHz by utilizing the equations referenced in TIA TSB-155.

55.7.2.1 Insertion loss

The insertion loss of each duplex channel shall meet the values determined using Equation (55–11).

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$$\text{Insertion loss}(f) \leq 1.05\left(1.82 \times \sqrt{f} + 0.0169 \times f + \frac{0.25}{\sqrt{f}}\right) + 4 \times 0.02 \times \sqrt{f} \quad \text{(dB)} \qquad (55\text{–}11)$$

where

f is the frequency in MHz; $1 \leq f \leq 500$

This includes the insertion loss of the balanced cabling pairs, including work area and equipment cables plus connector losses within each duplex channel.

For the purpose of calculating the link segment insertion loss for cabling less than 100 m the cable insertion loss is assumed to scale linearly with length as defined in Equation (55–27).

55.7.2.2 Differential characteristic impedance

The nominal differential characteristic impedance of each link segment duplex channel, which includes cable cords and connecting hardware, is 100 Ω for all frequencies between 1 MHz and 500 MHz.

55.7.2.3 Return loss

In order to limit the noise at the receiver due to impedance mismatches in the cabling system, each link segment duplex channel shall meet the values determined using Equation (55–12) at all frequencies from 1 MHz to 500 MHz. The reference impedance for the return loss specification is 100 Ω.

$$\text{Return loss} \geq \begin{cases} 19 & 1 \leq f < 10 \\ 24 - 5\log_{10}(f) & 10 \leq f < 40 \\ 32 - 10\log_{10}(f) & 40 \leq f < 400 \\ 6 & 400 \leq f \leq 500 \end{cases} \quad \text{(dB)} \qquad (55\text{–}12)$$

where

f is the frequency in MHz.

55.7.2.4 Coupling parameters between duplex channels comprising one link segment

In order to limit the noise coupled into a duplex channel from adjacent duplex channels, near-end crosstalk (NEXT) loss and equal level far-end crosstalk (ELFEXT) are specified for each link segment. In addition, each duplex channel can be disturbed by more than one duplex channel. To ensure the total NEXT loss and FEXT loss coupled into a duplex channel is limited, multiple disturber near-end crosstalk (MDNEXT) and multiple disturber ELFEXT (MDELFEXT) is specified.

55.7.2.4.1 Differential near-end crosstalk

In order to limit the crosstalk at the near end of a link segment, the differential pair-to-pair near-end crosstalk (NEXT) loss between a duplex channel and the other three duplex channels is specified to meet the bit error ratio objective specified in 55.1.1. The NEXT loss between any two duplex channels of a link segment shall meet the values determined using Equation (55–13)

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$$\text{NEXT loss}(f) \geq \begin{cases} -20\log_{10}\left(10^{\frac{74.3-15\log_{10}(f)}{-20}} + 2\times 10^{\frac{94-20\log_{10}(f)}{-20}}\right) \text{ (dB)} & 1 \leq f < 330 \\ 31 - 50\log_{10}\left(\frac{f}{330}\right) \text{ (dB)} & 330 \leq f \leq 500 \end{cases} \quad (55\text{–}13)$$

where

f is the frequency in MHz.

Calculations that result in NEXT loss values greater than 65 dB shall revert to a requirement of 65 dB minimum.

55.7.2.4.2 Multiple disturber near-end crosstalk (MDNEXT) loss

Since four duplex channels are used to transfer data between PMDs, the NEXT that is coupled into a data carrying channel is from the three adjacent disturbing duplex channels.

To ensure the total NEXT coupled into a duplex channel is limited, multiple disturber NEXT loss is specified as the power sum of the individual NEXT losses. The power sum loss between a duplex channel and the three adjacent disturbers shall meet the values determined using Equation (55–14).

$$\text{MDNEXT loss}(f) \geq \begin{cases} -20\log_{10}\left(10^{\frac{72.3-15\log_{10}(f)}{-20}} + 2\times 10^{\frac{90-20\log_{10}(f)}{-20}}\right) \text{ (dB)} & 1 \leq f < 330 \\ 28 - 50\log_{10}\left(\frac{f}{330}\right) \text{ (dB)} & 330 \leq f \leq 500 \end{cases} \quad (55\text{–}14)$$

where

f is the frequency in MHz.

Calculations that result in PS NEXT loss values greater than 62 dB shall revert to a requirement of 62 dB minimum.

55.7.2.4.3 Multiple disturber power sum near-end crosstalk (PSNEXT) loss

PS NEXT loss is determined by summing the power of the three individual pair-to-pair differential NEXT loss values over the frequency range 1 MHz to 500 MHz as follows in Equation (55–15).

$$\text{PSNEXT loss}(f) = \left(-10\log_{10}\sum_{i=1}^{n} 10^{\frac{-NL(f)i}{10}}\right) \text{ (dB)} \quad (55\text{–}15)$$

where

$NL(f)i$ is the magnitude in dB of NEXT loss at frequency f (in MHz) of pair combination i

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i is the pair-to-pair combination (1 to *n*)

n is the number of pair-to-pair combinations (*n*=3)

55.7.2.4.4 Equal level far-end crosstalk (ELFEXT)

Equal level far-end crosstalk (ELFEXT) is specified in order to limit the crosstalk at the far end of each link segment duplex channel and meet the bit error ratio objective specified in 55.1.1. Far-end crosstalk (FEXT) is crosstalk that appears at the far end of a duplex channel (disturbed channel), which is coupled from another duplex channel (disturbing channel) with the noise source (transmitters) at the near end.

FEXT loss is defined in Equation (55–16) as

$$\text{FEXT loss}(f) = 20\log_{10}\left(\frac{V_{pds}(f)}{V_{pcn}(f)}\right) \quad \text{(dB)} \tag{55–16}$$

and ELFEXT is defined in Equation (55–17) as

$$\text{ELFEXT}\ (f) = 20\log_{10}\left(\frac{V_{pds}(f)}{V_{pcn}(f)}\right) - \text{SLS_Loss(f) (dB)} \tag{55–17}$$

where

Vpds is the peak voltage of disturbing signal (near-end transmitter),
Vpcn is the peak crosstalk noise at far end of disturbed channel,
SLS_Loss is the insertion loss of disturbed channel in dB.

The worst pair ELFEXT between any two duplex channels shall meet the values determined using Equation (55–18).

$$\text{ELFEXT} \geq -20\log_{10}\left(10^{\frac{67.8 - 20\log_{10}(f)}{-20}} + 4 \times 10^{\frac{83.1 - 20\log_{10}(f)}{-20}}\right) \quad \text{(dB)} \tag{55–18}$$

where

f is the frequency in MHz and $1 \leq f \leq 500$.

The numerator of the first term “raised to the power of 10” in Equation (55–18) is the cable portion of the duplex channel of 100 m. The ELFEXT of the cable improves as the cable is reduced in length as defined in Equation (55–19). The equation assumes coupling over 100 m of cable including horizontal cable and cable cords

$$\text{ELFEXT}(f, L) = (67.8 - 20\log_{10}(f)) - 10\log_{10}\left(\frac{L}{100}\right) \quad \text{(dB)} \tag{55–19}$$

where

L is the length in meters of the link segment,
f is the frequency in MHz.

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55.7.2.4.5 Multiple disturber equal level far-end crosstalk (MDELFEXT)

Since four duplex channels are used to transfer data between PMDs, the FEXT that is coupled into a data carrying channel is from the three adjacent disturbing duplex channels. To ensure the total FEXT coupled into a duplex channel is limited, multiple disturber ELFEXT is specified as the power sum of the individual ELFEXT disturbers. The power sum loss between a duplex channel and the three adjacent disturbers shall meet the values determined using Equation (55–20).

$$\mathrm{MDELFEXT}(f) \geq -20\log_{10}\left(10^{\frac{64.8 - 20\log_{10}(f)}{-20}} + 4 \times 10^{\frac{80.1 - 20\log_{10}(f)}{-20}}\right) \quad \text{(dB)} \qquad \text{(dB)} \qquad (55\text{–}20)$$

where

f is the frequency $1 \leq f \leq 500$.

55.7.2.4.6 Multiple disturber power sum equal level far-end crosstalk (PS ELFEXT)

PS ELFEXT is determined by summing the power of the three individual pair-to-pair differential ELFEXT values over the frequency range 1 MHz to 500 MHz as follows in Equation (55–21):

$$\mathrm{PSELFEXT}\ (f) = -10\log_{10}\sum_{i=1}^{i=n} 10^{\frac{-EL(f)i}{10}} \quad \text{(dB)} \qquad (55\text{–}21)$$

where

EL(f)i is the magnitude of ELFEXT at frequency *f* of pair combination *i*,
i is the pair-to-pair combination (1 to *n*),
f is the frequency in MHz,
n is the number of pair-to-pair combinations (*n*=3).

55.7.2.5 Maximum link delay

The propagation delay of a link segment shall not exceed 570 ns at all frequencies between 2 MHz and 500 MHz.

55.7.2.6 Link delay skew

The difference in propagation delay, or skew, between all duplex channel pair combinations of a link segment, under all conditions, shall not exceed 50 ns at all frequencies from 2 MHz to 500 MHz. It is a further functional requirement that, once installed, the skew between any two of the four duplex channels due to environmental conditions shall not vary more than 10 ns within the above requirement.

55.7.3 Coupling parameters between link segments

Noise coupled between the disturbed duplex channel in a link segment and the disturbing duplex channels in other link segments is referred to as alien crosstalk noise. To ensure the total alien NEXT loss and alien FEXT loss coupled between link segments is limited, multiple disturber alien near-end crosstalk (MD ANEXT) loss and multiple disturber alien FEXT (MDAFEXT) loss is specified. In addition, to ensure the reliable operation of the link segment, a minimum alien crosstalk to insertion loss ratio are specified.

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55.7.3.1 Multiple disturber alien near-end crosstalk (MDANEXT) loss

In order to limit the alien crosstalk at the near end of a link segment, the differential pair-to-pair near-end crosstalk (NEXT) loss between the disturbed duplex channel in a link segment and the disturbing duplex channels in other link segments is specified to meet the bit error ratio objective specified in 55.1.1. To ensure the total alien NEXT coupled into a duplex channel is limited, multiple disturber alien NEXT loss is specified as the power sum of the individual alien NEXT disturbers.

55.7.3.1.1 Multiple disturber power sum alien near-end crosstalk (PSANEXT) loss

PS ANEXT loss is determined by summing the power of the individual pair-to-pair differential alien NEXT loss values over the frequency range 1 MHz to 500 MHz as follows in Equation (55–22):

$$\mathrm{PSANEXT}_N(f) = -10\log_{10}\sum_{j=1}^{m}\sum_{i=1}^{4} 10^{\frac{-AN(f)_{i,j,N}}{10}} \quad (\mathrm{dB}) \qquad (55\text{–}22)$$

where

$AN(f)_{i,j,N}$ is the magnitude in dB of the alien NEXT loss at frequency f of the individual pair combination i (1 to 4) of the disturbing link j (1 to m) for each disturbed pair N.

Annex 55B provides additional information on identifying the number of adjacent link segments to consider in the PSANEXT calculation.

The power sum ANEXT loss between a disturbed duplex channel in a link segment and the disturbing duplex channels in other link segments shall meet the values determined using Equation (55–23) independent of length.

$$\mathrm{PSANEXT}(f) \geq \begin{cases} X1 - 10\log_{10}\left(\frac{f}{100}\right) \ (\mathrm{dB}) & 1 \leq f \leq 100 \\ X1 - 15\log_{10}\left(\frac{f}{100}\right) \ (\mathrm{dB}) & 100 < f \leq 500 \end{cases} \qquad (55\text{–}23)$$

where

f is the frequency in MHz,
$X1$ is the value at f =100 MHz. $X1$ is referred to as the PSANEXT constant.

When the computed PSANEXT value at a certain frequency exceeds 67 dB, the PSANEXT result at that frequency is for information only.

The PSANEXT constant is determined in 55.7.3.1.2 constrained by the ratio of the PSANEXT to the insertion loss.

The average PSANEXT between a disturbed duplex channel in a link segment and the disturbing duplex channels in other link segments is the average of the individual-pair PSANEXT “across the 4-pairs” determined using Equation (55–24):

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$$\text{PSANEXT}avg(f) = \frac{\left(\sum_{i=1}^{n} \text{PSANEXT}(f)_\text{pair_i (dB)}\right)}{4} \qquad (55\text{–}24)$$

where

PSANEXT*(f)*_pair_i is the magnitude in dB of PSANEXT loss at frequency *f* of pair_i,
n is the number of individual-pairs (*n* = 4).

The average PSANEXT loss of the 4-pairs shall meet the values determined using Equation (55–25) independent of length.

$$\text{PSANEXT}avg(f) \geq \begin{cases} (X1 + 2.25) - 10\log_{10}\left(\frac{f}{100}\right) \text{ (dB)} & 1 \leq f \leq 100 \\ (X1 + 2.25) - 15\log_{10}\left(\frac{f}{100}\right) \text{ (dB)} & 100 < f \leq 500 \end{cases} \qquad (55\text{–}25)$$

where

f is the frequency in MHz,
X1 is the value at *f* =100 MHz. *X1* is referred to as the PSANEXT constant.

55.7.3.1.2 PSANEXT loss to insertion loss ratio requirements

To ensure reliable operation, a minimum insertion loss to alien crosstalk ratio shall be maintained. The PSANEXT loss requirement of 55.7.3.1.1 can be relaxed based on a reduction in the maximum insertion loss specified in 55.7.2.1. The insertion loss reduction can be achieved by utilizing link segments less than 100 m defined by (55–27) or the insertion loss at 250 MHz of the supported cabling types in Table 55–17.

The adjusted PSANEXT loss requirement is determined by first calculating the PSANEXT constant and utilizing the constant in the PSANEXT limit line Equation (55–23) and Equation (55–25).

The PSANEXT_constant shall be specified by the following Equation (55–26):

$$\text{PSANEXT_constant} = 62 - \frac{10GBTIL(250\text{ MHz}) - \text{IL}(250\text{ MHz})}{1.04} \text{ (dB)} \qquad (55\text{–}26)$$

where

10*GBTIL(*250*MHz)* is the link segment insertion loss at 250 MHz [Equation (55–11)],
IL(250*MHz*) is the insertion loss of a link segment less than 100 m [Equation (55–27)] or the insertion loss at 250 MHz of the supported cabling types in Table 55–17. For measurement-based calculations, IL(250 MHz) shall be the average of the insertion loss of the 4-pairs at 250 MHz.

The calculated PSANEXT_constant values less than 33.5 dB shall revert to a value of 33.5 dB.

For the purpose of calculating the link segment insertion loss for cabling less than 100 m the cable insertion loss is assumed to scale linearly with length.

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The scaled link segment is defined by the following Equation (55–27):

$$\text{Scaled_10GBTIL} = \frac{\text{Length_m}}{100} \times 1.05\left(1.82 \times \sqrt{f} + 0.0169 \times f + \frac{0.25}{\sqrt{f}}\right) + 4 \times 0.02 \times \sqrt{f} \quad \text{(dB)} \qquad (55\text{–}27)$$

where

Length_m is in meters,
f is the frequency in MHz.

Table 55–18 provides the calculated PSANEXT_constants for link segments of 100 m and 55 m.

Table 55–18— Calculated PS ANEXT constants

Link segment distance	PSANEXT_constant (dB)	PSANEXT_constant_avg average of the 4-pairs (dB)	Insertion loss at 250 MHz (dB)
100 m	62	64.25	35.9
55 m	47	49.25	20.3

Table 55–19 provides the calculated PSANEXT_constants for the supported cabling types.

Table 55–19— Calculated PSANEXT constants for supported cabling types

Cabling	Insertion loss at 250 MHz (dB)	PSANEXT_constant (dB)	PSANEXT_constant_avg average of the 4-pairs (dB)
Category 6/ Class E	35.9[a], 20.3[b]	62[a], 47[b]	64.25[a], 49.25[b]
Class E_A / Category 6A	33.8	60	62.25
Class F	33.8	60	62.25

[a]Link segment length of 100 m.
[b]Link segment length of 55 m.

Table 55–20 provides the calculated PSANEXT to insertion loss ratio for the supported cabling types.

Table 55–20— Calculated PSANEXT to insertion loss ratio at 250 MHz

Cabling	Insertion loss at 250 MHz (dB)	PSANEXT at 250 MHz (dB)	PSANEXT to insertion loss ratio at 250 MHz (dB)
Category 6/ Class E	35.9[a], 20.3[b]	56.0[a], 41.0[b]	20.1[a], 20.7[b]
Class E_A / Category 6A	33.8	54.0	20.2
Class F	33.8	54.0	20.2

[a]Link segment length of 100 m.
[b]Link segment length of 55 m.

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For simulating PHY performance to estimate system margin, the PSANEXT_constant is increased by 3.5 dB to account for an averaging of the PSANEXT over frequency and averaging the PSANEXT *across the 4-pairs*.

55.7.3.2 Multiple disturber alien far-end crosstalk (MDAFEXT) loss

In order to limit the alien crosstalk at the far-end of a link segment, the differential pair-to-pair alien far-end crosstalk loss between the disturbed duplex channel in a link segment and the disturbing duplex channels in other link segments is specified to meet the bit error ratio objective specified in 55.1.1. To ensure the total alien FEXT coupled into a duplex channel is limited, multiple disturber ELFEXT is specified as the power sum of the individual alien ELFEXT disturbers.

55.7.3.2.1 Multiple disturber power sum alien equal level far-end crosstalk (PSAELFEXT)

Power sum alien ELFEXT is determined by summing the power of the individual pair-to-pair differential alien ELFEXT values over the frequency range 1 MHz to 500 MHz as follows in Equation (55–28):

$$\mathrm{PSAELFEXT}_N(f) = -10\log_{10}\sum_{j=1}^{m}\sum_{i=1}^{4}10^{\frac{-EL(f)_{i,j,N}}{10}} \quad \text{(dB)} \tag{55–28}$$

where

$EL(f)_{i,j,N}$ is determined using Equation (55–29) as the magnitude in dB of the alien ELFEXT of the coupled length at frequency f of the individual pair combination i (1 to 4) of the disturbing link j (1 to m) for each disturbed pair N corrected by subtracting the $10\log_{10}$ ratio of the disturbed length insertion loss to the coupled length insertion loss. The coupled length is the length of cabling over which the crosstalk coupling can occur.

$$EL(f)_{i,j,N} = AlienELFEXT(f)_{i,j,N} - 10\log_{10}\left(\frac{DisturbedIL_N}{CoupledlengthIL_{i,j,N}}\right) \tag{55–29}$$

where

$AlienELFEXT(f)_{i,j,N}$ is determined using Equation (55–30) as the difference of the magnitude in dB of the Alien FEXT of the coupled length at frequency f of the individual pair combination i (1 to 4) of the disturbing link j (1 to m) for each disturbed pair N and the insertion loss of the coupled length.

$$AlienELFEXT(f)_{i,j,N} = AFEXT(f)_{i,j,N} - CoupledlengthIL(f)_{i,j,N} \tag{55–30}$$

where

$CoupledlengthIL(f)_{i,j,N}$ is determined using Equation (55–31) as the minimum of the insertion loss of the disturbed pair N and the disturbing individual pair i (1 to 4) of the disturbing link j (1 to m).

$$CoupledlengthIL(f)_{i,j,N} = min(DisturbedIL_N, DisturbingIL_{i,j}) \tag{55–31}$$

NOTE—The computation of PSAELFEXT in Equation (55–28) is consistent with the computation of power sum alien attenuation to crosstalk ratio far end (PS AACR-F). The term PS AACR-F is used in ISO/IEC TR 24750 and in the 1st amendment to the second edition of ISO/IEC 11801.

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The PSAELFEXT between a disturbed duplex channel in a link segment and the disturbing duplex channels in other link segments shall meet the values determined using Equation (55–32).

$$\text{PSAELFEXT}(f) \geq X2 - 20\log_{10}\left(\frac{f}{100}\right) \quad (dB) \qquad 1 \leq f \leq 500 \qquad (55\text{–}32)$$

where

f is the frequency in MHz,
X2 is the value at *f* =100 MHz. *X2* is referred to as the PSAELFEXT constant.

When the measured PSAFEXT limit value at a certain frequency exceeds 72-15log$_{10}$(*f*/100) dB, 67 dB max, the PSAELFEXT result at that frequency is for information only.

The average PSAELFEXT between a disturbed duplex channel in a link segment and the disturbing duplex channels in other link segments is the average of the individual-pair PS AELFEXT *across the 4-pairs* determined using Equation (55–33).

$$\text{PSAELFEXT}avg(f) = \frac{\left(\sum_{i=1}^{n} \text{PSAELFEXT}(f)_\text{pair_i (dB)}\right)}{4} \qquad (55\text{–}33)$$

where

PSAELFEXT(*f*)_pair_i is the magnitude in dB of PSAELFEXT loss at frequency *f* of pair *i*,
n is the number of individual-pairs (*n* = 4).

The average PSAELFEXT of the 4-pairs shall meet the values determined using Equation (55–34).

$$\text{PSAELFEXT}avg(f) \geq (X2 + 4) - 20\log_{10}\left(\frac{f}{100}\right) \quad (\text{dB}) \qquad 1 \leq f \leq 500 \qquad (55\text{–}34)$$

where

f is the frequency in MHz,
X2 is the value at *f* =100 MHz. The value at *f* =100 MHz is referred to as the PSAELFEXT constant.

The PSAELFEXT constant is determined in 55.7.3.2.2 by the ratio of the PS AELFEXT to the insertion loss and a length correction term. The insertion loss dependent term maintains the required SNR ratio and the IL independent term enables a relaxation of the PS AELFEXT due the reduction in crosstalk coupling for lengths less than 100 m.

55.7.3.2.2 PSAELFEXT to insertion loss ratio requirements

To ensure reliable operation, a minimum insertion loss to alien crosstalk ratio shall be maintained. The PS AELFEXT requirement of 55.7.3.2.1 can be relaxed based on a reduction in the maximum insertion loss specified in 55.7.2.1 and a reduction in the AELFEXT coupling for cabling lengths less than 100 m.

The adjusted PSAELFEXT requirement is determined by first calculating the PSAELFEXT constant and utilizing the constant in the PSAELFEXT limit line model of Equation (55–35).

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The PSAELFEXT_constant shall be specified by the following equation:

$$\text{PSAELFEXT_constant} = 37.9 - \left(\frac{10GBTIL(250\ \text{MHz}) - \overline{\overline{IL(250\ \text{MHz})}}}{2.29} \right) - 10\log_{10}\left(\frac{L}{100}\right) \quad (dB) \qquad (55\text{–}35)$$

where

$10GBTIL($250 MHz) is the link segment insertion loss at 250 MHz [Equation (55–11)],
IL(250 MHz) is the insertion loss of a link segment less than 100 m [Equation (55–27)] or the insertion loss of the supported cabling types in Table 55–17 at 250 MHz. For measurement based calculations, IL(250 MHz) shall be the average of the insertion loss of the 4-pairs at 250 MHz.
L is the length in meters of the link segment. The equation assumes coupling over 100 m of horizontal cable and cable cords. For measurement based calculations (e.g., field testing), L can derived from the measured insertion loss and substituted in Equation (55–35) as defined in Equation (55–36).

$$L = 2.77 \times (\text{measured insertion loss at 250 MHz}) \qquad (55\text{–}36)$$

For insertion loss values less than 10 dB at 250 MHz the calculated PSAELFEXT_constant values that exceed 32.5 dB shall revert to a value of 32.5 dB.

The field testing of length and insertion loss are addressed in TIA TSB-155-A and ISO/IEC TR 24750.

Table 55–21 provides the calculated PSAELFEXT_constants for link segments of 100 m and 55 m.

Table 55–21—Calculated PS AELFEXT constants

Link segment distance	PS AELFEXT_constant (dB)	PS AELFEXT_constant_avg average of the 4-pairs (dB)	Insertion loss at 250 MHz (dB)
100 m	37.9	41.9	35.9
55 m	33.7	37.7	20.3

Table 55–22 provides the calculated PSAELFEXT_constants for the supported cabling types.

Table 55–22—Calculated PSAELFEXT constants for supported cabling types

Cabling	Insertion loss at 250 MHz (dB)	PSAELFEXT_constant (dB)	PSAELFEXT_constant_avg average of the 4-pairs (dB)
Category 6/ Class E	35.9[a], 20.3[b]	37.9[a], 33.7[b]	41.9[a], 37.7[a]
Class E_A / Category 6A	33.8	37	41
Class F	33.8	37	41

[a]Link segment length of 100 m.
[b]Link segment length of 55 m.

Table 55–23 provides the calculated PS AELFEXT at 250 MHz for the supported cabling types.

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Table 55–23—Calculated PS AELFEXT at 250 MHz for supported cabling types

Cabling	Insertion loss at 250 MHz (dB)	PS AELFEXT at 250 MHz (dB)
Category 6/ Class E	35.9[a], 20.3[b]	29.9[a], 25.7[b]
Class E_A / Category 6A	33.8	29.0
Class F	33.8	29.0

[a]Link segment length of 100 m.
[b]Link segment length of 55 m.

55.7.3.3 Alien crosstalk margin computation

The objective of alien crosstalk margin computation is to further characterize the alien crosstalk coupling "between" link segments. The alien crosstalk margin computation ensures the total combined PSAFEXT and PSANEXT coupled into a duplex channel is limited in order to maintain the minimum signal-to-noise ratio. The alien crosstalk margin computation can be applied in the event that the PSANEXT limits specified in 55.7.3.1.1 [Equation (55–23) and Equation (55–25)] or the PSAELFEXT limits specified in 55.7.3.2. [Equation (55–32) and Equation (55–34)] are not met. The alien crosstalk margin is specified for each of the individual 4-pairs as well as the average "across the 4-pairs".

The alien crosstalk margin is determined by the following algorithm:

Step 1. Determine the length of the disturbed link segment and the disturbing link segments using Equation (55–37).

$$L = 277 \times \text{IL_avg} \tag{55–37}$$

where

IL_*avg*is the average measured insertion loss at 250 MHz "across the 4-pairs" of each disturbed and disturbing link segment.
L is the length in meters for each disturbed and disturbing link segment derived from the measured insertion loss.

Step 2. Determine the minimum power backoff (dB) for each disturbed and disturbing link segment from Table 55–11. Power backoff schedule utilizing the calculated link segment length from Step 1 (e.g., from Table 55–11; a length of 30 m has a minimum power backoff of 10 dB).

Step 3. Determine the insertion loss backoff factor using Equation (55–38).

$$\text{IL_bof}_j = \text{min_PBO_disturbing link}_j - \text{min_PBO_disturbed link} \tag{55–38}$$

where

IL_$bof_j$is calculated as the difference between the minimum power backoff (dB) of the disturbing link j and the disturbed link segments determined in Step 2.

Step 4. Determine the PSANEXT and the PSAFEXT from the measured ANEXT and AFEXT and the insertion loss backoff factor for each disturbed pair N = 1, 2, 3, 4 of a link segment using Equation (55–39) and Equation (55–40) respectively.

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$$\mathrm{PSANEXT}_N(f) = -10\log_{10}\sum_{j=1}^{m}\sum_{i=1}^{4} 10^{\frac{-(AN_\mathrm{pr(f)}_{i,j,N} + IL_\mathrm{bof}_j)}{10}} \quad (\mathrm{dB}) \qquad (55\text{–}39)$$

$$\mathrm{PSAFEXT}_N(f) = -10\log_{10}\sum_{j=1}^{m}\sum_{i=1}^{4} 10^{\frac{-(AF_\mathrm{pr(f)}_{i,j,N} + IL_\mathrm{bof}_j)}{10}} \quad (\mathrm{dB}) \qquad (55\text{–}40)$$

where

AN_pr(f)$_{i,j,N}$ is the measured ANEXT of the individual pair combination *i* (1 to 4) of the disturbing link *j* (1 to *m*) for each disturbed pair *N*.
AF_pr(f)$_{i,j,N}$ is the measured AFEXT of the individual pair combination *i* (1 to 4) of the disturbing link *j* (1 to *m*) for each disturbed pair *N*.
IL_bof$_j$ is the insertion loss backoff factor determined in Equation (55–38).

Step 5. Determine the individual-pair margin for each of the 4-pairs using Equation (55–41).

$$XWn(f) = -10\log_{10}\left(10^{\frac{\mathrm{PSANEXT}_N(f)}{-10}} + 10^{\frac{\mathrm{PSAFEXT}_N(f)}{-10}}\right) + 10\log_{10}\left(10^{\frac{AN_ipl(f)+2.5}{-10}} + 10^{\frac{AF_ipl(f)}{-10}}\right) \quad (\mathrm{dB}) \qquad (55\text{–}41)$$

where: *f* is the frequency in MHz,

XWn(f) is the individual-pair margin for each of the 4-pairs,

$\mathrm{PSANEXT}_N(f)$ is the measured PSANEXT loss in dB in the frequency range $10 \le f \le 400$ determined in Equation (55–39) adjusted for the insertion loss power backoff,

$\mathrm{PSAFEXT}_N(f)$ is the measured PSAFEXT loss in dB in the frequency range $10 \le f \le 400$ determined in Equation (55–40) adjusted for the insertion loss power backoff,

AN_ipl(f) is the individual-pair limit line for PSANEXT calculated using Equation (55–42). *AN_ipl(f)* is derived utilizing the average of the insertion loss of the 4-pairs at 250 MHz determined in Step 1 to calculate the PSANEXT constant using Equation (55–26).

$$AN_\mathrm{ipl}(f) = \begin{cases} \mathrm{PSANEXT\,constant} - 10\log_{10}\left(\frac{f}{100}\right) & (\mathrm{dB}) \quad 1 \le f \le 100 \\ \mathrm{PSANEXT\,constant} - 15\log_{10}\left(\frac{f}{100}\right) & (\mathrm{dB}) \quad 100 < f \le 500 \end{cases} \qquad (55\text{–}42)$$

AF_ipl(f) is the individual-pair line for PSAFEXT calculated using Equation (55–43) *AF_ipl(f)* is derived by adding the average of the measured insertion loss of the 4-pairs at 250 MHz determined in Step 1 to the PSAELFEXT limit line. The PSAELFEXT constant is derived using Equation (55–32) utilizing the average of the insertion loss of the 4-pairs at 250 MHz determined in Step 1.

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$$AF_ipl(f) = (\text{ PSAEFEXT constant }) - 20\log_{10}\left(\frac{f}{100}\right) + IL_avg(f)\ (dB)\quad 1 \le f \le 500 \qquad (55\text{–}43)$$

NOTE—The 2.5 dB is the PSANEXT allowance for the peak-to-average difference across frequency.

Step 6. Determine the average value "across frequency" of XWn(f) from 10 MHz to 400 MHz, for each individual-pair of the 4-pair cabling using Equation (55–44).

$$XAWn = \frac{\int_{f=10}^{400} XWn(f)df}{390}(\text{dB}) \qquad (55\text{–}44)$$

where

f is the frequency in MHz,

XAWn is the average value "across frequency" for the individual-pair number n (n = 1,2,3,4).

Step 7. Determine the individual-pair margin as the minimum of the average value "across frequency" of each of the individual pairs of the 4-pair cabling determined from Step 2 using Equation (55–45).

$$Y_{inp} = \min(XAW1, XAW2, XAW3, XAW4)(\text{dB}) \qquad (55\text{–}45)$$

where

Y_{inp} is the individual-pair margin.

Step 8. Determine the power sum of the PSANEXT and PSAFEXT for each of the 4-pairs using Equation (55–46).

$$XXn(f) = 10\log_{10}\left(10^{\frac{AN(f)}{-10}} + 10^{\frac{AF(f)}{-10}}\right)(\text{dB}) \qquad (55\text{–}46)$$

where

f is the frequency in MHz,

XXn(f) is the power sum of the PSANEXT and PSAFEXT for each of the 4-pairs,

AN(f) is the measured PSANEXT loss in dB in the frequency range $10 \le f \le 400$ determined in Equation (55–39) adjusted for the insertion loss power backoff,

AF(f) is the measured PSAFEXT loss in dB in the frequency range $10 \le f \le 400$ determined in Equation (55–40) adjusted for the insertion loss power backoff.

Step 9. Determine the average of the power sum of the PSANEXT and PSAFEXT of the 4-pairs using Equation (55–47).

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$$XXavg(f) = \frac{\left(\sum_{i=1}^{n} XXi(f)\right)}{4} (\text{dB}) \quad (55\text{–}47)$$

where

XXavg(f) is the average of the power sum of the PSANEXT and PSAFEXT of the 4-pairs,

n is the number of individual pairs; *n* = 4.

Step 10. Determine the average margin using Equation (55–48).

$$XA(f) = -XXavg + 10\log_{10}\left(10^{\frac{AN_avgl(f)}{-10}} + 10^{\frac{AF_avgl(f)}{-10}}\right) \quad (\text{dB}) \quad (55\text{–}48)$$

where

XA(f) is the average margin,

AN_avgl(f) is the average limit line for PSANEXT calculated using Equation (55–49). AN_avgl(f) is derived using the PSANEXT constant determined in Step 5.

$$AN_\text{avgl(f)} = \begin{cases} PSANEXT_{\text{constant}} + 3.5 - 10\log_{10}\left(\frac{f}{100}\right) & (\text{dB}) \quad 1 \le f \le 100 \\ PSANEXT_{\text{constant}} + 3.5 - 15\log_{10}\left(\frac{f}{100}\right) & (\text{dB}) \quad 100 < f \le 500 \end{cases} \quad (55\text{–}49)$$

where

f is the frequency in MHz,

AF_avgl(f) is the average limit line for PSAFEXT calculated using Equation (55–50). *AF_avgl(f)* is derived by adding the average of the measured insertion loss of the 4-pairs at 250 MHz determined in Step 1 to the PSAELFEXT limit line using the PSAELFEXT constant determined in Step 5.

$$AF_avg1(f) = (\text{PSAELFEXT constant} + 4) - 20\log_{10}\left(\frac{f}{100}\right) + IL_\text{avg}(f) \quad (\text{dB}) \quad 1 \le f \le 500 \quad (55\text{–}50)$$

Step 11. Determine the average margin as the average value across frequency of *XA(f)* using Equation (55–51).

$$Y_{\text{avg}} = \frac{\int_{f=10}^{400} XAfdf}{390} (\text{dB}) \quad (55\text{–}51)$$

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where

f is the frequency in MHz,
Y_{avg} is the average value "across frequency" of *XA(f)* from 10 to 400 MHz.

Step 12. Determine the alien crosstalk margin as the minimum value of the individual pair margin [Equation (55–45)] and the average margin [Equation (55–51)] using Equation (55–52).

$$YL = min(Y_{inp}, Y_{avg}) \text{ (dB)} \quad (55–52)$$

The alien crosstalk margin *YL* shall be greater than zero.

55.7.4 Noise environment

The 10GBASE-T noise environment consists of noise from many sources. The primary noise sources that impact the objective BER are the crosstalk and echo interference of a link segment, which are reduced to a small residual noise, and the noise coupled between the link segments referred to as alien crosstalk noise. The remaining noise sources, which are secondary sources, are discussed in the following. The 10GBASE-T noise environment consists of the following:

a) Echo from the local transmitter on the same duplex channel (cable pair). Echo is caused by the hybrid function used to achieve simultaneous bi-directional transmission of data and by impedance mismatches in the link segment. It is impractical to achieve the objective BER without using echo cancellation. Since the symbols transmitted by the local disturbing transmitter are available to the cancellation processor, echo interference can be reduced to a small residual noise using echo cancellation methods.

b) Near-end crosstalk (NEXT) interference from the local transmitters on the duplex channels (cable pairs) of the link segment. Each receiver experiences NEXT interference from three adjacent transmitters. NEXT cancellers are used to reduce the interference from each of the three disturbing transmitters to a small residual noise. NEXT cancellation is possible since the symbols transmitted by the three disturbing local transmitters are available to the cancellation processor.

c) Far-end crosstalk (FEXT) noise at a receiver is from three disturbing transmitters at the far end of the duplex channel (cable pairs) of the link segment. FEXT noise can be reduced through cross coupled equalizers although the symbols from the remote transmitters are not immediately available.

d) Intersymbol interference (ISI). ISI is the extraneous energy from one signaling symbol that interferes with the reception of another symbol on the same channel. 10GBASE-T supports the use of Tomlinson-Harashima Precoding as a mechanism to reduce the effects of ISI.

e) Noise from non-idealities in the duplex channel, transmitters, and receivers; for example, DAC/ADC non-linearity, electrical noise (shot and thermal), and non-linear channel characteristics. 10GBASE-T limits the effects of some of these non-idealities by a variety of PMA electrical specifications.

f) Noise coupled between link segments. Noise coupled between the disturbed duplex channel in a link segment and the disturbing duplex channels in other link segments is referred to as alien crosstalk noise. Since the transmitted symbols from the alien crosstalk noise sources are not available to the cancellation processor (they are in another cable), it is very difficult to cancel the alien crosstalk noise. To ensure robust operation the alien crosstalk is specified in 55.7.3.

g) The background noise for 10GBASE-T is expected not to exceed –150 dBm/Hz. A background noise limit of –150 dBm/Hz was assumed for determining the minimum signal-to-noise ratio.

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55.8 MDI specification

This subclause defines the MDI. The link topology requires a crossover function in a DTE-to-DTE connection. See 55.4.4 for a description of the automatic MDI/MDI-X configuration.

55.8.1 MDI connectors

Eight-pin connectors meeting the requirements of IEC 60603-7-4 (unscreened) or IEC 60603-7-5 (screened) shall be used as the mechanical interface to the balanced cabling. The plug connector shall be used on the balanced cabling and the jack on the PHY. These connectors are depicted (for informational use only) in Figure 55–39 and Figure 55–40. The assignment of PMA signals to connector contacts for PHYs is shown in Table 55–24.

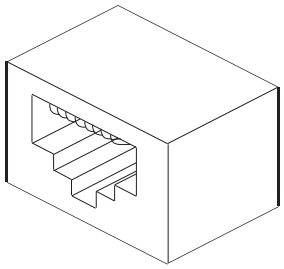

Figure 55–39—MDI connector

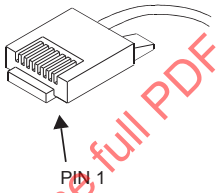

Figure 55–40—Balanced cabling connector

Table 55–24—Assignment of PMA signal to MDI and MDI-X pin-outs

Contact	MDI	MDI-X
1	BI_DA+	BI_DB+
2	BI_DA–	BI_DB–
3	BI_DB+	BI_DA+
4	BI_DC+	BI_DD+
5	BI_DC–	BI_DD–
6	BI_DB–	BI_DA–
7	BI_DD+	BI_DC+
8	BI_DD–	BI_DC–

55.8.2 MDI electrical specifications

The MDI connector (jack) when mated with a specified balanced cabling connector (plug) shall meet the FEXT requirements as specified in Equation (55–53):

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$$\text{FEXT loss} \geq 43.1 - 20\log_{10}(f/100) \quad \text{(dB)} \tag{55–53}$$

where f is the frequency over the range 1 MHz to 500 MHz between all contact pair combinations shown in Table 55–24.

No spurious signals shall be emitted onto the MDI when the PHY is held in power-down mode (as defined in 22.2.4.1.5), when released from power-down mode, or when external power is first applied to the PHY.

55.8.2.1 MDI return loss

The differential impedance at the MDI for each transmit/receive channel shall be such that any reflection due to differential signals incident upon the MDI from a balanced cabling having a nominal differential characteristic impedance of 100 Ω is attenuated, relative to the incident signal as per the relationship:

$$\text{Return loss} \geq \begin{cases} 16 & 1 \leq f \leq 40 \quad \text{(dB)} \\ 16 - 10\log_{10}(f/40) & 40 < f \leq 400 \quad \text{(dB)} \\ 6 - 30\log_{10}(f/400) & 400 < f \leq 500 \quad \text{(dB)} \end{cases} \tag{55–54}$$

where f is in MHz.

55.8.2.2 MDI impedance balance

Impedance balance is a measure of the impedance-to-ground difference between the two MDI contacts used by a duplex link channel and is referred to as common-mode-to-differential-mode impedance balance. The common-mode-to-differential-mode impedance balance, $Bal(f)$, of each channel of the MDI shall meet the relationship:

$$Bal(f) \geq \begin{cases} 48 & 1 \leq f < 30 \quad \text{(dB)} \\ 44 - 19.2\log_{10}\left(\frac{f}{50}\right) & 30 \leq f \leq 500 \quad \text{(dB)} \end{cases} \tag{55–55}$$

where f is the frequency in MHz when the transmitter is transmitting random or pseudo random data. Test-mode 4 may be used to generate an appropriate transmitter output. The impedance balance (in dB) is defined as:

$$Bal(f) = 20\log_{10}\left(\frac{E_{cm}(f)}{E_{dif}(f)}\right) - IL_{cal}(f) \quad \text{(dB)} \tag{55–56}$$

where E_{cm} is an externally applied common-mode sinusoidal voltage as shown in Figure 55–41, E_{dif} is the resulting differential waveform due only to the applied sine wave E_{cm} and not the transmitted data, and $IL_{cal}(f)$ is the coupling circuit common-mode insertion loss (in dB). The coupling circuit common-mode insertion loss is defined as:

$$IL_{\text{cal}}(f) = 20\log_{10}\left(\frac{E_{cin}(f)}{E_{cout}(f)}\right) \quad \text{(dB)} \tag{55–57}$$

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where E_{cin} and E_{cout} are test signals used to measure the coupling circuit common-mode insertion loss as shown in Figure 55–42.

The impedance balance is measured with a common-mode coupling circuit presenting a differential termination of 100 Ω and a common-mode termination of 50 Ω to the MDI pair under test as shown in Figure 55–41. The return loss for both differential and common terminations in the common-mode coupling circuit should be greater than 20 dB from 10 MHz to 500 MHz. The insertion loss IL_{cal} (in dB) of the common-mode coupling circuit can be measured with the test circuit shown in Figure 55–42.

NOTE 1—Triggered averaging can be used to separate the component due to the applied common-mode sine wave from the transmitted data component.
NOTE 2—The imbalance of the test equipment should be insignificant relative to the balance requirements.

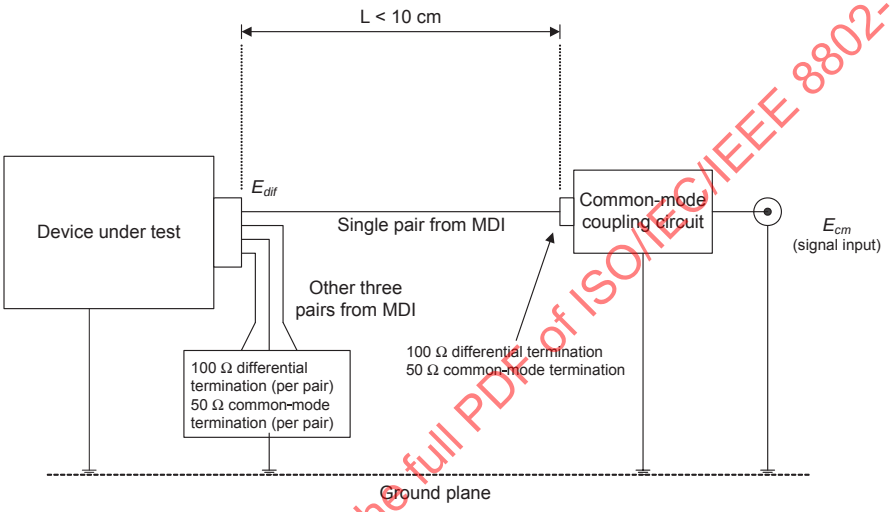

Figure 55–41—MDI impedance balance test circuit

The impedance balance may also be measured with a mixed mode four port network analyzer capable of measuring the common-mode voltage and differential mode voltage of a balanced port. Impedance balance is the S parameter measurement of Scd11 in dB at the MDI where two ports of the four port network analyzer are connected between two MDI contacts used by a duplex link channel and these two ports are configured as a single balanced port. For this test the PHY ground is connected to the network analyzer ground. The other two ports of the network analyzer are unconnected. The network analyzer should be capable of measuring Scd11 to at least –60 dB and should use a differential input impedance of 100 Ω and a common-mode impedance of 75 Ω.

During the test the PHY is connected to the MDI as in normal operation, but with the transmitter output disabled.

55.8.2.3 MDI fault tolerance

Each wire pair of the MDI shall, under all operating conditions, withstand without damage the application of short circuits of any wire to any other wire within the 4-pair cable for an indefinite period of time and shall resume normal operation after the short circuit(s) are removed. The magnitude of the current through such a short circuit shall not exceed 300 mA.

A 10GBASE-T PHY shall be able to sustain, without damage, connection to a PSE and shall not cause damage to the PSE as defined in 33.2.

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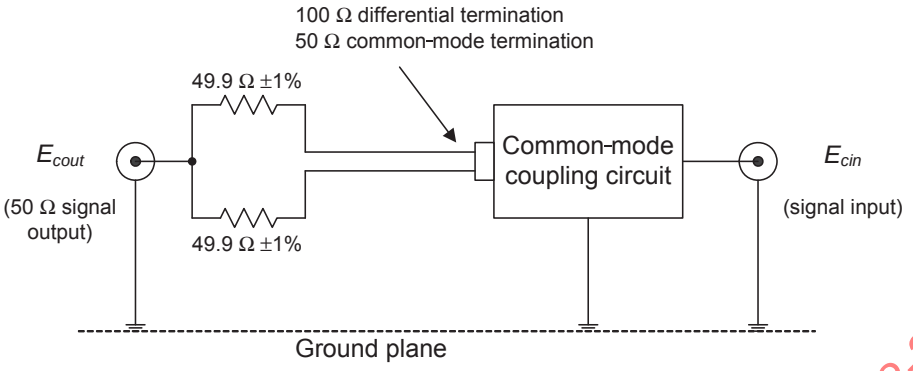

Figure 55–42— Impedance balance calibration circuit

Each wire pair shall withstand without damage a 1000 V common-mode impulse of either polarity. The shape of the impulse is 0.3/50 μs (300 ns virtual front time, 50 μs virtual time of half value), as defined in IEC 60060. See Figure 40–33 in 40.8.3.4.

55.9 Environmental specifications

55.9.1 General safety

All equipment meeting this standard shall conform to IEC 60950-1.

55.9.2 Network safety

This subclause sets forth a number of recommendations and guidelines related to safety concerns; the list is neither complete nor does it address all possible safety issues. The designer is urged to consult the relevant local, national, and international safety regulations to ensure compliance with the appropriate requirements.

LAN cabling systems described in this subclause are subject to at least four direct electrical safety hazards during their installation and use. These hazards are as follows:

a) Direct contact between LAN components and power, lighting, or communications circuits.
b) Static charge buildup on LAN cabling and components.
c) High-energy transients coupled onto the LAN cabling system.
d) Voltage potential differences between safety grounds to which various LAN components are connected.

Such electrical safety hazards should be avoided or appropriately protected against for proper network installation and performance. In addition to provisions for proper handling of these conditions in an operational system, special measures should be taken to ensure that the intended safety features are not negated during installation of a new network or during modification or maintenance of an existing network.

55.9.3 Installation and maintenance guidelines

It is recommended that sound installation practice, including screen management, as defined by applicable local codes and regulations, be followed in every instance in which such practice is applicable. In addition, Annex 55B provides additional cabling guidelines for 10GBASE-T deployment on balanced copper cabling systems.

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It is a mandatory requirement that, during installation of the cabling plant, care be taken to ensure that non-insulated network cabling conductors do not make electrical contact with unintended conductors or ground.

55.9.4 Telephone voltages

The use of building wiring brings with it the possibility of wiring errors that may connect telephony voltages to 10GBASE-T. Other than voice signals (which are low voltage), the primary voltages that may be encountered are the "battery" and ringing voltages. Although there is no universal standard, the following maximums generally apply.

a) Battery voltage to a telephone line is generally 56 V dc applied to the line through a balanced 400 Ω source impedance.
b) Ringing voltage is a composite signal consisting of an ac component and a dc component. The ac component is up to 175 V peak at 20 Hz to 60 Hz with a 100 Ω source resistance. The dc component is 56 V dc with a 300 Ω to 600 Ω source resistance. Large reactive transients can occur at the start and end of each ring interval.

Although 10GBASE-T equipment is not required to survive such wiring hazards without damage, application of any of the above voltages shall not result in any safety hazard.

55.9.5 Electromagnetic compatibility

A system integrating the 10GBASE-T shall comply with applicable local and national codes for the limitation of electromagnetic interference.

55.9.6 Temperature and humidity

A system integrating the 10GBASE-T is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

55.10 PHY labeling

It is recommended that each PHY (and supporting documentation) be labeled in a manner visible to the user with at least the following parameters:

a) Data rate capability and units thereof
b) Power level in terms of maximum current drain (for external PHYs)
c) Port type (i.e., 10GBASE-T)
d) Any applicable safety warnings
e) EEE support
f) Fast retrain support

55.11 Delay constraints

In full duplex mode, predictable operation of the MAC Control PAUSE operation (Clause 31, Annex 31B) also demands that there be an upper bound on the propagation delays through the network. This implies that MAC, MAC Control sublayer, and PHY implementers conform to certain delay maxima, and that network planners and administrators conform to constraints regarding the cable topology and concatenation of devices.

The sum of the transmit and receive data delays for an implementation of a 10GBASE-T PHY shall not exceed 25 600 BT. Transmit data delay is measured from the input of a given unit of data at the XGMII to the presentation of the same unit of data by the PHY to the MDI. Receive data delay is measured from the

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input of a given unit of data at the MDI to the presentation of the same unit of data by the PHY to the XGMII.

NOTE—The physical medium interconnecting two PHYs introduces additional delay in a link. Equation (44–1) specifies the calculation of bit time per meter of electrical cable and Table 44–3 can also be used to convert electrical cable delay values specified relative to the speed of light or in nanoseconds per meter.

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55.12 Protocol implementation conformance statement (PICS) proforma for Clause 55—Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer and baseband medium, type 10GBASE-T[22]

The supplier of a protocol implementation that is claimed to conform to this clause shall complete the protocol implementation conformance statement (PICS) proforma listed in the following subclauses.

Instructions for interpreting and filling out the PICS proforma may be found in Clause 21.

55.12.1 Identification

55.12.1.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

55.12.1.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 55, Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer, and baseband medium, type 10GBASE-T
Identification of amendments and corrigenda to this PICS proforma which have been completed as part of this PICS	
Have any Exceptions items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	
Date of Statement	

[22]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so it can be used for its intended purpose and may further publish the completed PICS.

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55.12.2 Major capabilities/options

Item	Feature	Subclause	Status	Support	Value/Comment
XGE	XGMII compatibility interface	46, 55.1.5	O	Yes [ ] No [ ]	Compatibility interface is supported
*LT	Support of loop timing		O	Yes [ ] No [ ]	
*EEE	Support of EEE capability		O	Yes [ ] No [ ]	55.1.3.3
*FR	Support of Fast Retrain capability		O	Yes [ ] No [ ]	55.4.2.5.15

55.12.3 Physical Coding Sublayer (PCS)

Item	Feature	Subclause	Status	Support	Value/Comment
PCT1	PCS Transmit function state diagram	55.3.2.2	M	Yes [ ]	See Figure 55–16
PCT2	PCS Transmit function state diagram with EEE states	55.3.2.2	EEE:M	Yes [ ]	See Figure 55–16 and Figure 55–17
PCT3	PCS Transmit bit ordering	55.3.2.2.4	M	Yes [ ]	See Figure 55–6 and Figure 55–8
PCT4	Invalid control code handling	55.3.2.2.6	M	Yes [ ]	
PCT5	/I/ insertion and deletion	55.3.2.2.9	M	Yes [ ]	
PCT6	/LI/ insertion and deletion	55.3.2.2.10	EEE:M	Yes [ ]	
PCT7	/O/ deletion	55.3.2.2.13	M	Yes [ ]	
PCT8	Scrambler as MASTER	55.3.2.2.16	M	Yes [ ]	
PCT9	Scrambler as SLAVE	55.3.2.2.16	M	Yes [ ]	
PCT10	CRC8	55.3.2.2.17	M	Yes [ ]	See Figure 55–11
PCT11	LDPC encoding	55.3.2.2.18	M	Yes [ ]	Generator matrix is described in Annex 55A
PCT12	DSQ128 mapping	55.3.2.2.19	M	Yes [ ]	
PCT13	EEE Transmit function state diagram	55.3.2.2.22	EEE:M	Yes [ ]	See Figure 55–20
PCT14	LP_IDLE input to scrambler during LPI mode	55.3.2.2.22	EEE:M	Yes [ ]	
PCT15	lpi_tx_mode control	55.3.2.2.22	EEE:M	Yes [ ]	
PCT16	PCS test pattern mode	55.3.3	M	Yes [ ]	See Figure 55–6
PCT17	PMA training - MASTER scrambler	55.3.4	M	Yes [ ]	
PCT18	PMA training - SLAVE scrambler	55.3.4	M	Yes [ ]	

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Item	Feature	Subclause	Status	Support	Value/Comment
PCT19	PMA training scrambler reset	55.3.4	M	Yes [ ]	If requested by Link Partner during Auto Negotiation
PCT20	PMA training scrambler initial state	55.3.4	M	Yes [ ]	In no case shall the scrambler state be initialized to all zeros
PCT21	LPI active pair and refresh_active signals	55.3.5.1	EEE:M	Yes [ ]	
PCT22	Alert signaling in place of refresh signaling	55.3.5.3	EEE:M	Yes [ ]	
PCT23	Slave synchronization	55.3.5.1	EEE:M	Yes [ ]	
PCT24	Quiet launch power	55.3.5.2	EEE:M	Yes [ ]	
PCT25	LPI sleep timer	55.3.6.2.3	EEE:M	Yes [ ]	
PCT26	LPI alert timer	55.3.6.2.3	EEE:M	Yes [ ]	
PCT27	LPI wake timer	55.3.6.2.3	EEE:M	Yes [ ]	
PCT28	LPI rx wake timer	55.3.6.2.3	EEE:M	Yes [ ]	
PCT29	LPI tx wake timer	55.3.6.2.3	EEE:M	Yes [ ]	
PCT30	LPI scrambler	55.3.5.3	EEE:M	Yes [ ]	The training sequence without periodic re-initialization described in 55.3.5 shall be used
PCT31	Disable scrambler reinitialization	55.3.5.3	EEE:M	Yes [ ]	
PCT32	Refresh using THP	55.3.5.3	EEE:M	Yes [ ]	
PCT33	Reset THP at the start of refresh	55.3.5.3	EEE:M	Yes [ ]	
PCT34	Master alert on pair A, other pairs silent	55.3.5.3	EEE:M	Yes [ ]	
PCT35	Slave alert on pair C, other pairs silent	55.3.5.3	EEE:M	Yes [ ]	
PCT36	Inactive pairs transmit zeros	55.3.5.3	EEE:M	Yes [ ]	
PCT37	ENCODE function	55.3.6.2.4	M	Yes [ ]	Encode the block as specified in 55.3.2.2.2
PCT38	PCS loopback setup	55.3.7.3	M	Yes [ ]	

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55.12.3.1 PCS Receive functions

Item	Feature	Subclause	Status	Support	Value/Comment
PCR1	PCS Receive function state diagram	55.3.2.3	M	Yes [ ]	See Figure 55–18 and state variables as specified in 55.3.6.2.
PCR2	PCS Receive bit ordering	55.3.2.3.1	M	Yes [ ]	See Figure 55–7
PCR3	Descrambling as MASTER	55.3.2.3.2	M	Yes [ ]	
PCR4	Descrambling as SLAVE	55.3.2.3.2	M	Yes [ ]	
PCR5	PMA training descrambler - MASTER	55.3.4.3	M	Yes [ ]	
PCR6	PMA training descrambler - SLAVE	55.3.4.3	M	Yes [ ]	
PCR7	DECODE operation	55.3.6.2.4	M	Yes [ ]	Decode the block as specified in 55.3.4
PCR8	LFER monitor	55.3.6.4	M	Yes [ ]	See state diagrams in Figure 55–15, Figure 55–16 and Figure 55–18.

55.12.3.2 Other PCS functions

Item	Feature	Subclause	Status	Support	Value/Comment
PCO1	PCS Reset function	55.3.2.1	M	Yes [ ]	

55.12.4 Physical Medium Attachment (PMA)

Item	Feature	Subclause	Status	Support	Value/Comment
PMF1	PMA Reset function	55.4.2.1	M	Yes [ ]	
PMF2	PMA transmission	55.4.2.2	M	Yes [ ]	
PMF3	Transmitter clocking	55.4.2.2	M	Yes [ ]	All driven by TX_TCLK
PMF4	PMA Transmit mapping	55.4.2.2	M	Yes [ ]	Per mathematical description given in 55.4.3.1
PMF5	PMA Transmit electrical compliance	55.4.2.2	M	Yes [ ]	See PMA electrical specifications given in 55.5
PMF6	Clocking as MASTER	55.4.2.2	M	Yes [ ]	Source the transmit clock TX_TCLK from a local clock
PMF7	Clocking as SLAVE in loop timed mode	55.4.2.2	M	Yes [ ]	Source the transmit clock TX_TCLK from the recovered clock

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Item	Feature	Subclause	Status	Support	Value/Comment
PMF8	Transmit fault mapping	55.4.2.2	O	Yes [ ]	Contribute to the transmit fault bit as specified in 45.2.1.7.4
PMF9	Generates alert signal	55.4.2.2	EEE:M	Yes [ ]	Generates the alert signal defined in 55.4.2.2.1
PMF10	Generates link failure signaling	55.4.2.2	FR:M	Yes [ ] No [ ]	Generates the link failure signal defined in 55.4.2.2.2
PMF11	PMA Receive function performance	55.4.2.4	M	Yes [ ]	LDPC frame error ratio of less than 3.2×10^{-9}
PMF12	Receive fault mapping	55.4.2.4	O	Yes [ ]	Contribute to the receive fault bit as specified in 45.2.1.7.5
PMF13	Implement alert_detect	55.4.2.4	EEE:M	Yes [ ]	Generates alert_detect when the alert signal is detected at the receiver
PMF14	Detect link failure signaling	55.4.2.4	FR:M	Yes [ ] No [ ]	Sets link_fail_detect to true when the link failure signal is detected
PMF15	PHY Control function	55.4.2.5	M	Yes [ ]	See state diagram in Figure 55–28 and state diagrams in Figure 55–29 and Figure 55–30
PMF16	InfoField	55.4.2.5	M	Yes [ ]	All subclauses from 55.4.2.5.1 to 55.4.2.5.13
PMF17	THP initialization	55.4.2.5.14	M	Yes [ ]	Last 16 symbols of PMA_Coeff_Exch
PMF18	PBO exchange	55.4.2.5.14	M	Yes [ ]	
PMF19	Slave PBO setting	55.4.2.5.14	M	Yes [ ]	Slave's PBO final setting within two levels (4 dB) of the MASTER's PBO level
PMF20	THP coefficient exchange	55.4.2.5.14	M	Yes [ ]	
PMF21	Recommended startup sequence timing	55.4.2.5.14	O	Yes [ ] No [ ]	See Table 55–9
PMF22	Implements fast retrain state diagram	55.4.2.5.15	FR:M	Yes [ ] No [ ]	
PMF23	Behavior after fast retrain request	55.4.2.5.15	FR:M	Yes [ ] No [ ]	Transmit PAM2 within 9 LDPC frame periods following link failure request
PMF24	Behavior after fast retrain signal detection	55.4.2.5.15	FR:M	Yes [ ] No [ ]	Transmit PAM2 within 9 LDPC frame periods following link failure signal detection
PMF25	Link Monitor	55.4.2.6	M	Yes [ ]	See state diagram in Figure 55–31
PMF26	Refresh monitor state diagram	55.4.2.7	EEE:M	Yes [ ] No [ ]	Implements state diagram of Figure 55–19
PMF27	Recommended fast retrain sequence timing	55.4.2.5.15	FR:O	Yes [ ] No [ ]	See Table 55–10

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Item	Feature	Subclause	Status	Support	Value/Comment
PMF28	Clock Recovery function	55.4.2.8	M	Yes [ ]	
PMF29	MDIX for EEE refreshes and alert	55.4.4	EEE:M	Yes [ ]	
PMF30	Symbol response	55.4.3.1	M	Yes [ ]	Per electrical specifications given in 55.5
PMF31	THP filter coefficient setting	55.4.3.1	M	Yes [ ]	Fixed after startup
PMF32	PMA Transmit power backoff settings	55.4.3.1	M	Yes [ ]	
PMF33	Minimum power backoff requested	55.4.3.1	M	Yes [ ]	Per Table 55–11
PMF34	Automatic configuration	55.4.4	M	Yes [ ]	Comply with the specifications of 40.4.4.1 and 40.4.4.2
PMF35	Pair/Polarity swap detection and correction	55.4.4	M	Yes [ ]	
PMF36	PMA_CONFIG.indicate generation	55.4.5.1	M	Yes [ ]	
PMF37	Maxwait_timer expiration	55.4.5.2	M	Yes [ ]	
PMF38	Minwait_timer expiration	55.4.5.2	M	Yes [ ]	

55.12.5 Management interface

Item	Feature	Subclause	Status	Support	Value/Comment
MF1	Support for Auto-Negotiation	55.6.1	M	Yes [ ]	See Clause 28
MF2	MASTER and SLAVE operation	55.6.1	M	Yes [ ]	Capable of operating either as MASTER or SLAVE
MF3	Extended Next Page support	55.6.1	M	Yes [ ]	
MF4	Optimized FLP timing	55.6.1	M	Yes [ ]	
MF5	Management registers	55.6.1.1	M	Yes [ ]	As defined in Table 55–14
MF6	10GBASE-T Extended Next Page bit assignments	55.6.1.2	M	Yes [ ]	As defined in Table 55–15
MF7	EEE advertisement	55.6.1.2	EEE:M	Yes [ ]	As defined in Table 55–15
MF8	Fast retrain ability advertisement	55.6.1.2	FR:M	Yes [ ]	As defined in Table 55–15
MF9	MASTER-SLAVE resolution with both or neither devices supporting loop timing	55.6.2	M	Yes [ ]	As defined in Table 55–16
MF10	MASTER-SLAVE resolution with one device supporting loop timing	55.6.2	M	Yes [ ]	Device supporting loop timing forced to SLAVE

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Item	Feature	Subclause	Status	Support	Value/Comment
MF11	Resolution completion	55.6.2	M	Yes [ ]	Successful completion of resolution treated as MASTER-SLAVE configuration resolution complete.
MF12	Seed counter	55.6.2	M	Yes [ ]	Counter provided to track number of seed attempts
MF13	Counter set to zero at startup	55.6.2	M	Yes [ ]	
MF14	Counter increment	55.6.2	M	Yes [ ]	
MF15	Counter reset	55.6.2	M	Yes [ ]	After resolution is complete
MF16	Bit 7.33.15 set to zero after resolution is complete	55.6.2	M	Yes [ ]	After resolution is complete
MF17	Resolution fault declared	55.6.2	M	Yes [ ]	After generation of seven seeds
MF18	MASTER-SLAVE fault condition	55.6.2	M	Yes [ ]	Condition occurs when both devices manually select MASTER or SLAVE
MF19	MASTER-SLAVE fault condition bit	55.6.2	M	Yes [ ]	Set to one upon fault condition
MF20	MASTER-SLAVE fault resolution	55.6.2	M	Yes [ ]	Fault condition treated as MASTER-SLAVE resolution complete
MF21	MASTER-SLAVE fault condition indication	55.6.2	M	Yes [ ]	link_status_10GigT set to FAIL

55.12.6 PMA Electrical Specifications

Item	Feature	Subclause	Status	Support	Value/Comment
PME1	Electrical isolation	55.5.1	M	Yes [ ]	One of three electrical strength tests listed in 55.5.1
PME2	Insulation breakdown after test	55.5.1	M	Yes [ ]	>2 MΩ, measured at 500 V dc
PME3	Test modes supported	55.5.2	M	Yes [ ]	
PME4	Test mode enablement	55.5.2	M	Yes [ ]	Per management register settings shown in Table 55–12
PME5	The test modes only change the data symbols	55.5.2	M	Yes [ ]	
PME6	Alternate way to enable the test modes	55.5.2	O	Yes [ ]	Mandatory for PHYs without MDIO
PME7	Test mode 1 operation	55.5.2	M	Yes [ ]	
PME8	Test mode 2 operation	55.5.2	M	Yes [ ]	
PME9	Test mode 3 operation, pair D	55.5.2	LT:M	Yes [ ] N/A [ ]	Mandatory for PHY that supports loop timing

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Item	Feature	Subclause	Status	Support	Value/Comment
PME10	Test mode 3 operation, pairs A, B and C	55.5.2	M	Yes [ ]	Transmit silence
PME11	Test mode 4 waveform	55.5.2	M	Yes [ ]	Tones per Table 55–13
PME12	Test mode 4 levels	55.5.2	M	Yes [ ]	
PME13	Test mode 5 operation	55.5.2	M	Yes [ ]	
PME14	Test mode 6 operation	55.5.2	M	Yes [ ]	
PME15	Test mode 7 operation	55.5.2	M	Yes [ ]	
PME16	Text fixture 3 isolation	55.5.2	M	Yes [ ]	>30 dB between signals on any of {pairs A, B, C} and pair D
PME17	Transmitter nominal load	55.5.3	M	Yes [ ]	
PME18	AC-coupling to the MDI	55.5.3	M	Yes [ ]	
PME19	Droop test	55.5.3.1	M	Yes [ ]	
PME20	SFDR of transmitter	55.5.3.2	M	Yes [ ]	
PME21	Transmitter jitter as MASTER	55.5.3.3	M	Yes [ ]	
PME22	Transmitter jitter as loop-timed SLAVE	55.5.3.3	LT: M	N/A [ ] Yes [ ]	Applicable only if loop timing is supported
PME23	Transmit power level	55.5.3.4	M	Yes [ ]	
PME24	Transmitter PSD	55.5.3.4	M	Yes [ ]	
PME25	MASTER symbol rate	55.5.3.5	M	Yes [ ]	
PME26	Maximum short term rate of frequency variation during LPI	55.5.3.5	EEE:M	Yes [ ]	Less than 0.1 ppm/s
PME27	Maximum short term rate of frequency variation when switching to and from LPI	55.5.3.5	EEE:M	Yes [ ]	Less than 0.1 ppm/s
PME28	BER over a 55.7 compliant link	55.5.4.1	M	Yes [ ]	
PME29	Receiver frequency tolerance	55.5.4.2	M	Yes [ ]	
PME30	Alien noise tolerance	55.5.4.4	M	Yes [ ]	

55.12.7 Characteristics of the link segment

Item	Feature	Subclause	Status	Support	Value/Comment
LKS1	MDI compatibility	55.7	M	Yes [ ]	
LKS2	Insertion loss of each duplex channel	55.7.2.1	M	Yes [ ]	See Equation (55–11)
LKS3	Return loss	55.7.2.3	M	Yes [ ]	See (55–12)
LKS4	NEXT loss within pairs in a link segment	55.7.2.4.1	M	Yes [ ]	See (55–13)

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Item	Feature	Subclause	Status	Support	Value/Comment
LKS5	Power sum NEXT loss	55.7.2.4.2	M	Yes [ ]	See (55–14)
LKS6	Worst pair ELFEXT loss	55.7.2.4.4	M	Yes [ ]	See (55–18)
LKS7	Power sum ELFEXT loss	55.7.2.4.5	M	Yes [ ]	See (55–20)
LKS8	Propagation delay	55.7.2.5	M	Yes [ ]	
LKS9	Delay skew	55.7.2.6	M	Yes [ ]	
LKS10	Delay skew change	55.7.2.6	M	Yes [ ]	
LKS11	Power sum ANEXT loss	55.7.3.1.1	M	Yes [ ]	See (55–23)
LKS12	Average PS ANEXT loss	55.7.3.1.1	M	Yes [ ]	See (55–25)
LKS13	PSANEXT_constant	55.7.3.1.2	M	Yes [ ]	See (55–26)
LKS14	IL(250) used in PSANEXT_ constant equation	55.7.3.1.2	M	Yes [ ]	Actual measured insertion loss at 250 MHz
LKS15	PS AELFEXT loss	55.7.3.2.1	M	Yes [ ]	See (55–32)
LKS16	Average PS AELFEXT loss	55.7.3.2.1	M	Yes [ ]	See (55–34)
LKS17	PSAELFEXT_constant	55.7.3.2.2	M	Yes [ ]	See (55–35)
LKS18	IL(250) used in PSAELFEXT_ constant equation	55.7.3.2.2	M	Yes [ ]	Actual measured insertion loss at 250 MHz
LKS19	Alien crosstalk margin *YL*	55.7.3.3	M	Yes [ ]	Greater than zero

55.12.8 MDI requirements

Item	Feature	Subclause	Status	Support	Value/Comment
MDI1	MDI connector	55.8.1	M	Yes [ ]	8-Way connector per IEC 60603-7:1996
MDI2	Cabling connector	55.8.1	M	Yes [ ]	Plug
MDI3	PHY connector	55.8.1	M	Yes [ ]	Jack (as opposed to plug)
MDI4	MDI connector jack plus plug performance	55.8.2	M	Yes [ ]	
MDI5	Mated MDI connector FEXT loss	55.8.2	M	Yes [ ]	Per (55–53)
MDI6	MDI power down	55.8.2	M	Yes [ ]	
MDI7	MDI return loss	55.8.2.1	M	Yes [ ]	
MDI8	MDI impedance balance	55.8.2.2	M	Yes [ ]	
MDI9	MDI fault tolerance to short circuits	55.8.2.3	M	Yes [ ]	No damage with an indefinite short
MDI10	Recovery from short	55.8.2.3	M	Yes [ ]	
MDI11	Short circuit current	55.8.2.3	M	Yes [ ]	Less than 300 mA

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Item	Feature	Subclause	Status	Support	Value/Comment
MDI12	Connection to PSE	55.8.2.3	M	Yes [ ]	No damage to PHY
MDI13	Connection to PSE	55.8.2.3	M	Yes [ ]	No damage to PSE
MDI14	Common-mode impulse tolerance	55.8.2.3	M	Yes [ ]	1000 V common-mode impulse of either polarity

55.12.9 General safety and environmental requirements

Item	Feature	Subclause	Status	Support	Value/Comment
ENV1	Conformance to safety specifications	55.9.1	M	Yes [ ]	IEC 60950-1
ENV2	Installation isolation integrity	55.9.3	INS:M	N/A [ ] Yes [ ]	No electrical contact with unintended conductors or ground
ENV3	Phone voltage immunity	55.9.4	M	Yes [ ]	
ENV4	Electromagnetic compatibility	55.9.5	INS:M	N/A [ ] Yes [ ]	With local and national codes

55.12.10 Timing requirements

Item	Feature	Subclause	Status	Support	Value/Comment
TR1	Delay	55.11	M	Yes [ ]	

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Annex 44A

(informative)

Diagram of Data Flow

This annex contains diagrams of the data flow from the MAC to the MDI in the transmit direction and from the MDI to the MAC in the receive direction. The diagrams are provided as a reference, and the corresponding clause should be reviewed for the complete information.

44A.1 10GBASE-R bit ordering

Figure 44A–1 shows the bit ordering on the LAN serial transmit data path.

Figure 44A–2 shows the bit ordering on the LAN serial receive data path.

The 10GBASE-R diagrams reference the following clauses: 46 (XGMII and RS), 47 (XGXS and XAUI), 49 (64B/66B PCS), and 51 (serial PMA).

44A.2 10GBASE-W serial bit ordering

Figure 44A–3 shows the bit ordering on the WAN serial transmit data path.

Figure 44A–4 shows the bit ordering on the WAN serial receive data path.

The 10GBASE-W serial diagrams reference the following clauses: 46 (XGMII and RS), 47 (XGXS and XAUI), 49 (64B/66B PCS), 50 (WIS), and 51 (serial PMA).

44A.3 10GBASE-LX4 bit ordering

Figure 44A–5 shows the bit ordering on the LAN WDM transmit path.

Figure 44A–6 shows the bit ordering on the LAN WDM receive path.

The 10GBASE-LX4 diagrams reference the following clauses: 46 (XGMII and RS) and 48 (8B/10B PCS and PMA).

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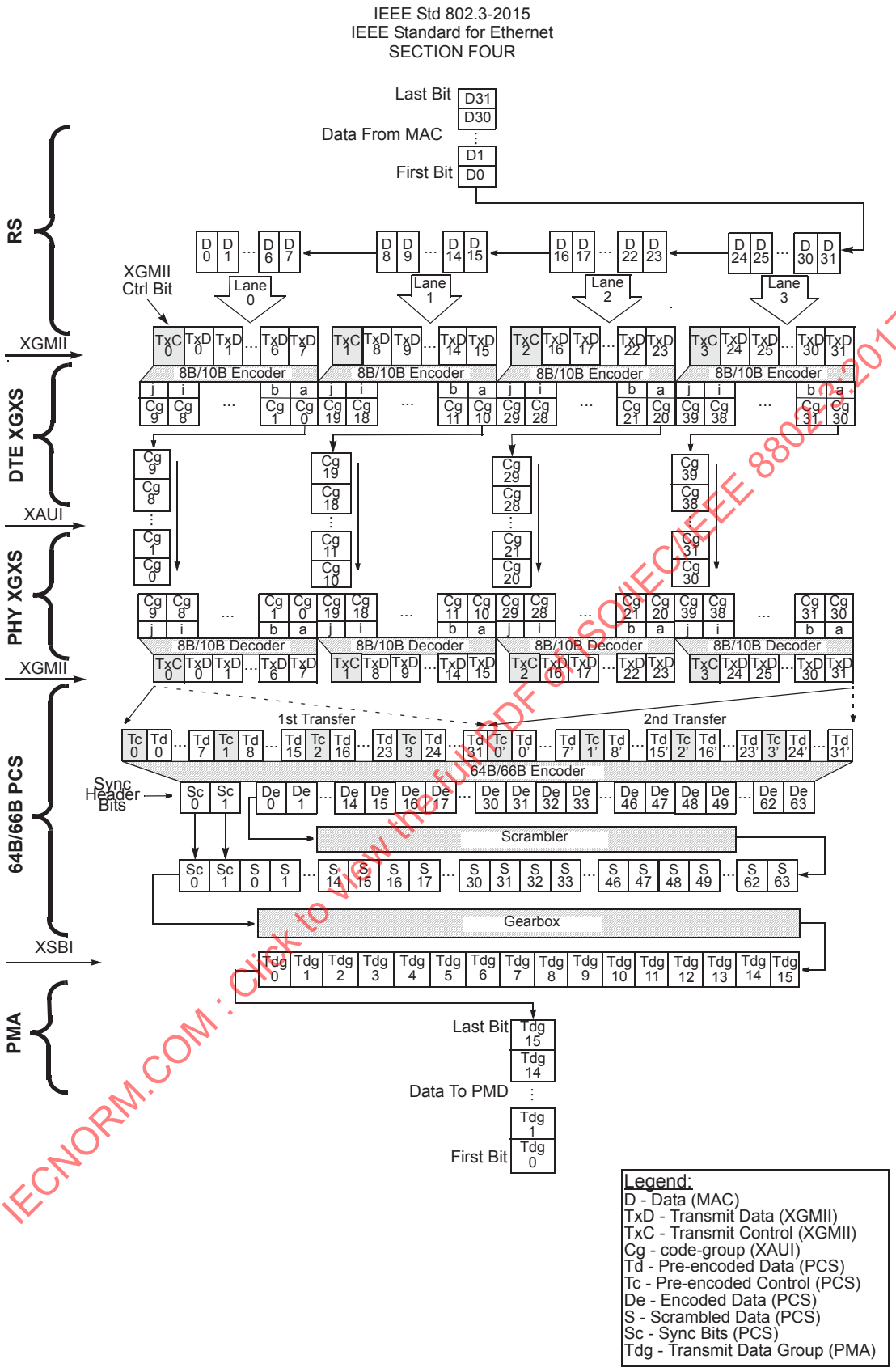

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Figure 44A–1—10GBASE-R transmit data path bit ordering

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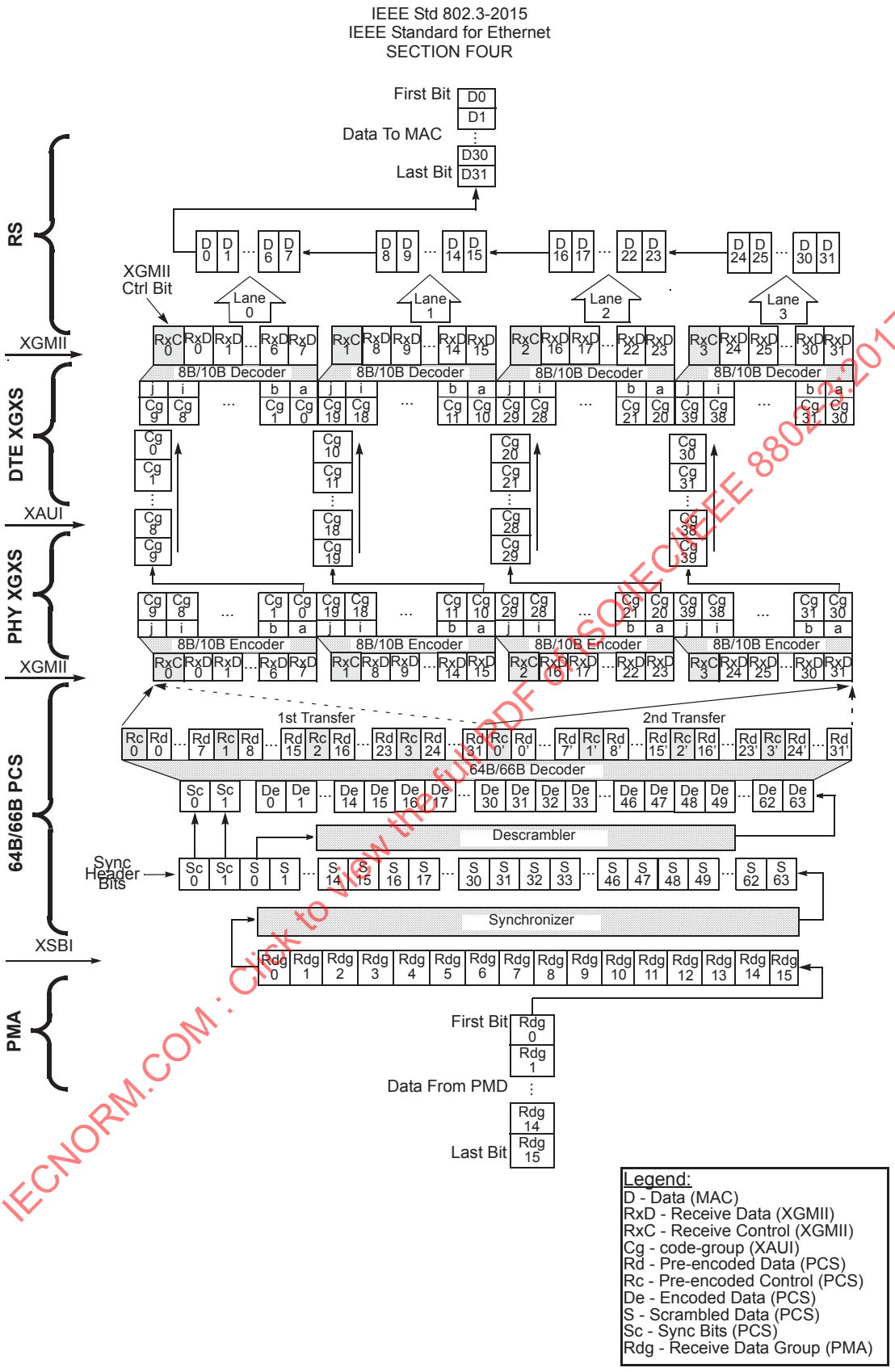

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Figure 44A–2—10GBASE-R receive data path bit ordering

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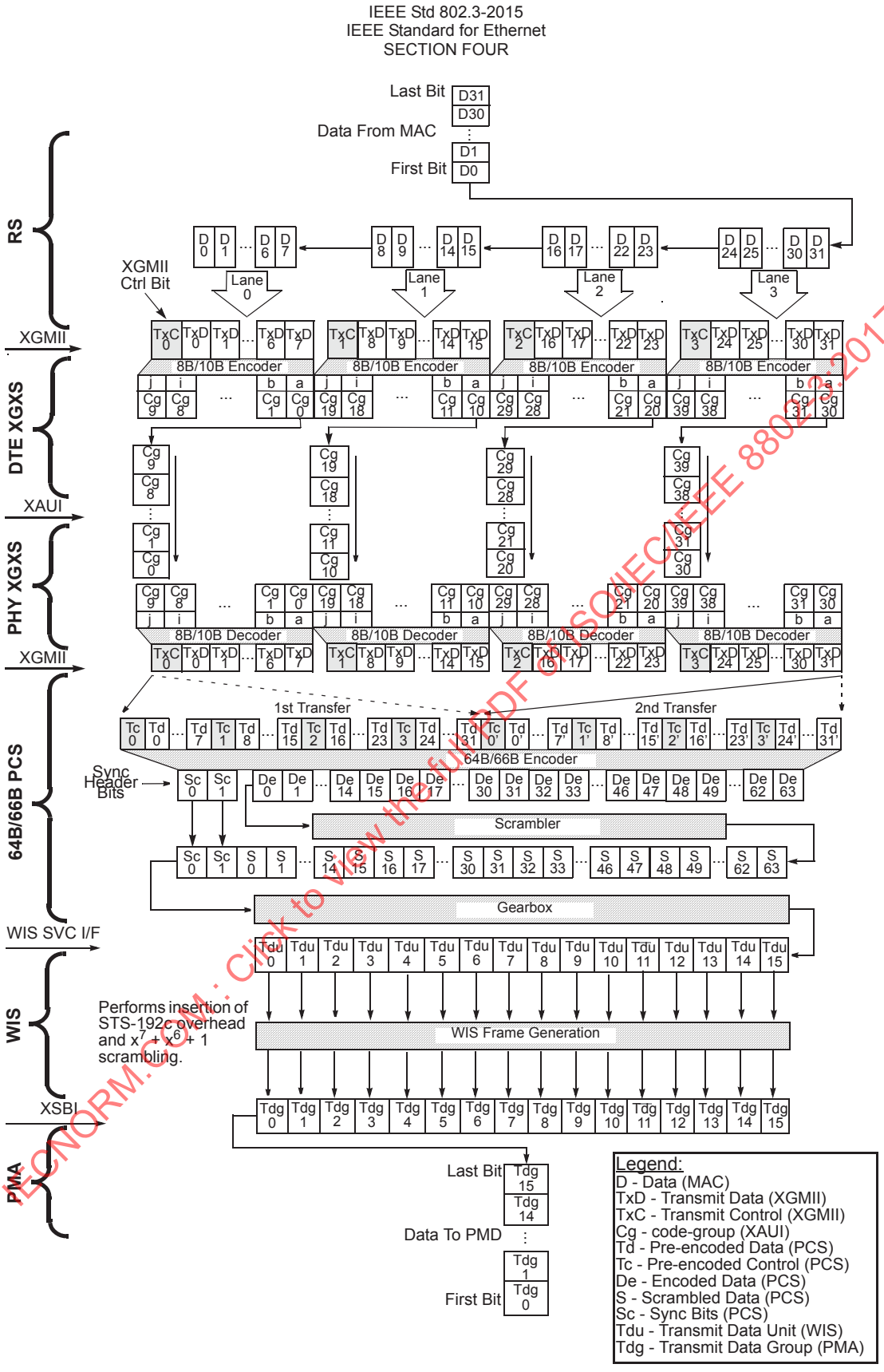

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Figure 44A–3—10GBASE-W serial transmit data path bit ordering

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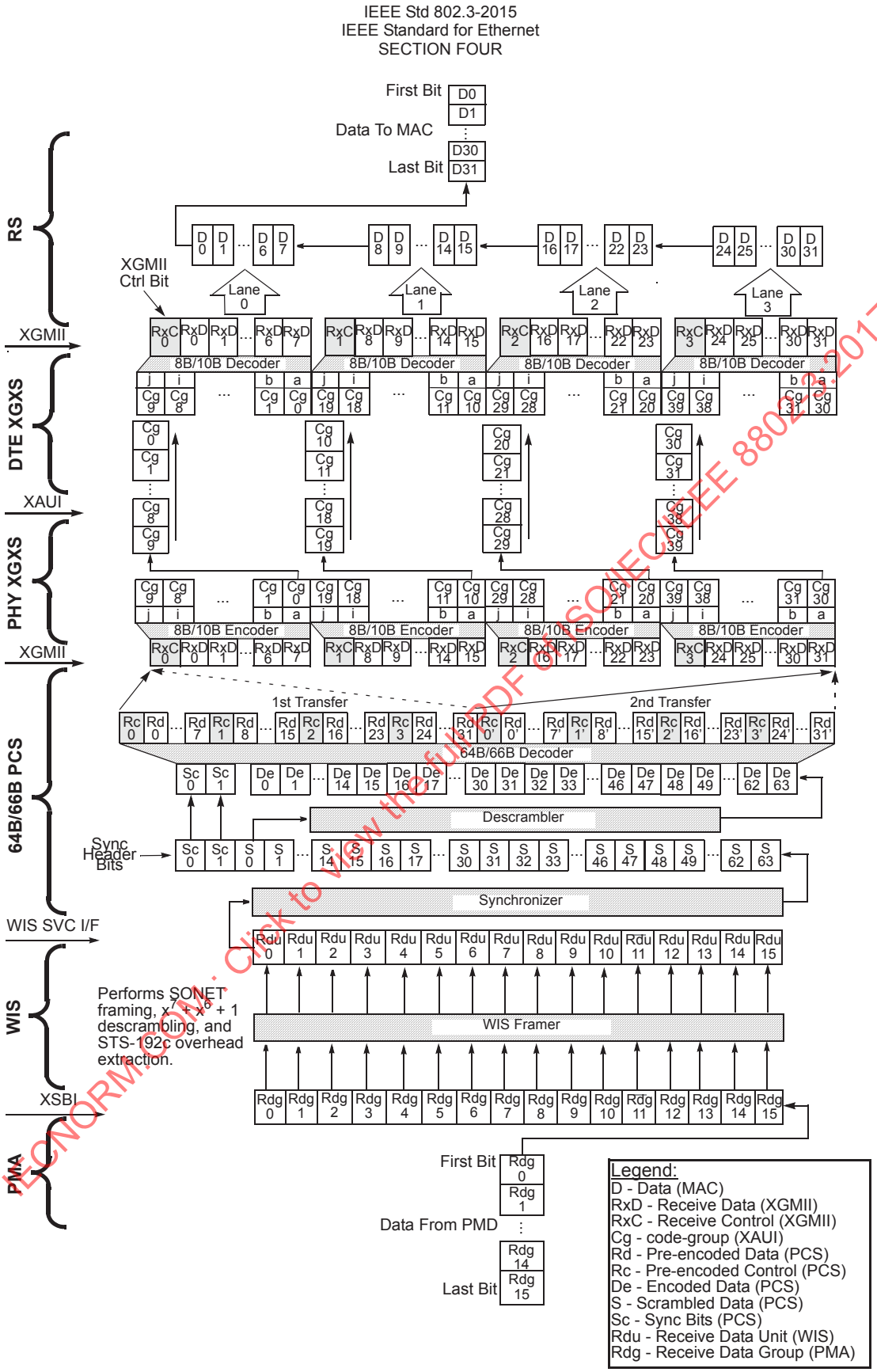

Figure 44A–4—10GBASE-W serial receive data path bit ordering

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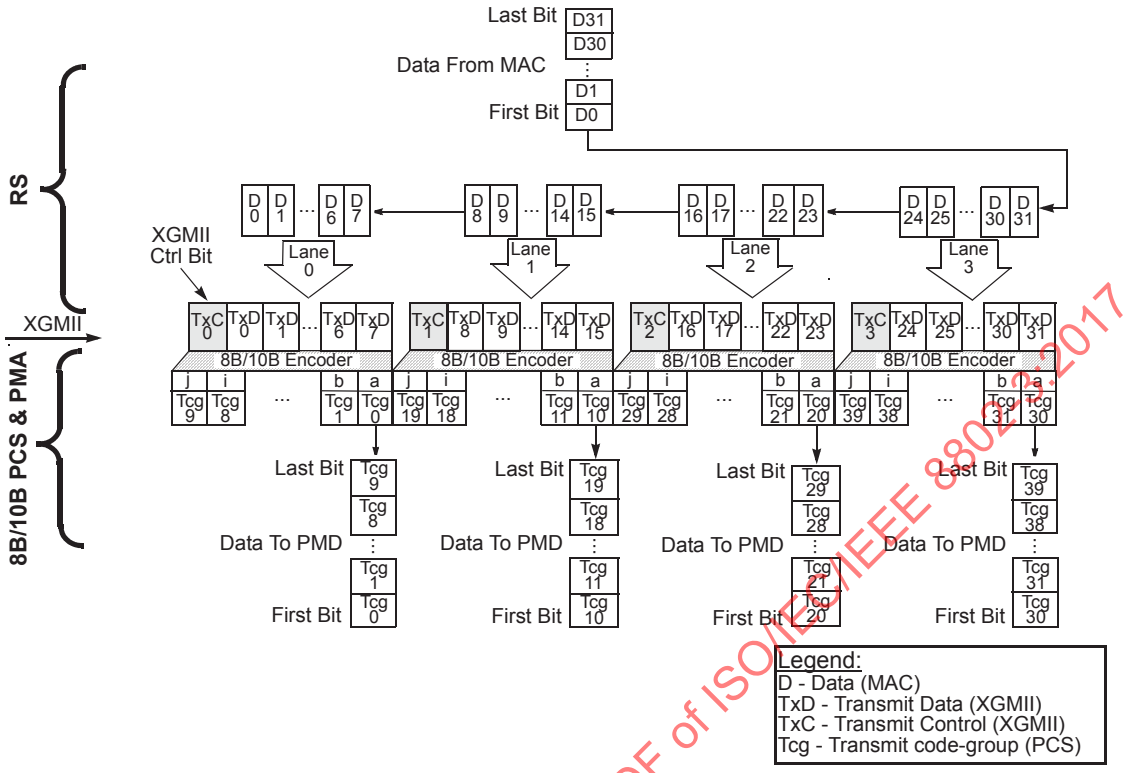

Figure 44A–5—10GBASE-LX4 transmit data path bit ordering

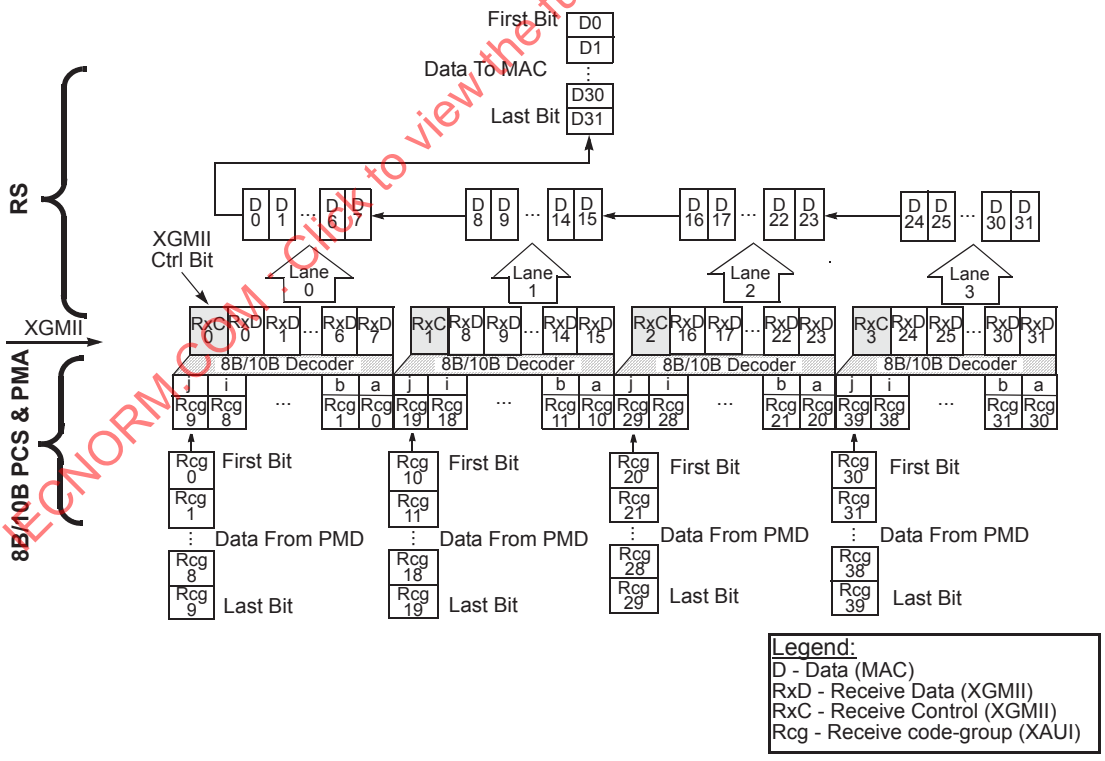

Figure 44A–6—10GBASE-LX4 receive data path bit ordering

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44A.4 Loopback locations

Figure 44A–7 diagrams the impact of the various loopback signals on the generation of signal detect and local fault. Clause 46 describes the handling of local fault via the XGMII. If the WIS is not present, the PMA_SIGNAL.indication passes directly from the PMA sublayer to the PCS as is the case in 10GBASE-X and 10GBASE-R devices.

Figure 44A–7 represents an implementation of loopback where loopback is implemented in accordance with the recommendation that it exercises as much of the circuitry in the sublayer as possible. If the loopback is implemented above part of the circuitry in a sublayer, then any data valid signals produced below the loopback point should be ignored during loopback as are any data valid signals from below the sublayer. For instance, if loopback in a WIS implementation was done above the framer, then data valid signals from the framer should be logically OR'ed with loopback.

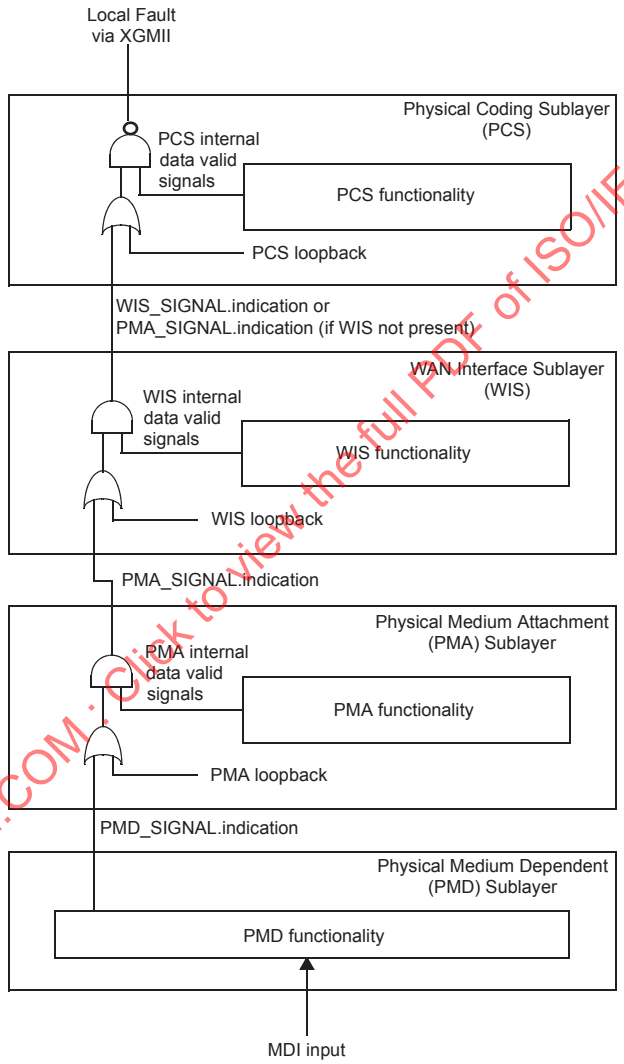

Figure 44A–7—Signal Detect handling across sublayers

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Annex 45A

(informative)

Clause 45 MDIO electrical interface

45A.1 MDIO driver

It is possible to implement the MDIO electrical driver using an open drain driver, as the MDIO signal is pulled up to 1.2 V using a resistor. This is shown in Figure 45A–1.

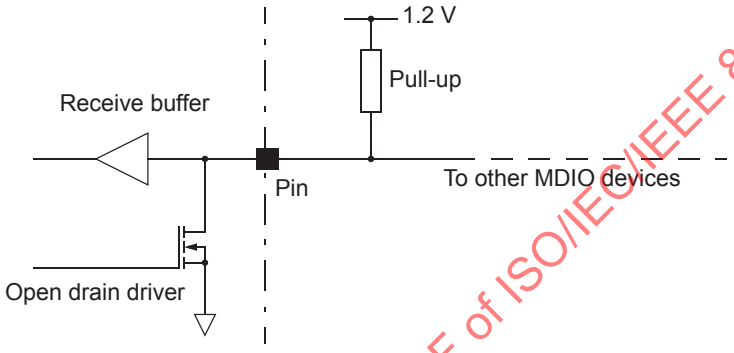

Figure 45A–1—Use of open drain driver for MDIO electrical interface

45A.2 Single Clause 45 electrical interface

As the Clause 45 MDIO electrical interface is significantly different from the Clause 22 MII Management electrical interface, it is not possible to directly attach a Clause 45 MMD to a Clause 22 MII Management Interface. Clause 45 MMDs that include Clause 22 registers may have their Clause 22 registers accessed via the Clause 45 electrical interface. This obviates the requirement to provide a Clause 22 compliant electrical interface in such systems. This is shown in Figure 45A–2.

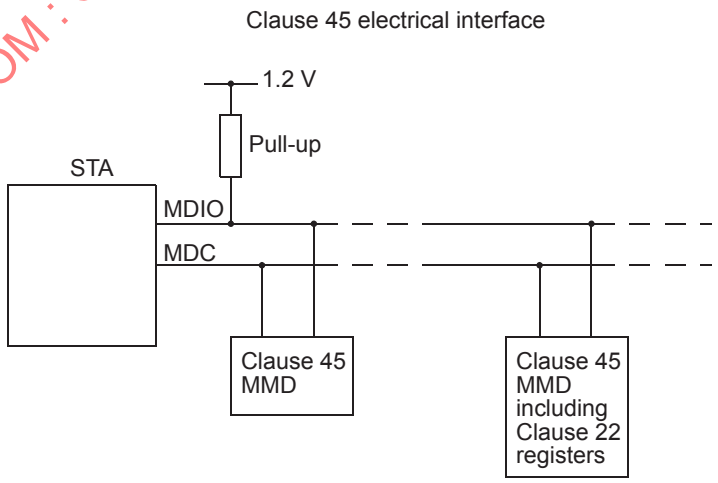

Figure 45A–2—Support of Clause 22 registers via the Clause 45 MDIO interface

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45A.3 Clause 45 electrical interface for STA with Clause 22 electrical interface to PHYs

If Clause 22 PHYs are to be attached to a Clause 45 MDIO interface, then a voltage translation device is required. One possible solution is a protocol aware voltage translation device. This arrangement is shown in Figure 45A–3. Such a translation device must correctly drive both the Clause 45 MDIO interface and the Clause 22 MII Management interface using the voltages and timings specified in the appropriate clause. In order to drive the interfaces correctly, the device must have knowledge of the Clause 22 PHY addresses present on the Clause 22 Management interface. When any PHY attached to the Clause 22 MII Management interface is driving the MDIO, the translation device must drive the Clause 45 MDIO interface with the same logical state that is being driven on to the Clause 22 Management interface by the PHY. Whenever the STA drives the Clause 45 MDIO interface, the translation device must drive the Clause 22 Management interface with the same logical state that is being driven on to the Clause 45 MDIO interface. In addition, the translation device must drive the Clause 45 MDC on to the Clause 22 Management interface. Even though the Clause 45 MDIO frames using the ST=00 frame code will also be driven on to the Clause 22 MII Management interface, the Clause 22 PHYs will ignore the frames.

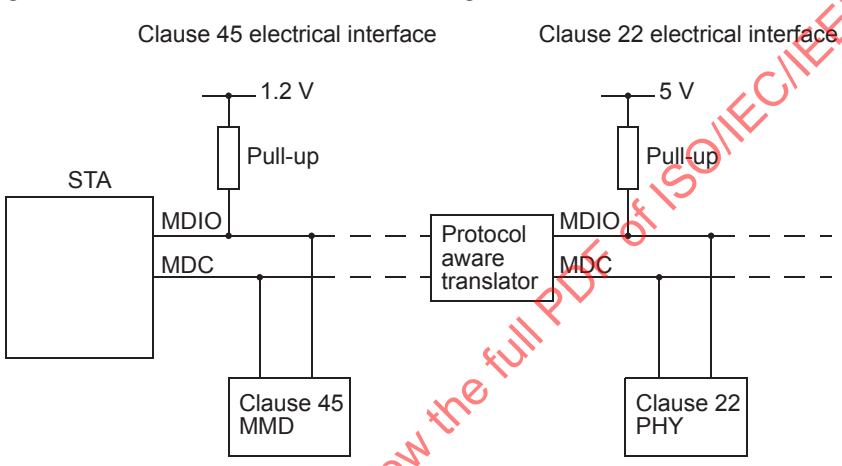

Figure 45A–3—Protocol aware voltage translator between Clause 45 and Clause 22

45A.4 Clause 22 electrical interface for STA with Clause 45 electrical interface to MMDs

If Clause 45 MMDs are to be attached to a Clause 22 MII management interface, then a voltage translation device is required. One possible solution is a protocol aware voltage translation device. This arrangement is shown in Figure 45A–4. Such a translation device must correctly drive both the Clause 22 MII Management interface and the Clause 45 MDIO interface using the voltages and timings specified in the appropriate clause. In order to drive the interfaces correctly, the device must have knowledge of any Clause 22 PHY addresses present within MMDs attached to the Clause 45 MDIO Management interface. When any Clause 45 MMD, including embedded Clause 22 PHYs, attached to the Clause 45 MDIO Management interface is driving the MDIO, the translation device must drive the Clause 22 MII Management interface with the same logical state that is being driven on to the Clause 45 MDIO interface by the PHY. Whenever the STA drives the Clause 22 MII Management interface, the translation device must drive the Clause 45 MDIO interface with the same logical state that is being driven on to the Clause 22 MII Management interface. In addition, the translation device must drive the Clause 22 MII Management interface MDC on to the Clause 45 MDIO interface. The Clause 22 MII Management interface must be capable of generating the MDIO frame structure specified in Clause 45. Even though the Clause 45 MDIO frames using the ST=00

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frame code will be driven on to the Clause 22 MII Management interface, the Clause 22 PHYs will ignore such frames.

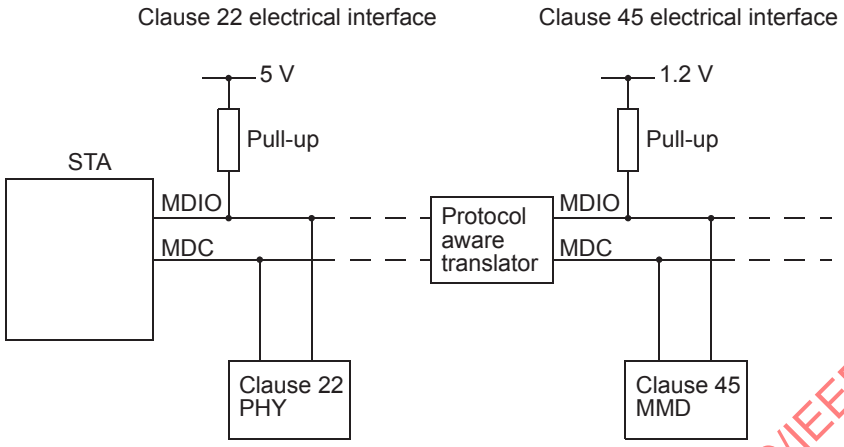

Figure 45A–4—Protocol aware voltage translator between Clause 22 and Clause 45

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Annex 48A

(normative)

Jitter test patterns

This annex defines test patterns that allow the 10GBASE-X PHY described in Clause 48 to test either its attached PMD described in Clause 53 or its XAUI interface described in Clause 47 for compliance in a system environment, or for unspecified diagnostic purposes. The patterns may be implemented at a bit, code-group or frame level and may be used for transmitter testing. The receiver may not have the capability to accept these diagnostic sequences; however, system debug can be improved if a receiver is able to test for one or more of these patterns and report bit errors (e.g., 8B/10B decoder errors) back to the user.

48A.1 High-frequency test pattern

The intent of this test pattern is to test random jitter (RJ) at a BER of 10^{-12} and also to test the asymmetry of transition times. This pattern is not intended for jitter compliance testing. This high-frequency test pattern generates a one, or light on, for a duration of 1 unit interval (UI), followed by a zero, or light off, for a duration of 1 UI. This pattern repeats continuously on each lane for the duration of the test. For example, 10101010101010101010101010101010101010...

NOTE—This pattern can be generated by the repeated transmission of the D21.5 code-group on each lane. Disparity rules are followed.

48A.2 Low-frequency test pattern

The intent of this test pattern is to test low-frequency RJ and also to test PLL tracking error. This pattern is not intended for jitter compliance testing. This low-frequency test pattern generates a one, or light on, for a duration of 5 UI, followed by a zero, or light off, for a duration of 5 UI. This pattern repeats continuously on each lane for the duration of the test. For example, 11111000001111100000111110000011111000000...

NOTE—This pattern can be generated by the repeated transmission of the K28.7 code-group on each lane. Disparity rules are followed.

48A.3 Mixed-frequency test pattern

The intent of this test pattern is to test the combination of RJ and deterministic jitter (DJ) due to high-frequency ISI. This pattern is not intended for jitter compliance testing. This mixed-frequency test pattern generates a one, or light on, for a duration of 5 UI, followed by a zero, or light off, for a duration of 1 UI, followed by a one for 1 UI followed by a zero for 1 UI followed by a one for 2 UI followed by a zero for 5 UI followed by a one for 1 UI followed by a zero for 1 UI followed by a one for 1 UI followed by a zero for 2 UI. This pattern repeats continuously on each lane for the duration of the test. For example, 11111010110000010100111110101100000101000...

NOTE—This pattern can be generated by the repeated transmission of the K28.5 code-group on each lane. Disparity rules are followed.

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48A.4 Continuous random test pattern (CRPAT)

The continuous random test pattern is intended to provide broad spectral content and minimal peaking that can be used for the measurement of jitter at either a component or system level. This pattern is not intended for jitter compliance testing.

NOTE—The basis of this pattern may be found in NCITS TR-25:1999 [B47], “Fibre Channel - Methodologies for Jitter Specification”. This annex uses similar modifications to fit the RPAT test pattern into an IEEE 802.3 frame.

The continuous random test pattern consists of a continuous stream of identical packets, separated by a minimum IPG. Each packet is encapsulated within delimiters as specified in Clause 48 in the ordinary way. The contents of each packet is composed of the following octet sequences, as observed at the XGMII, before 8B/10B coding.

Each packet in the continuous random test pattern consists of 8 octets of PREAMBLE/SFD, followed by 1488 data octets (124 repetitions of the 12-octet modified RPAT sequence), plus 4 CRC octets, followed by a minimum IPG of 12 octets of IDLE.

START/PREAMBLE/SFD:

FB 55 55 55 55 55 55 D5

MODIFIED RPAT SEQUENCE (REPEAT ENTIRE SEQUENCE 31 TIMES CONSECUTIVELY):

BE for 4 octets;
D7 for 4 octets;
23 for 4 octets;
47 for 4 octets;
6B for 4 octets;
8F for 4 octets;
B3 for 4 octets;
14 for 4 octets;
5E for 4 octets;
FB for 4 octets;
35 for 4 octets;
59 for 4 octets.

CRC

F8 79 05 59

IPG

FD 07 07 07 07 07 07 07 07 07 07 07

END

NOTE—The data values for this pattern are in hexadecimal.

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48A.5 Continuous jitter test pattern (CJPAT)

The continuous jitter test pattern is intended to expose a receiver's CDR to large instantaneous phase jumps. The pattern alternates repeating low-transition density patterns with repeating high-transition density patterns. The repeating code-group durations should be longer than the time constants in the receiver clock recovery circuit. This assures that the clock phase has followed the systematic pattern jitter and the data sampling circuitry is exposed to large systematic phase jumps. This stresses the timing margins in the received eye. The following pattern is intended for receive jitter compliance testing.

NOTE—The basis of this pattern may be found in NCITS TR-25:1999 [B47]. This annex uses similar modifications to fit the JTPAT test pattern into an IEEE 802.3 frame.

The continuous jitter test pattern consists of a continuous stream of identical packets, separated by a minimum IPG. Each packet is encapsulated within delimiters, as specified in Clause 48, in the ordinary way. The contents of each packet is composed of the following octet sequences, as observed at the XGMII, before 8B/10B coding.

Each packet in the continuous jitter test pattern consists of 8 octets of PREAMBLE/SFD, followed by 1504 data octets, plus 4 CRC octets, followed by a minimum IPG of 12 octets of IDLE.

START/PREAMBLE/SFD:

FB 55 55 55 55 55 55 D5

MODIFIED JTPAT SEQUENCE

0B for 1 octet (lane 0);

7E for 3 octets (lanes 1, 2, 3);

7E for 524 octets—Low-density transition pattern;

F4 for 4 octets—Phase jump;

EB for 4 octets—Phase jump;

F4 for 4 octets—Phase jump;

EB for 4 octets—Phase jump;

F4 for 4 octets—Phase jump;

EB for 4 octets—Phase jump;

F4 for 4 octets—Phase jump;

AB for 4 octets—Phase jump;

B5 for 160 octets—High-density transition pattern;

EB for 4 octets—Phase jump;

F4 for 4 octets—Phase jump;

EB for 4 octets—Phase jump;

F4 for 4 octets—Phase jump;

EB for 4 octets—Phase jump;

F4 for 4 octets—Phase jump;

EB for 4 octets—Phase jump;

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F4 for 4 octets—Phase jump;

7E for 528 octets—Low-density transition pattern;

F4 for 4 octets—Phase jump;

EB for 4 octets—Phase jump;

F4 for 4 octets—Phase jump;

EB for 4 octets—Phase jump;

F4 for 4 octets—Phase jump;

EB for 4 octets—Phase jump;

F4 for 4 octets—Phase jump;

AB for 4 octets—Phase jump;

B5 for 160 octets—High-density transition pattern;

EB for 4 octets—Phase jump;

F4 for 4 octets—Phase jump;

EB for 4 octets—Phase jump;

F4 for 4 octets—Phase jump;

EB for 4 octets—Phase jump;

F4 for 4 octets—Phase jump;

EB for 4 octets—Phase jump;

F4 for 4 octets—Phase jump.

CRC

BD 9F 1E AB

IPG

FD 07 07 07 07 07 07 07 07 07 07 07

END

NOTE—The data values for this pattern are in hexadecimal.

48A.5.1 Continuous jitter test pattern (CJPAT) 10 bit values

The following tables depict a 10-bit encoding for CJPAT. This is the encoding which will occur when each lane has negative disparity before the Start column. The actual 10-bit encoding sent when CJPAT is transmitted will be one of 16 encodings depending upon the disparity of each lane at the beginning of the packet. CJPAT has been designed to produce the same disparity on each lane after the Terminate column as that lane had before the Start column. When CJPAT is sent continuously, two of the sixteen possible encodings will occur because Idle will either leave the disparity the same or flip the disparity on all lanes.

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Table 48A–1—Start/Preamble/SFD/First 8 Data Octets

Lane0 abcdei fghj		Lane1 abcdei fghj		Lane2 abcdei fghj		Lane3 abcdei fghj	
FB	1101101000	55	1010100101	55	1010100101	55	1010100101
55	1010100101	55	1010100101	55	1010100101	D5	1010100110
0B	1101001011	7E	0111100011	7E	0111100011	7E	0111100011
7E	1000011100	7E	1000011100	7E	1000011100	7E	1000011100

Table 48A–2—Low-density transition pattern (repeat 65 times)

Lane0 abcdei fghj		Lane1 abcdei fghj		Lane2 abcdei fghj		Lane3 abcdei fghj	
7E	0111100011	7E	0111100011	7E	0111100011	7E	0111100011
7E	1000011100	7E	1000011100	7E	1000011100	7E	1000011100

Table 48A–3—Phase jump

Lane0 abcdei fghj		Lane1 abcdei fghj		Lane2 abcdei fghj		Lane3 abcdei fghj	
F4	0010110111	F4	0010110111	F4	0010110111	F4	0010110111
EB	1101001000	EB	1101001000	EB	1101001000	EB	1101001000
F4	0010110111	F4	0010110111	F4	0010110111	F4	0010110111
EB	1101001000	EB	1101001000	EB	1101001000	EB	1101001000
F4	0010110111	F4	0010110111	F4	0010110111	F4	0010110111
EB	1101001000	EB	1101001000	EB	1101001000	EB	1101001000
F4	0010110111	F4	0010110111	F4	0010110111	F4	0010110111
AB	1101001010	AB	1101001010	AB	1101001010	AB	1101001010

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Table 48A–4—High-density transition pattern (repeat 20 times)

Lane0 abcdei fghj		Lane1 abcdei fghj		Lane2 abcdei fghj		Lane3 abcdei fghj	
B5	1010101010	B5	1010101010	B5	1010101010	B5	1010101010
B5	1010101010	B5	1010101010	B5	1010101010	B5	1010101010

Table 48A–5—Phase jump (repeat 4 times)

Lane0 abcdei fghj		Lane1 abcdei fghj		Lane2 abcdei fghj		Lane3 abcdei fghj	
EB	1101001000	EB	1101001000	EB	1101001000	EB	1101001000
F4	0010110111	F4	0010110111	F4	0010110111	F4	0010110111

Table 48A–6—Low-density transition pattern (repeat 66 times)

Lane0 abcdei fghj		Lane1 abcdei fghj		Lane2 abcdei fghj		Lane3 abcdei fghj	
7E	1000011100	7E	1000011100	7E	1000011100	7E	1000011100
7E	0111100011	7E	0111100011	7E	0111100011	7E	0111100011

Table 48A–7—Phase jump

Lane0 abcdei fghj		Lane1 abcdei fghj		Lane2 abcdei fghj		Lane3 abcdei fghj	
F4	0010110001	F4	0010110001	F4	0010110001	F4	0010110001
EB	1101001110	EB	1101001110	EB	1101001110	EB	1101001110
F4	0010110001	F4	0010110001	F4	0010110001	F4	0010110001
EB	1101001110	EB	1101001110	EB	1101001110	EB	1101001110
F4	0010110001	F4	0010110001	F4	0010110001	F4	0010110001
EB	1101001110	EB	1101001110	EB	1101001110	EB	1101001110
F4	0010110001	F4	0010110001	F4	0010110001	F4	0010110001
AB	1101001010	AB	1101001010	AB	1101001010	AB	1101001010

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Table 48A–8—High-density transition pattern (repeat 20 times)

Lane0 abcdei fghj		Lane1 abcdei fghj		Lane2 abcdei fghj		Lane3 abcdei fghj	
B5	1010101010	B5	1010101010	B5	1010101010	B5	1010101010
B5	1010101010	B5	1010101010	B5	1010101010	B5	1010101010

Table 48A–9—Phase jump (repeat 4 times)

Lane0 abcdei fghj		Lane1 abcdei fghj		Lane2 abcdei fghj		Lane3 abcdei fghj	
EB	1101001110	EB	1101001110	EB	1101001110	EB	1101001110
F4	0010110001	F4	0010110001	F4	0010110001	F4	0010110001

Table 48A–10—CRC/Terminate/IPG

Lane0 abcdei fghj		Lane1 abcdei fghj		Lane2 abcdei fghj		Lane3 abcdei fghj	
BD	1011101010	9F	1010110010	1E	0111100100	AB	1101001010
FD	0100010111	07	0011111010	07	0011111010	07	0011111010
07	1100001100	07	1100001100	07	1100001100	07	1100001100
07	0011110100	07	0011110100	07	0011110100	07	0011110100

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Annex 48B

(informative)

Jitter test methods

This annex specifies the definitions and measurement requirements for the jitter specification of the XGXS and XAUI described in Clause 47, the 10GBASE-LX4 PMD described in Clause 53 and the 10GBASE-CX4 PMD described in Clause 54. These measurement methods and specifications are intended to be used for jitter and wander compliance testing, but are not definitive.

While jitter specifications are required to be met for all lanes during operation, the methods described in this annex are written for testing of a single lane. Each lane can be tested with these methods individually or concurrently.

48B.1 BER and jitter model

Measurement of BER within a data eye is not only the fundamental indicator of signal quality, it is a valuable tool to infer jitter properties. Insight into the relationship between jitter, eye opening and error ratio can be gained through mathematical modeling.

48B.1.1 Description of dual Dirac mathematical model

Figure 48B–1 considers a typical eye diagram that may be seen on an oscilloscope. For the purpose of discussion, assume that an ideal trigger source is used so that the eye is accurately depicted. Jitter is indicated by distributed transitions (crossings) of the threshold as the data toggles between logic states. Histograms of transition regions can be taken at the threshold level. The width of the histograms can then be estimated, including standard deviation, etc.

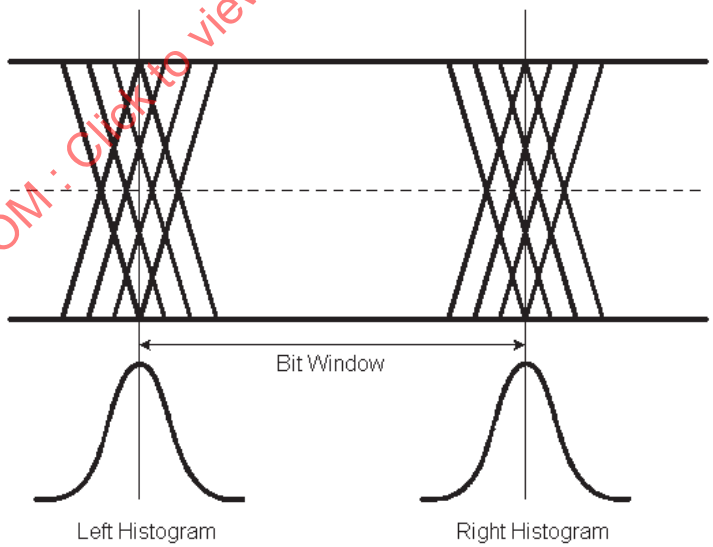

Figure 48B–1—Eye Diagram sketch

The histograms represent probability density functions (PDFs) of the jitter and statistically describe the locations in time of the transitions. The PDFs are placed with their means at the ideal transition times of the

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logic states. To simplify matters, the time scale is given in terms of unit intervals (UI) with 0.5 located at the exact center of the eye. The means of the two PDFs are at 0 and +1 UI.

Ideally, the receiver samples the eye at the center where the tails of the transition histograms are small, as shown in Figure 48B–2. To calculate the probability of either transition causing an error due to jitter, the area under its PDF tail on the errored side of the sample point (time) must be calculated. This is the complementary cumulative distribution function, or CDF. For the left hand PDF, the tail is integrated from to the sample point to $+\infty$; the right hand PDF's tail is integrated from $-\infty$ to the sample point. The overall probability of transition error is the sum of the two CDFs. It is assumed that the tails of the neighboring bits do not contribute to the probability of error.

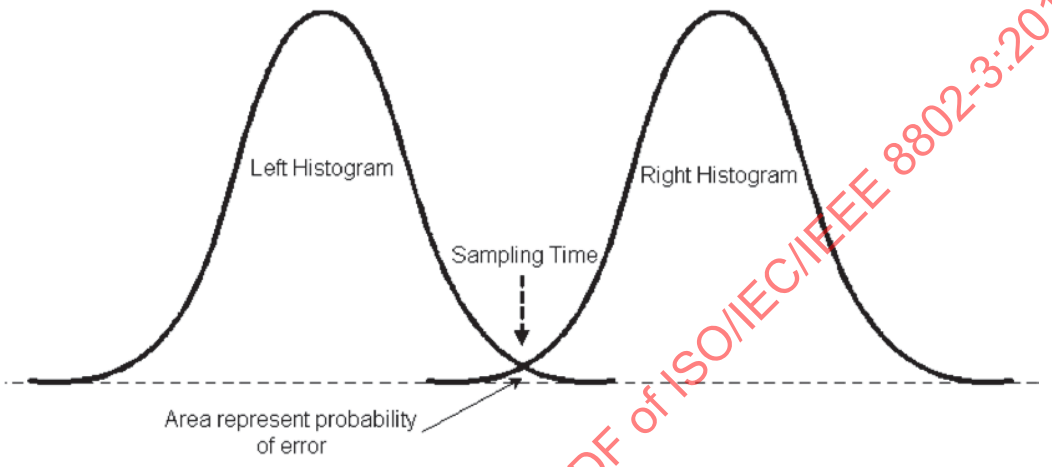

Figure 48B–2—Eye sampling and probability of error

To determine the BER, the probability of a transition caused error must be multiplied by the probability of a transition occurring. Nominally, the latter may be seen as the average transition density. This model assumes typical data streams have a transition density of 50%.

To demonstrate these concepts, define a general jitter PDF, $JT(\tau, W, \sigma)$, centered at 0, where τ is time, W is the peak-to-peak value of deterministic jitter, and σ is the rms value of random jitter. The left PDF histogram (centered at 0) causes bit errors as:

$$BER_{left}(\tau_{sample}, W, \sigma) = \Gamma_{transistion} \cdot \int_{\infty}^{\tau_{sample}} JT(\tau, W, \sigma)\delta\tau \qquad (48B\text{-}1)$$

where τ_{sample} is the sampling instant in time, and $\Gamma_{transistion}$ is the transition density. Similarly, the right PDF histogram (shifted and centered at 1 UI) causes bit errors as

$$BER_{right}(\tau_{sample}, W, \sigma) = \Gamma_{transistion} \cdot \int_{-\infty}^{\tau_{sample}} JT(\tau - UI, W, \sigma)\delta\tau \qquad (48B\text{-}2)$$

The sum of these two functions provides the total (BER) due to jitter,

$$BER_{total}(\tau_{sample}, W, \sigma) = BER_{left}(\tau_{sample}, W, \sigma) + BER_{right}(\tau_{sample}, W, \sigma) \qquad (48B\text{-}3)$$

In the BERT scan, BER is measured as the sample point, τ_{sample}, is swept between the two eye crossings. The probability of error as a function of the sample point is commonly known as a BER bathtub curve.

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48B.1.2 Random Jitter

For random or Gaussian jitter (RJ) only the standard deviation, σ, is necessary to define the PDF

$$RT(\tau, \sigma) = \frac{1}{\sqrt{2\pi}} \cdot \frac{1}{\sigma} \cdot e^{-\left(\frac{\tau^2}{2\sigma^2}\right)} \tag{48B-4}$$

The CDF for this Gaussian PDF function is the complementary error function (erfc).

48B.1.3 Addition of Deterministic Jitter

Total jitter is comprised of both random and deterministic components. The DJ component can be defined, as for RJ, by a PDF, where the combined total jitter PDF is a convolution of the DJ and RJ PDFs.

Simple peak-to-peak is insufficient as the measurement of DJ. An overall weighting function that captures not only the peak-to-peak but also the shape of the density function is required. This may be known as "effective DJ." For purposes of simplicity, effective DJ in this annex is based on the dual Dirac function, where it is assumed that the DJ PDF is comprised only of a pair of delta functions. Other PDFs are certainly possible, however, in the prediction of low BERs, this simplification is sufficient. All references to DJ in Clauses 47 and 53 should be understood as effective DJ.

An example of effective DJ is duty cycle distortion (DCD), which when convolved with RJ results in two Gaussian functions, one centered at each of the two delta functions.

The magnitude of the DJ, is given as peak-to-peak amplitude, *W*. Therefore, each delta function is offset from the mean crossing position by the peak value of DJ, *W*/2. The PDF for deterministic jitter, centered at 0, is therefore defined as:

$$JT(\tau, W, \sigma) = \frac{\delta\left(\tau, -\frac{W}{2}\right)}{2} + \frac{\delta\left(\tau, \frac{W}{2}\right)}{2} \tag{48B-5}$$

When convolved with random jitter, the PDF, centered at 0, becomes:

$$JT(\tau, W, \sigma) = \frac{1}{2\sqrt{2\pi}} \cdot \frac{1}{\sigma} \cdot \left(e^{-\left(\frac{\left(\tau - \frac{W}{2}\right)^2}{2\sigma^2}\right)} + e^{-\left(\frac{\left(\tau + \frac{W}{2}\right)^2}{2\sigma^2}\right)} \right) \tag{48B-6}$$

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48B.1.4 Effects of jitter high-pass filtering and CJPAT on deterministic jitter

It is understood that CDRs track low-frequency jitter, and that including this effect in the specifications could ease requirements on clock oscillators (lower cost designs tend to exhibit low-frequency RJ), serializer (SERDES, same advantage) designs and switching power supplies, layouts, bypassing, etc. All jitter specifications include the effects of a high-pass filter (to suppress the significance of low-frequency jitter) to emulate CDR tracking.

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It is also realized that, due to frequency content, long complex patterns cause phenomena that are not observed with short patterns—data dependent jitter (DDJ, a form of DJ) can have extreme ranges of frequency content from well below to well above the CDR corner frequencies. Effects are usually seen in both transmitters and receivers. Jitter test patterns are specified in Annex 48A.

48B.2 Jitter tolerance test methodologies

An important measurement in determining link integrity is the characterization of a receiver's (i.e., CDR's) ability to tolerate jittered inputs yet recover error-free data. This is accomplished by inputting a well-controlled, jittered signal to a CDR while measuring the BER at the output of the CDR. As the source signal is modified in amplitude and spectral content, the change in BER is measured. This subclause describes some useful test methodologies for testing a receiver's jitter tolerance.

48B.2.1 Calibration of a signal source using the BERT scan technique

The jitter model described in 48B.1 can be used to calibrate the signal source for tolerance measurements as well as to provide a method for extrapolating lower BER. In this approach, curve fitting of the dual Dirac model onto bathtub curves derived from BERT Scans give the jitter content.

Figure 48B–3 shows an example of how to generate controlled amounts of jitter in a signal to be used for tolerance measurement.[23] Three sources of jitter are provided: Deterministic (DDJ and sinusoidal (SJ)) and Gaussian (RJ). Each of these is added to the serial signal generated by a BERT Pattern Generator. A sinewave generator modulates the clock to the Pattern Generator to provide Sinusoidal jitter modulation from 10 Hz to 20 MHz. A filter or cable adds deterministic jitter. A white noise source[24] with a bandwidth greater than 500 MHz[25] is added to the signal to provide random jitter.

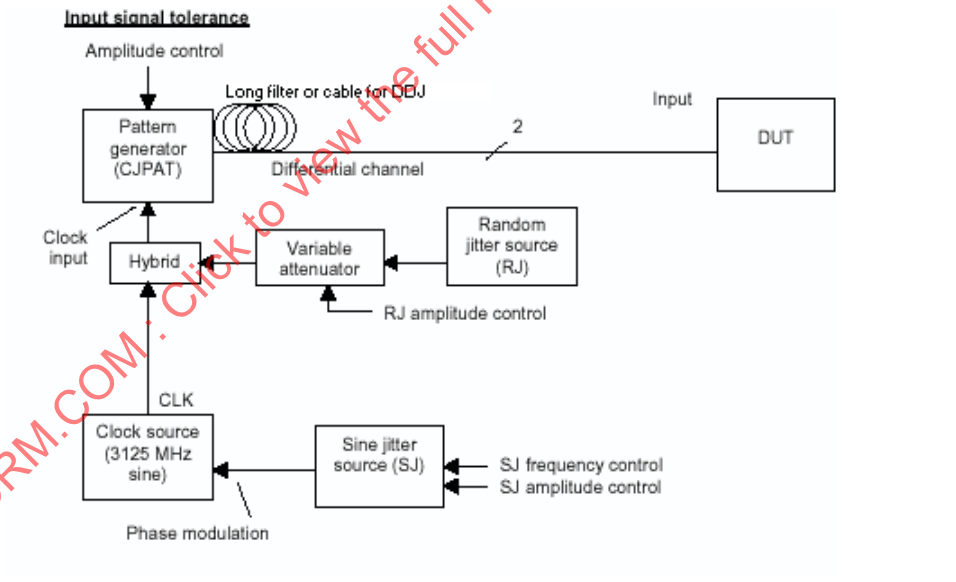

Figure 48B–3—BERT Jitter Tolerance Source

[23]Beware of instrument noise floors and data dependencies, as these may lead to test signals with less stress than intended.

[24]RJ must be Gaussian and not clipped out to >BER being tested (spec is 1E-12). Simply measuring the rms value does not guarantee that the tails exist and that the Rx will be sufficiently stressed as specified.

[25]The spectrum of the portion of RJ that is calibrated must be from greater than 20MHz. The sketch as shown assumes the pattern generator passes clock input jitter through to the data with >>20 MHz BW. This may not be the case. The RJ spectrum need not be white above 20 MHz, but a wider spectrum is preferred.

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Amplitude calibration is not possible on a scope due to the low probability of the peak-to-peak RJ effects. For better visibility for amplitude calibration, the RJ portion may be temporarily replaced with an equivalent amount of peak-to-peak SJ to bring TJ up to the same specified output jitter level, allowing the desired amplitude value to be met.[26,27]

If the clock data recovery circuit of the system under test has a corner frequency above the maximum sine wave generator frequency, be sure to increase the amount of the applied deterministic jitter by the amount of the specified high-frequency value sinusoidal jitter.

When calibrating the jitter tolerance test setup, the effects of high pass filtering in the time/jitter domain must be understood and included per the specifications. Per 48B.1.4, high pass filtering can have profound effects on pattern dependent jitter (it will increase measured DJ with patterns such as CJPAT) and also track out jitter below the specified corner frequency. [28]

After complete, calibration must be verified using the methods described in 48B.3 and iterated as needed until the required specifications are met.

It should be noted that the XAUI is a differential input and calibration of the test signal must be performed using the differential signal. If test equipment only provides single-ended possibilities, care should be taken to calibrate and test with a balun to convert differential signals to single-ended signals. Single-ended signals should not be directly used, due to the possibility of asymmetric characteristics.

48B.3 Jitter output test methodologies

Three viable methodologies for measuring jitter output are described in this subclause. They are as follows:

a) Time domain measurement using an oscilloscope to characterize the data eye.
b) Time domain measurement using BERT scan by moving of the data sampling point within the data eye.
c) Time interval analysis based on accurate measurement of the time interval between threshold crossings of the transmitter waveform.

48B.3.1 Time domain measurement—Scope and BERT scan

It is easy to grasp that if the eye is larger than the eye mask, it must be ok. This is not necessarily true. Given the probabilistic nature of random jitter, it is necessary either to test for an extended amount of time to reach a high confidence level for achieving 1×10^{-12} BER or to perform some kind of statistical extrapolation.

48B.3.1.1 Jitter high pass filtering (using Golden PLL)

Due to the issues mentioned in 48B.1.4, when testing either at the component level or the system level, the test clock should be derived from the data with a given high-pass filter function of the jitter using, for example, a golden PLL.

Given a typical test setup, the serial bit pattern is transmitted to the input of a BERT and a golden PLL. The golden PLL extracts a reference clock to trigger the sampling scope or clock the BERT.

[26]Amplitude calibration should be done before addition of SJ, as SJ is designed to add margin into the design. NOTE—This footnote is not referring to the suggestion of temporarily substituting SJ and RJ during amplitude calibration, but to the SJ that is required as part of the specifications.

[27]It may be required to add amplification to achieve the required test signal amplitude.

[28]Beware of autocorrelation effects.

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48B.3.1.2 Time domain scope measurement

Time domain measurement uses the high-speed sampling scopes to view the jitter output data eye. Most high-speed sampling scopes today provide features to collect and present data on the output jitter. Some oscilloscopes provide a feature to compare the measured data to an "eye mask." An eye mask is a specification for allowed eye opening. The advantage of an eye mask is that it tests for amplitude as well as timing compliance. The general physical media transmitter pulse shape characteristics are specified in the form of a mask of the transmitter eye diagram at any of the compliance measurement points. These characteristics include rise time, fall time, pulse overshoot, pulse undershoot, and ringing, all of which prevent excessive degradation of the receiver sensitivity. For the purpose of an assessment of the transmit signal, it is important to not only consider the eye opening, but also the overshoot and undershoot limitations. The parameters specifying the mask of the transmitter diagram (eye mask) can be found in the clause of the applicable Physical Layer specification whether it be copper or fiber physical media. The eye mask, through its use of a specified time range in which the transmit signal can change state from the logic low to logic high levels, is also specifying a measure of the allowed jitter.

It is strongly advised not to use the eye mask to verify that total jitter is within specification because of the nature of the test. The eye mask test is generally a short test, and thus the eye diagram is not captured for a sufficient time to capture the full extent of the random jitter's peak-to-peak value. It is necessary to capture the eye pattern for a sufficient period to insure the full extent of the deterministic jitter is captured by the test instrument. Since the peak-to-peak of the random jitter for a BER of 1×10^{-12} is 14 times the sigma, it is not possible to capture the full extent of random jitter's peak-to-peak value due to the low sampling rate.

48B.3.1.3 BERT Scan

As implied by the jitter model in 48B.1, a BERT scan approach can provide random and deterministic jitter components and provides a mechanism to extrapolate to lower BER (less than 1×10^{-12}) without impossibly long test times due to the inherent high sampling rate.

48B.3.1.3.1 Approximate curve-fitting for BERT scan

48B.3.1.3 describes a technique for using a BERT scan to determine eye opening and jitter. For highest accuracy, the bathtub curve should be measured over a high number points at low BER and curve-fitted with a least-squares method to estimate equivalent DJ, RJ, and TJ values. However, a simple and fast method for estimating these values may be applied using only two measurement points.

The following steps describe a process for estimating equivalent RJ, DJ, and TJ values from a two point BERT scan measurement:

a) Measure the eye opening at 2 different BER, BER_0 @τ_0 and BER_1 @τ_1 (e.g., 10^{-9} and 10^{-5}).

b) For each BER_n, determine the associated Q_n from the inverse normal cumulative probability distribution, adjusted for transition density, e.g., $Q = 3.94$ for BER = 10^{-5}, and $Q = 5.77$ for BER = 10^{-9}, where transition density is assumed to be 0.5.

c) Calculate the individual jitter components using the equations for Random Jitter and Deterministic Jitter, and then calculate the total jitter for the given BER = 10^{-12}, using the following three equations:

Random Jitter—

$$RJ_{RMS} = 0.5\left|\frac{t_1 - t_0}{Q_1 - Q_0}\right| \tag{48B-7}$$

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Deterministic Jitter—

$$DJ = UI - t_0 - (2Q_0 RJ_{RMS}) \quad \text{(48B-8)}$$

Total Jitter—

$$TJ = DJ + 13.8 \cdot RJ_{RMS} \quad \text{(48B-9)}$$

The minimum value for measured BER is constrained by test time (10 errors are suggested as an absolute minimum to get reasonable statistical confidence); the maximum value is constrained by potential departure of actual results from the assumed curve fit shape (BER = 10^{-5} should be the maximum value used).

48B.3.2 Time Interval Analysis

Time Interval Analysis (TIA) uses many accurate, single-shot, edge-to-edge time measurements. The statistics of these measurements can be used to perform jitter calculations. True random jitter (RJ) and true deterministic jitter (DJ) can be measured using this technique on repeated patterns as well as random data streams. From the true RJ and DJ measurements, an error probability density function, or bathtub curve can be generated. Using the bathtub curve, effective DJ and effective RJ can be calculated. There are two measurement methods defined for executing this test:

a) TIA with Golden PLL
b) TIA armed on pattern trigger

Each method uses the basic TIA methodology, but with different schemes for acquiring the data. In the first method, the TIA is used with a Golden PLL, as described in 48B.3.1.1, and time measurements are made from the recovered reference clock to the data transitions. The low-frequency content that would be tracked by the receiver is presented on the reference clock, and thus eliminated from the jitter data before being presented to the TIA. The second method is used to acquire data when a Golden PLL is not available, or, when jitter on just the data is desired. This method requires a pattern trigger to synchronize the jitter measurements relative to a specific location in the pattern. The TIA can extract the pattern trigger from the data based on a unique bit sequence or pattern length.

48B.3.2.1 TIA with Golden PLL

In this option, a Golden PLL is required to provide a reference clock derived from the data stream to trigger the TIA. This scheme effectively removes low-frequency content from the measured data in a manner similar to that done in a receiver. The configuration used for this option is shown in Figure 48B–4 (note that only a single channel is shown). The Golden PLL in Figure 48B–4 is shown with a differential input; other approaches are possible, but it is important that the balance of the data signals is not disturbed and that both phases are included in clock recovery. A Golden PLL is used for each data signal so as to ensure proper CDR modeling on each data signal. Each Golden PLL is intended to track low-frequency jitter content occurring on the data signal applied to the input stage of that PLL. It cannot be assumed that the clock extracted from one data signal can be used for the other signals since the low-frequency jitter content may be different. Some TIA models have this algorithm integrated internally in the instrument, and some TIA models have integrated Golden PLL or high-pass filtering algorithms.

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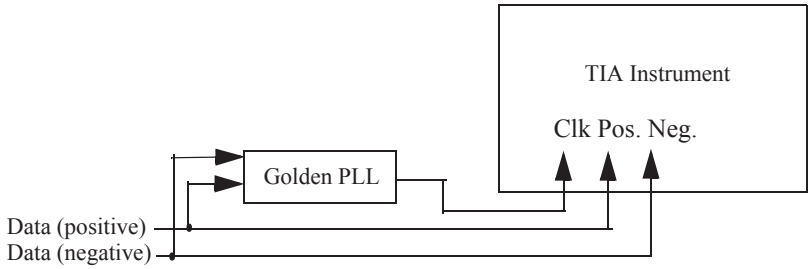

Figure 48B–4—TIA with Golden PLL configured for jitter measurement

48B.3.2.1.1 Test method

The TIA is capable of measuring the time from the data transitions to the reference clock as extracted with the Golden PLL. This results in a clock to data histogram that describes the jitter occurring on the data transitions relative to the reference clock (as is the case with a bit clock triggered BERT measurement). RJ can be estimated by fitting a Gaussian curve to the tail region of the histogram. DJ can be estimated by measuring the separation of the means of the fitted Gaussian curves. Some sampling TIA instruments have built in algorithms specifically designed for this process, and can automatically estimate RJ, DJ, and TJ in this configuration. Figure 48B–5 shows a typical clock to data histogram for a communication signal. Note the highlighted curves that represent the fitted Gaussian curves. Also note that the rising edges are treated separately from the falling edges so as to accurately group the jitter contributors. This is critical in cases where the cross point of the data signal is not at the measured voltage. In Figure 48B–5, the rising edge histogram is shifted to the right of the falling edge histogram, indicating that the cross point was below the test voltage. The outer most histogram on a given side is used for the RJ and DJ calculations for that side of the histogram. Each side is treated independently.

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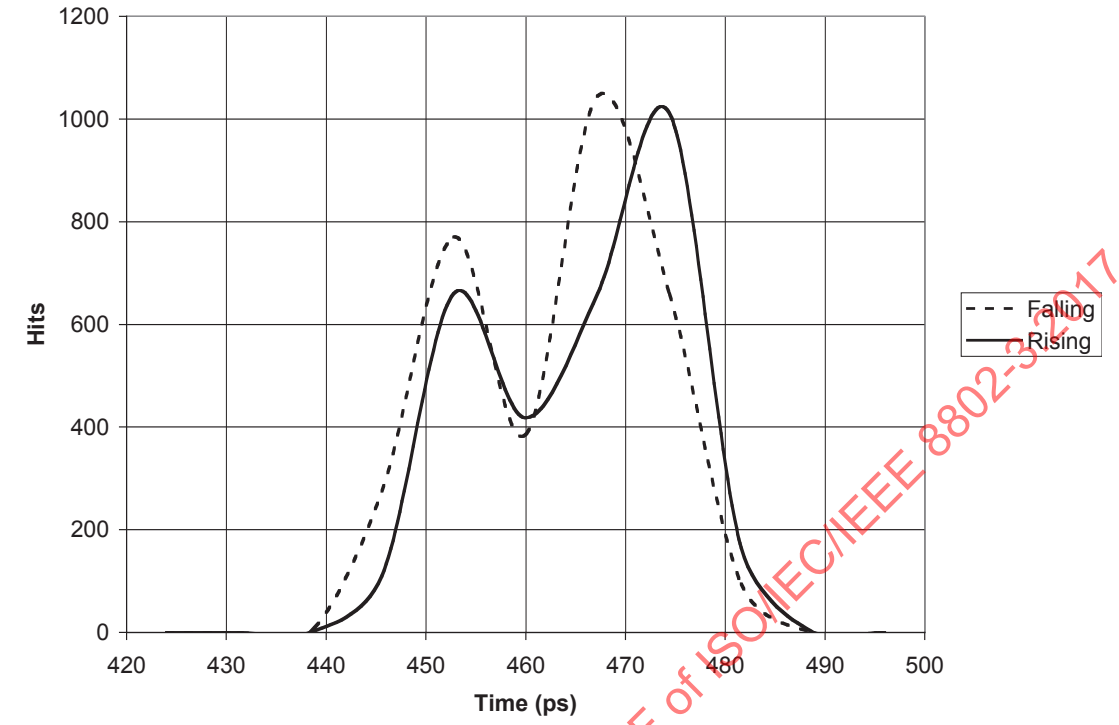

Figure 48B–5—Typical clock to data histogram with fitted Gaussian curves

Jitter values such as DJ, RJ, and TJ can also be displayed on the plot corresponding to 1E-12 BER as shown in Figure 48B–5. Effective Jitter is calculated from the bathtub curve using the same calculations used by the BERT scan method described in 48B.3.1.3.1. To quantify the quality of the measurement, a goodness of fit calculation can be made which compares the quality of the fit of the Gaussian to the actual histogram. Acceptable goodness-of-fit values (χ) for probability confidence level (approximately 1E-4) should be in the range of $0.8 < \chi < 1.2$. The measured DJ and TJ values using this method can be compared against the maximum jitter as specified.

48B.3.2.2 TIA with pattern trigger

The basic setup for this option is shown in Figure 48B–6 (note that only one channel is shown). The pattern trigger can be generated internally to the TIA based on the identification of a unique bit sequence within the data stream or pattern length of the repeated pattern. No measurements are made from the pattern trigger. All measurements are made within the data signal thereby eliminating any error attributed to the bit clock. The high-pass filter characteristic of the Golden PLL is applied using a DSP algorithm thereby eliminating the need for external hardware. Some TIA instruments have this algorithm fully integrated.

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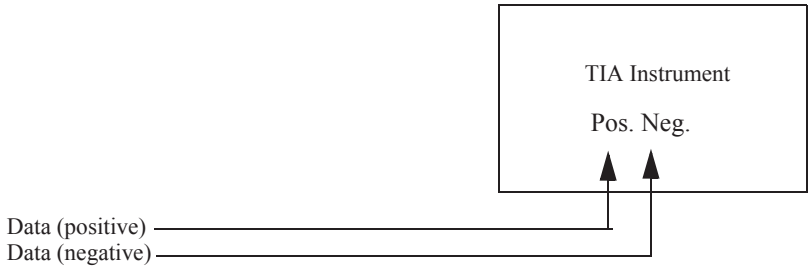

Figure 48B–6—TIA with pattern trigger configured for jitter measurement

48B.3.2.2.1 Test Method

All time measurement are made from the same reference edge within the data pattern. This edge is identified by the pattern trigger. Thousands of measurements are made of each transition within the data pattern relative to the reference edge. Histograms for each transition are captured from this data. An FFT of the autocorrelation algorithm of the variance information from these histograms is used to extract SJ. Using the tail fit algorithm described in 48B.3.2.1.1, RJ is measured from each of these histograms and the results plotted in the FFT display. The RJ, bounded by the high-pass filter function is calculated from the FFT of the autocorrelation function. Data dependent jitter is measured from the histograms of each transition based on the displacement of each histogram mean relative to integer multiples of the measured bit period. TJ is calculated and the bathtub curve generated based on the convolution of the RJ PDF, DDJ PDF, and the SJ PDF. This method directly measures the DJ PDF and thereby does not need to assume that the DJ PDF is a dual Dirac function. Effective DJ and Effective RJ is calculated from the bathtub curve using the same formulas used for the BERT scan method, thereby ensuring correlation. Some TIA instruments have this algorithm fully integrated, simplifying the measurement methodology.

48B.3.2.3 Approximate curve fitting for TIA bathtub curve

Since the TIA is capable of measuring true DJ and its probability density function (PDF), the TIA can accurately display total jitter (TJ) as a function of BER in the form of an error probability density function, or bathtub curve. From the Error PDF, the effective DJ can be estimated using the same curve fit technique described in 48B.3.1.3.1.

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Annex 50A

(informative)

Thresholds for Severely Errored Second calculations

This annex provides tables of threshold values that may be used to determine the generation of Section, Line and Path Severely Errored Second (SES) events for various error ratios. An SES event is deemed to have occurred when the number of bit errors, detected via the corresponding Bit Interleaved Parity (BIP) check, exceeds some predefined threshold value when accumulated over a 1 s interval; reporting of an SES event indicates that the actual bit error ratio on the medium has increased to a point where Station Management must be notified. These threshold values are referred to as *x* in the Layer Management definitions in Clause 30. This annex also defines the terms "Path Block Error" and "Far End Path Block Error."

The values in these tables are derived according to the algorithms given in Annex C of ANSI T1.231-1997.

50A.1 Section SES threshold

The Section SES threshold is referenced as *x* in 30.8.1.1.3.

Table 50A–1 gives the values to be used for the Section SES threshold in order to report Section SES events at various limiting bit error ratios. A BER of 10^{-6} corresponds to the default Section SES threshold of 8554 in 30.8.1.1.3.

Table 50A–1—Section SES

BER	Threshold, *x*
10^{-6}	8554
10^{-7}	980
10^{-8}	99
10^{-9}	10
10^{-10}	1

50A.2 Line SES threshold

The Line SES threshold is referenced as *x* in 30.8.1.1.11.

Table 50A–2 gives the values to be used for the Line SES threshold in order to report Line SES events at various limiting bit error ratios. A BER of 10^{-6} corresponds to the default Line SES threshold of 9835 in 30.8.1.1.11.

50A.3 Path SES threshold

The Path SES threshold is referenced as *x* in 30.8.1.1.19.

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Table 50A–2—Line SES

BER	Threshold, *x*
10^{-6}	9835
10^{-7}	984
10^{-8}	98
10^{-9}	10
10^{-10}	1

Table 50A–3 gives the values to be used for the Path SES threshold in order to report Path SES events at various limiting bit error ratios. The default Path SES threshold of 2400 in 30.8.1.1.19 corresponds to a situation where 30% of all the SPEs being received have parity errors detected via the Path BIP checks.

Table 50A–3—Path SES

Fraction of SPEs with parity errors	Threshold, *x*
30%	2400
25%	2000
20%	1600
15%	1200
10%	800

50A.4 Definition of Path Block Error

A Path Block Error (see Section 8.1.1.1.2 of ANSI T1.231-1997) is declared when one or more of the 8 BIP-8 parity bits that are computed over the received Synchronous Payload Envelope, and compared to the B3 octet of the Path Overhead, are found to be in error. At most one Path Block Error can be declared per WIS frame (i.e., a maximum rate of 8000 counts per second), regardless of the actual number of parity errors detected using a particular B3 octet.

50A.5 Definition of Far End Path Block Error

A Far End Path Block Error is declared when the G1 octet extracted from a received WIS frame indicates that the far end WIS has detected one or more BIP-8 parity errors in the SPE of a previously transmitted WIS frame. The far end WIS reports these parity errors via the REI-P field of the G1 octet. At most one Far End Path Block Error can be declared per received WIS frame (i.e., a maximum rate of 8000 counts per second), regardless of the actual number of parity errors reported in the REI-P field of a particular G1 octet.

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Annex 55A

(normative)

LDPC details

55A.1 The generator matrix

The generator matrix, G, uniquely specifies the mapping of information bits to codewords. G.txt contains a representation of G. G.txt contains 1723 rows, one for each row of G. Each row has numbers ranging from 0 to 2047 separated by spaces. Each number represents the column index of the "1" entries in the specific row. All other entries of G are "0" and are not referenced in G.txt. G.txt is available online in the file matrices.zip.[29]

55A.2 The sparse parity check matrix H

Codewords that are generated using G are in the null space of a sparse parity check matrix H. The H matrix is available in machine readable format in file H.txt. This H matrix was obtained by permuting the columns of another sparse matrix using the permutations specified in col_swap.txt. The file row_swap.txt describes row permutations of H that can put it in pseudo-lower triangular form. H.txt, col_swap.txt and row_swap.txt are informative and are also available online in the file matrices.zip.[29]

For further information on LDPC codes, see Gallagher [B32].

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[29]matrices.zip is available at: http://standards.ieee.org/downloads/802.3/.

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Annex 55B

(informative)

Additional cabling design guidelines for 10GBASE-T

This annex provides additional cabling guidelines for 10GBASE-T deployment on balanced copper cabling systems as specified in 55.7. These guidelines are intended to supplement those in Clause 55.

55B.1 Alien crosstalk considerations

The noise coupled between the adjacent link segments illustrated in Figure 55B–3 and Figure 55B–4 is referred to as alien crosstalk (Figure 55B–1).

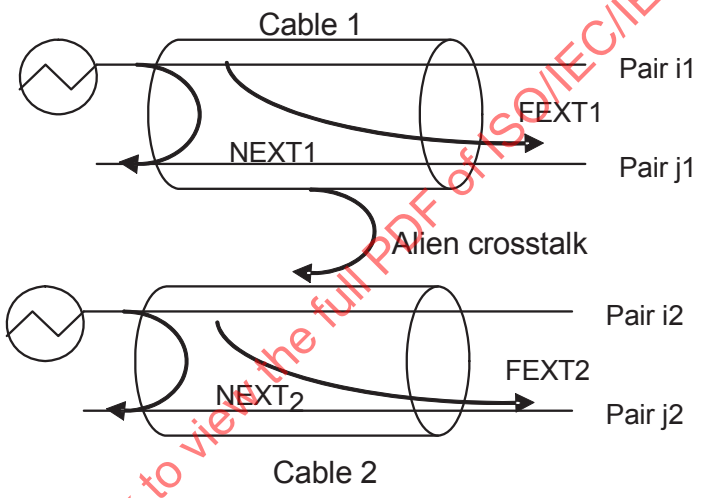

Figure 55B–1—Alien crosstalk coupling between link segments

The alien crosstalk noise levels are dependent on the number and proximity of adjacent cables and connectors. The alien crosstalk link segment specifications of PS ANEXT and PS AELFEXT given in 55.7 are based on the alien crosstalk measurements between cabling channels configured in a six-around-one orientation where the disturbed cable is the central cable and adjacent to all of the other disturbing cables. The alien crosstalk coupling between a cable and six adjacent cables tightly bound in a six-around-one configuration exhibits a “worse case”.

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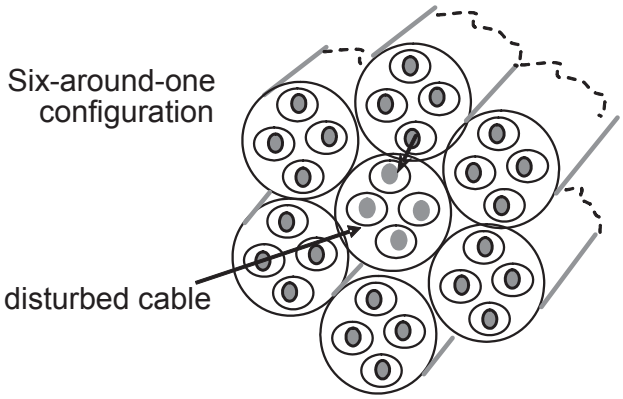


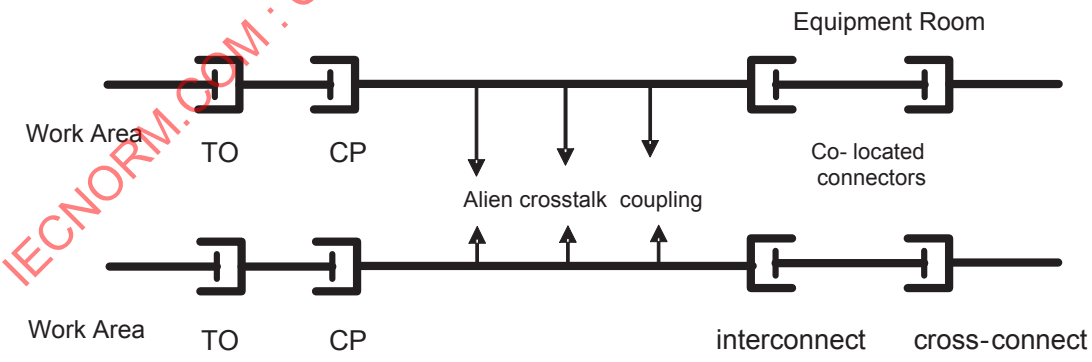
Figure 55B–2—Six-around-one cable configuration

The alien crosstalk coupling is a function of the distance between the cabling components. Removing or loosening cable bindings, separating equipment and patch cordage, and utilizing non-adjacent connectors all have a significant impact on reducing the levels of alien crosstalk noise.

In many topologies, the cables are only bundled together for relatively short distances and laid in cable trays. The star wiring topology, where the cables are distributed radially from a centralized telecommunication closet to each work area, reduces the distances over which link segments are in close proximity.

55B.1.1 Alien crosstalk mitigation

10GBASE-T is designed to operate over a channel that meets the specifications of 55.7 and the channel configuration shown Figure 55B–3. However, if the channel specifications of 55.7 cannot be met when using the channel configuration shown in Figure 55B–3, the configuration shown in Figure 55B–4 is recommended. This optimized channel for a 10GBASE-T link segment deletes the consolidation point or optional transition point and runs an equipment patch cord directly between the LAN equipment and the connector termination of the permanent link. This reduces the number of connectors and cordage and their associated alien crosstalk.



CP = consolidation point connector
TO = telecommunication outlet connector

Figure 55B–3—Maximum horizontal cabling configuration

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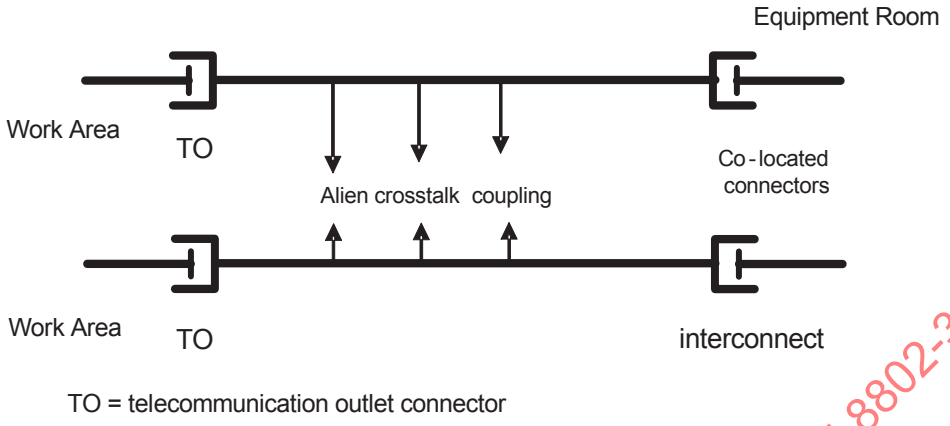

Figure 55B–4—Minimum horizontal cabling configuration

55B.1.2 Alien crosstalk mitigation procedure

This annex provides procedures and cabling guidelines designed to mitigate the alien crosstalk in the event that the alien crosstalk transmission parameters given in 55.7 are not met. For more information on mitigation techniques, see TIA TSB-155-A and ISO/IEC TR 24750.

The mitigation actions outlined below are based on four connector channels. In the majority of initially non-compliant cases, fewer than all corrective actions are required. Select the option(s) that is most appropriate for your situation.

a) When selective deployment of 10GBASE-T is possible, non-adjacent patch panel positions in the equipment room should be used. The adjacent positions may be used for other applications.
b) Reduce the number of co-located connectors by implementing an interconnect configuration to attach equipment to the horizontal cabling rather than a cross-connect. In general, connectors and cordage in the work area are not co-located.
c) Reduce the alien crosstalk coupling in the first 5 m to 20 m of the horizontal cabling by separating the equipment cords and the patch cords and un-bundling the horizontal cabling: in the case of a telecommunications room un-bundle the cabling to the point it exits the telecommunications room. A significant portion of the ANEXT coupling occurs in less than the first 20 m of cabling.
d) An alternative to separating equipment cords is to utilize equipment cords sufficiently specified to mitigate the alien crosstalk coupling.
e) Replace connectors with Category 6A/Class E_A.

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IEEE Standard for Ethernet

SECTION FIVE

This section includes Clause 56 through Clause 77 and Annex 57A through Annex 76A.

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56. Introduction to Ethernet for subscriber access networks

56.1 Overview

Ethernet for subscriber access networks, also referred to as "Ethernet in the First Mile," or EFM, combines a minimal set of extensions to the IEEE 802.3 Media Access Control (MAC) and MAC Control sublayers with a family of Physical Layers. These Physical Layers include optical fiber and voice grade copper cable Physical Medium Dependent sublayers (PMDs) for point-to-point (P2P) connections in subscriber access networks. EFM also introduces the concept of Ethernet Passive Optical Networks (EPONs), in which a point-to-multipoint (P2MP) network topology is implemented with passive optical splitters, along with extensions to the MAC Control sublayer and Reconciliation sublayer as well as optical fiber PMDs to support this topology. In addition, a mechanism for network Operations, Administration, and Maintenance (OAM) is included to facilitate network operation and troubleshooting. 100BASE-LX10 extends the reach of 100BASE-X to achieve 10 km over conventional single-mode two-fiber cabling. The relationships between these EFM elements and the ISO/IEC Open System Interconnection (OSI) reference model are shown in Figure 56–1 for point-to-point topologies, Figure 56–2 for 1G-EPON topologies, Figure 56–3 for 10/10G-EPON topologies, and Figure 56–4 for 10/1G-EPON topologies.

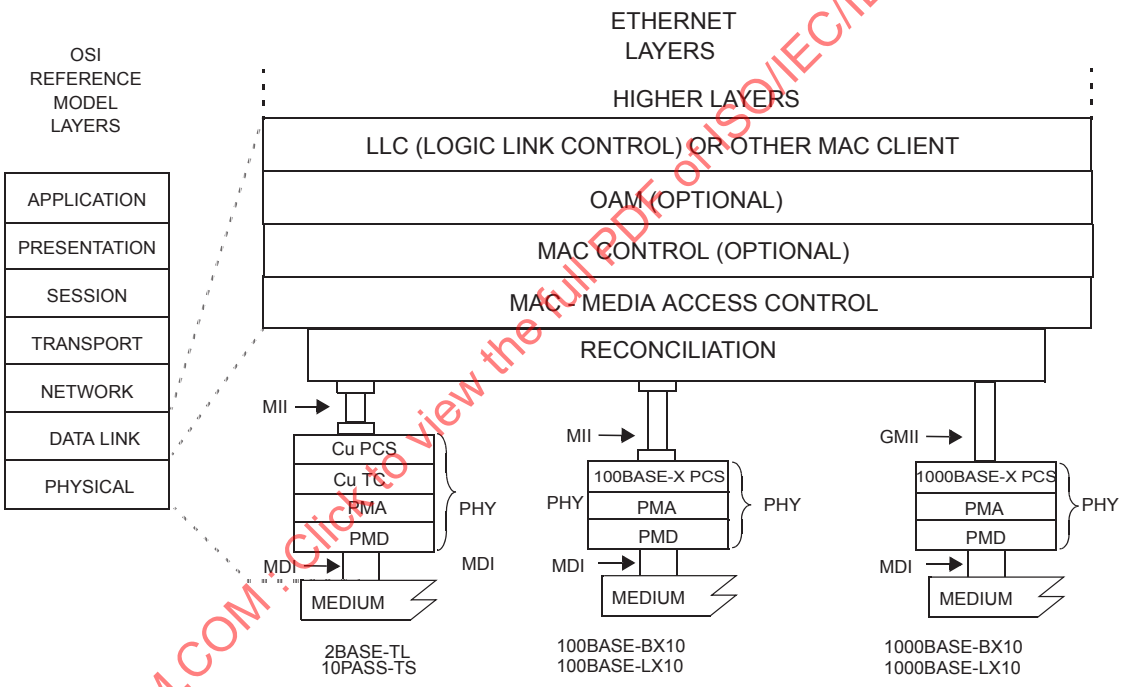

Figure 56–1—Architectural positioning of EFM: P2P Topologies

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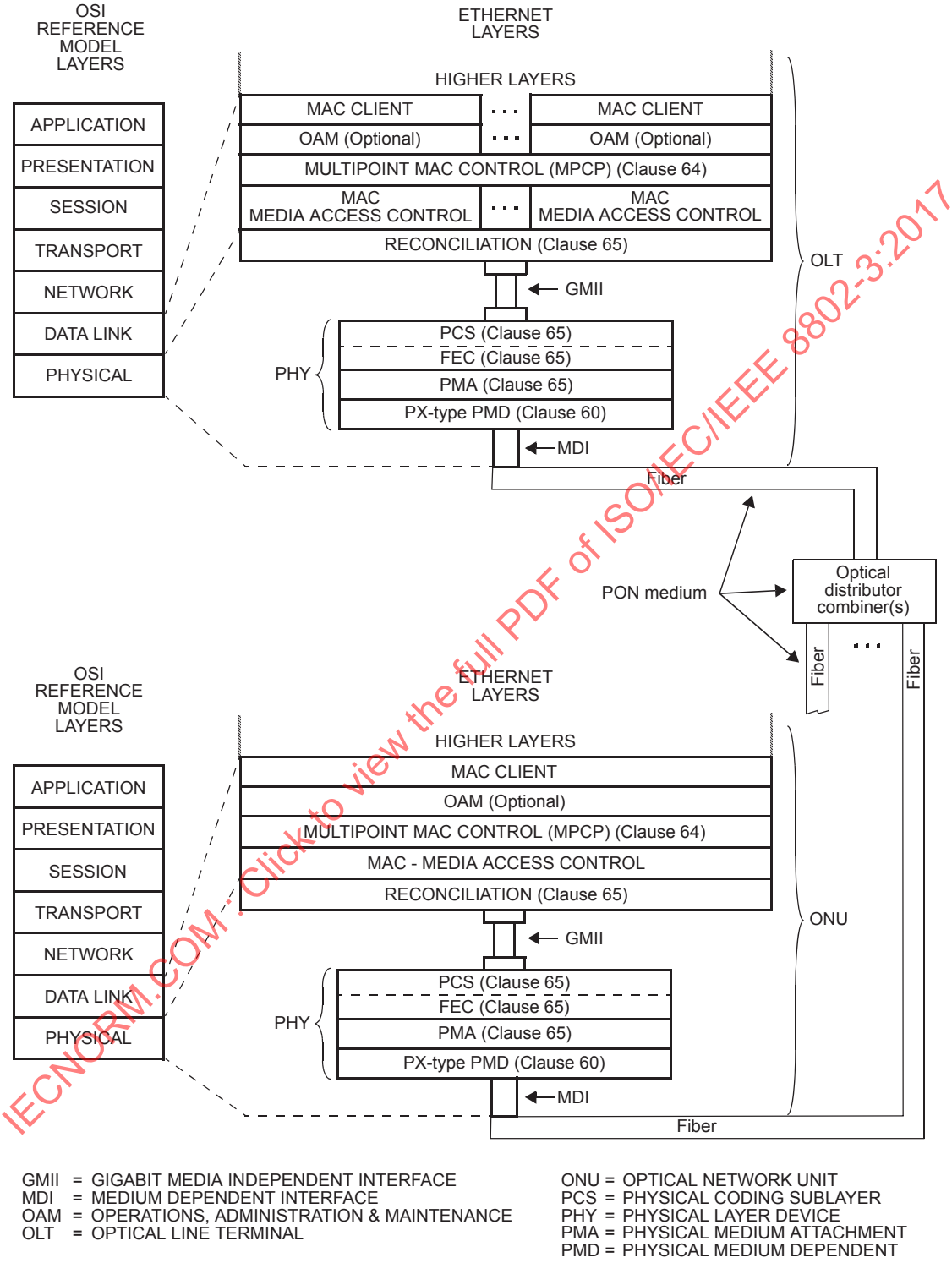

GMII = GIGABIT MEDIA INDEPENDENT INTERFACE
MDI = MEDIUM DEPENDENT INTERFACE
OAM = OPERATIONS, ADMINISTRATION & MAINTENANCE
OLT = OPTICAL LINE TERMINAL
ONU = OPTICAL NETWORK UNIT
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

**Figure 56–2—Architectural positioning of EFM:
P2MP 1G-EPON architecture (1 Gb/s downstream, 1 Gb/s upstream)**

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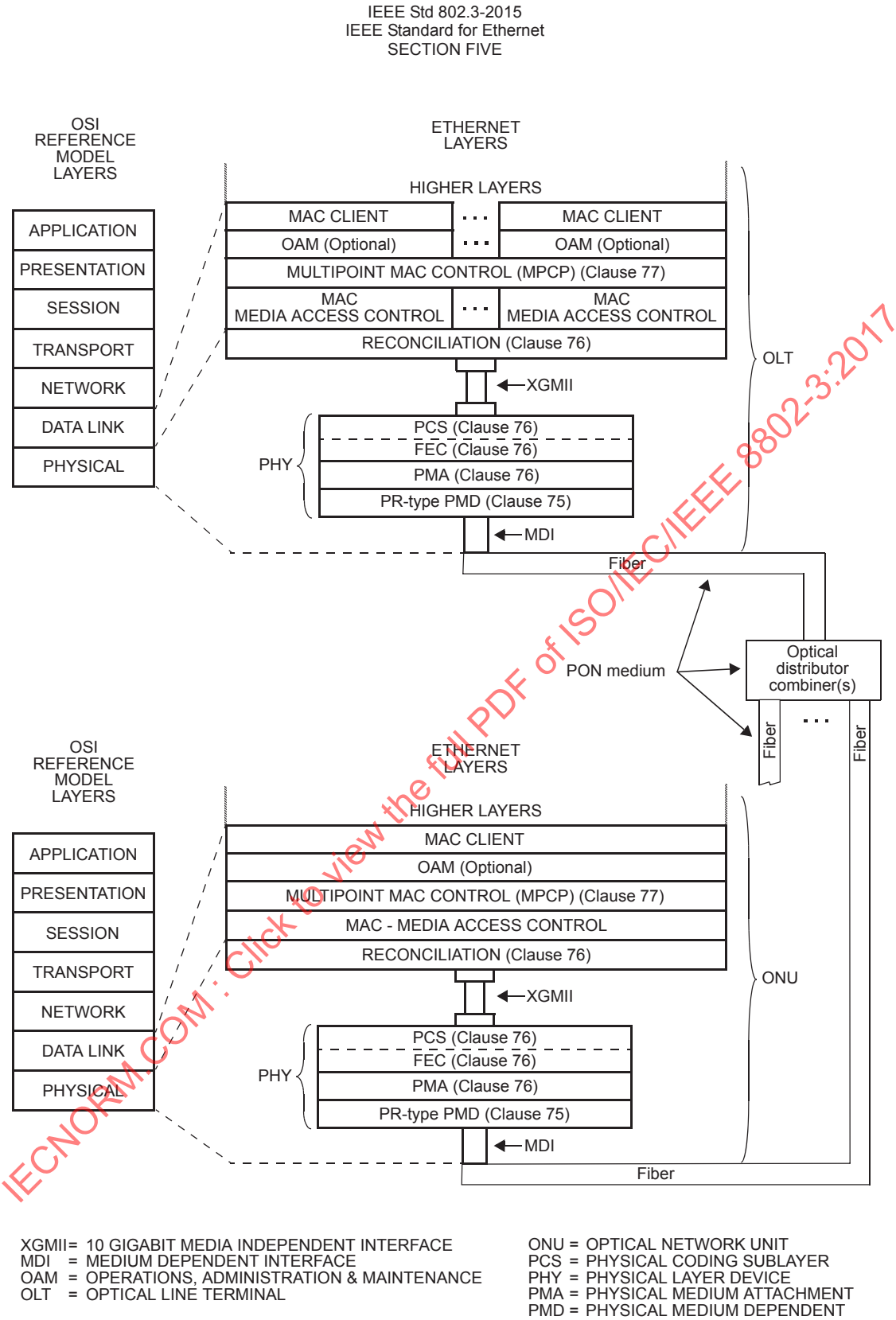

Figure 56–3—Architectural positioning of EFM:
P2MP 10/10G–EPON architecture (10 Gb/s downstream, 10 Gb/s upstream)

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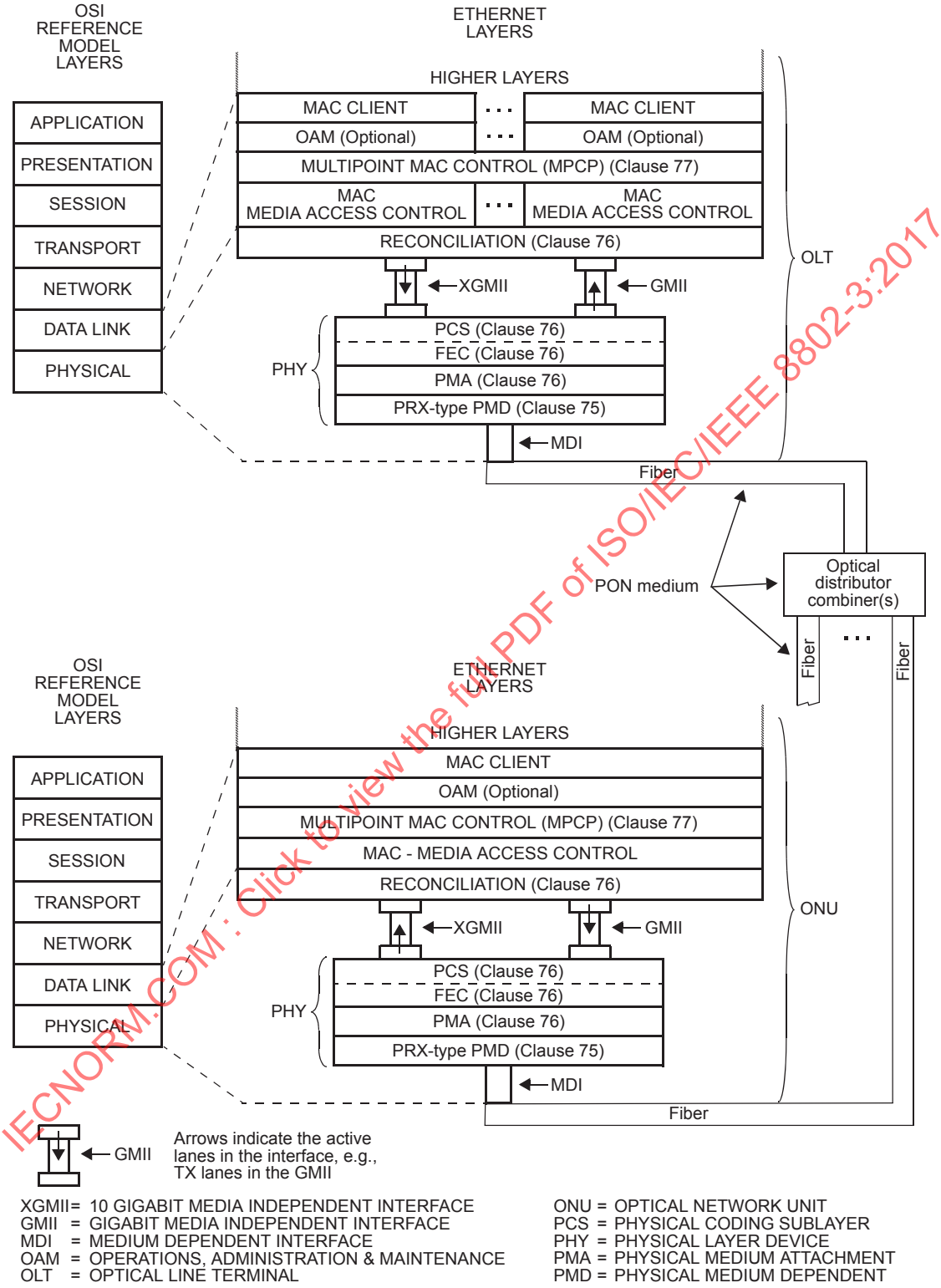

XGMII= 10 GIGABIT MEDIA INDEPENDENT INTERFACE
GMII = GIGABIT MEDIA INDEPENDENT INTERFACE
MDI = MEDIUM DEPENDENT INTERFACE
OAM = OPERATIONS, ADMINISTRATION & MAINTENANCE
OLT = OPTICAL LINE TERMINAL
ONU = OPTICAL NETWORK UNIT
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

Figure 56–4—Architectural positioning of EFM:
P2MP 10/1G–EPON architecture (10 Gb/s downstream, 1 Gb/s upstream)

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An important characteristic of EFM is that only full duplex links are supported. A simplified full duplex MAC is defined in Annex 4A for use in EFM networks. P2MP applications must use this simplified full duplex MAC. EFM Copper applications may use either this simplified full duplex MAC or the Clause 4 MAC operating in half duplex mode as described in 61.1.4.1.2. All other EFM P2P applications may use either this simplified full duplex MAC or the Clause 4 MAC operating in full duplex mode.

The EFM architecture is extended in Clause 75 and Clause 76 by the addition of 10G–EPON. 10G–EPON includes the 10/10G-EPON (10 Gb/s downstream and 10 Gb/s upstream) as well as 10/1G-EPON (10 Gb/s downstream and 1 Gb/s upstream) PONs.

56.1.1 Summary of P2P sublayers

EFM P2P supports operation at several different bit rates, depending on the characteristics of the underlying medium. In the case of point-to-point optical fiber media, bit rates of 100 Mb/s and 1000 Mb/s are supported, using the 100BASE-X and 1000BASE-X Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA) sublayers defined in 66.1 and 66.2, respectively. In the case of point-to-point copper, EFM supports a variety of bit rates, depending on the span and the signal-to-noise ratio (SNR) characteristics of the medium as described in Clause 61 through Clause 63. 2BASE-TL supports a nominal bit rate of 2 Mb/s at a nominal reach of 2700 meters.[1] 10PASS-TS supports a nominal bit rate of 10 Mb/s at a nominal reach of 750 meters.[2]

56.1.2 Summary of P2MP sublayers

For P2MP optical fiber topologies, EFM supports two systems:

a) PON with a nominal bit rate of 1000 Mb/s in both downstream and upstream directions (1G-EPON), shared amongst the population of Optical Network Units (ONUs) attached to the P2MP topology. The P2MP PHYs use the 1000BASE-PX Physical Coding Sublayer (PCS), the Physical Medium Attachment (PMA) sublayer defined in Clause 65 and an optional forward error correction (FEC) function defined in Clause 65.

b) PON with a nominal bit rate of 10 Gb/s in both the downstream and upstream directions (10/10G-EPON) as well as PON with a nominal bit rate of 10 Gb/s in the downstream direction and 1 Gb/s in the upstream direction (10/1G-EPON), shared amongst the population of ONUs attached to the P2MP topology. The P2MP PHYs for the 10/10G-EPON use the 10GBASE-PR PCS and PMA (see Clause 75). The P2MP PHYs for 10/1G-EPON use the 10GBASE-PRX PCS and PMA (see Clause 76). EPONs using a nominal 10 Gb/s bit rate use a mandatory FEC function defined in Clause 76 in any direction running at the 10 Gb/s bit rate.

56.1.2.1 Multipoint MAC Control Protocol (MPCP)

The Multipoint MAC Control Protocol (MPCP) for 1G-EPON uses messages, state diagrams, and timers, as defined in Clause 64, to control access to a P2MP topology, while Clause 77 defines the messages, state diagrams, and timers required to control access to a P2MP topology in 10G-EPON. The issues related to coexistence of 1G-EPON and 10G-EPON on the same fiber plant are described in 77.4.

Every P2MP topology consists of one Optical Line Terminal (OLT) plus one or more ONUs, as shown in Figure 56–2, Figure 56–3, and Figure 56–4, for 1G-EPON, 10/10G-EPON and 10/1G-EPON, respectively. One of several instances of the MPCP in the OLT communicates with the instance of the MPCP in the ONU. A pair of MPCPs that communicate between the OLT and ONU are a distinct and associated pair.

[1]Refer to Annex 63B for a more detailed discussion of bit rates and reach.
[2]Refer to Annex 62B for a more detailed discussion of bit rates and reach.

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56.1.2.2 Reconciliation Sublayer (RS) and media independent interfaces

The Clause 22 RS and MII, Clause 35 RS and GMII, and Clause 46 RS and XGMII are all employed for the same purpose in EFM, that being the interconnection between the MAC sublayer and the PHY sublayers. Extensions to the Clause 35 RS for P2MP topologies are described in Clause 65, while the RS for 10G-EPON P2MP topologies is described in Clause 76.

The combination of MPCP and the extension of the Reconciliation Sublayer (RS) for P2P Emulation allows an underlying P2MP network to appear as a collection of point-to-point links to the higher protocol layers (at and above the MAC Client).

The MPCP achieves this by providing a Logical Link Identification (LLID) in each packet by replacing two octets of the preamble.

This is described in Clause 65 for EPON and in Clause 76 for 10G-EPON. EFM Copper links use the MII of Clause 22 operating at 100 Mb/s. This is described in 61.1.4.1.2.

56.1.3 Physical Layer signaling systems

EFM extends the family of 100BASE-X Physical Layer signaling systems to include 100BASE-LX10 (long wavelength), plus the combination of the 100BASE-BX10-D (Bidirectional long wavelength Downstream) and the 100BASE-BX10-U (Bidirectional long wavelength Upstream), as defined in Clause 58. All of these systems employ the 100BASE-X PCS and PMA as defined in Clause 66.

EFM also extends the family of 1000BASE-X Physical Layer signaling systems to include 1000BASE-LX10 (long wavelength), plus the combination of the 1000BASE-BX10-D (Bidirectional long wavelength Downstream) and the 1000BASE-BX10-U (Bidirectional long wavelength Upstream), as defined in Clause 59. All of these systems employ the 1000BASE-X PCS and PMA as defined in Clause 66. 1000BASE-LX10 is interoperable with 1000BASE-LX on single-mode and multimode fiber, and offers greater reach than 1000BASE-LX on single-mode fiber.

For P2MP topologies, EFM introduces a family of Physical Layer signaling systems that are derived from 1000BASE-X, but which include extensions to the RS, PCS and PMA, along with an optional forward error correction (FEC) capability, as defined in Clause 65. The family of P2MP Physical Layer signaling systems includes the combination of 1000BASE-PX10-D (Passive Optical Network Downstream 10 km), plus 1000BASE-PX10-U (PON Upstream 10 km), the combination of 1000BASE-PX20-D (PON Downstream 20 km) plus 1000BASE-PX20-U (PON Upstream 20 km), the combination of 1000BASE-PX30-D (PON Downstream 20 km) plus 1000BASE-PX30-U (PON Upstream 20 km), and the combination of 1000BASE-PX40-D (PON Downstream 20 km) plus 1000BASE-PX40-U (PON Upstream 20 km), as defined in Clause 60.

Additionally, EFM introduces a family of Physical Layer signaling systems which are derived from 10GBASE-R, but which include RS, PCS and PMA sublayers adapted for 10G-EPON, along with a mandatory FEC capability, as defined in Clause 76. All of these systems employ the PMD defined in Clause 75. The family of P2MP Physical Layer signaling systems utilizes 10GBASE-R signaling for the downstream direction while supporting both 10GBASE-R and 1000BASE-X upstream signaling in the following series of PMD combinations:

a) 10GBASE–PR–D1 and 10GBASE–PR–U1, creating a PR10 power budget, with 10 Gb/s downstream and 10 Gb/s upstream data rates, supporting a reach of at least 10 km and a split ratio of at least 1:16.
b) 10GBASE–PR–D2 and 10GBASE–PR–U1, creating a PR20 power budget, with 10 Gb/s downstream and 10 Gb/s upstream data rates, supporting a reach of at least 20 km and a split ratio of at least 1:16 or the reach of at least 10 km and the split ratio of at least 1:32.

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c) 10GBASE–PR–D3 and 10GBASE–PR–U3, creating a PR30 power budget, with 10 Gb/s downstream and 10 Gb/s upstream data rates, supporting a reach of at least 20 km and a split ratio of at least 1:32.
d) 10GBASE–PR–D4 and 10GBASE–PR–U4, creating a PR40 power budget, with 10 Gb/s downstream and 10 Gb/s upstream data rates, supporting a reach of at least 20 km and a split ratio of at least 1:64.
e) 10/1GBASE–PRX–D1 and 10/1GBASE–PRX–U1, creating a PRX10 power budget, with 10 Gb/s downstream and 1 Gb/s upstream data rates, supporting a reach of at least 10 km and a split ratio of at least 1:16.
f) 10/1GBASE–PRX–D2 and 10/1GBASE–PRX–U2, creating a PRX20 power budget, with 10 Gb/s downstream and 1 Gb/s upstream data rates, supporting a reach of at least 20 km and a split ratio of at least 1:16.
g) 10/1GBASE–PRX–D3 and 10/1GBASE–PRX–U3, creating a PRX30 power budget, with 10 Gb/s downstream and 1 Gb/s upstream data rates, supporting a reach of at least 20 km and a split ratio of at least 1:32.
h) 10/1GBASE–PRX–D4 and 10/1GBASE–PRX–U4, creating a PRX40 power budget, with 10 Gb/s downstream and 1 Gb/s upstream data rates, supporting a reach of at least 20 km and a split ratio of at least 1:64.

All 10G-EPON PMDs are defined in Clause 75.

For copper cabling, EFM introduces a family of Physical Layer signaling systems. There are two distinct signaling systems specified for copper cabling. Both of them share a set of common functions and interfaces as described in Clause 61. Clause 61 also includes an optional specification that supports combined operation on multiple copper pairs, affording greater data rate capability for a given link span. Underlying these functions, two Physical Layer signaling system specific PMAs and PMDs are described in Clause 62 and Clause 63. Non-loaded cable is a requirement of the signaling methods employed.

For high-speed applications, the 10PASS-TS signaling system is defined in Clause 62. 10PASS-TS relies on a technique referred to as Frequency Division Duplexing (FDD) to accomplish full duplex communication on a single wire pair. 10PASS-TS is a passband signaling system derived from the Very high-speed Digital Subscriber Line (VDSL) standard defined in American National Standard T1.424, using Multiple Carrier Modulation (MCM, also referred to as Discrete Multi-Tone or DMT). This PHY supports a nominal full duplex data rate of 10 Mb/s, hence the identifier 10PASS-TS. For the 10PASS-TS PHY, two subtypes are defined: 10PASS-TS-O and 10PASS-TS-R. A connection can be established only between a 10PASS-TS-O PHY on one end of the voice-grade copper line, and a 10PASS-TS-R PHY on the other end. In public networks, a 10PASS-TS-O PHY is used at a central office (CO), a cabinet, or other centralized distribution point; a 10PASS-TS-R PHY is used at the subscriber premises. In private networks, the network administrator will designate one end of each link as the network end. A PHY implementation may be equipped to support both subtypes and provide means to be configured as a 10PASS-TS-O or a 10PASS-TS-R.

For long distance applications, the 2BASE-TL signaling system is defined in Clause 63. 2BASE-TL is a baseband signaling system derived from the Single-Pair High-Speed Digital Subscriber Line (SHDSL) standards defined by ITU-T. The 2BASE-TL PMD supports a nominal full duplex data rate of approximately 2 Mb/s. As is the case with the 10PASS-TS PHY, the 2BASE-TL PHY consists of two subtypes: 2BASE-TL-O (network end) and 2BASE-TL-R (subscriber end).

System considerations for Ethernet subscriber access networks are described in Clause 67.

Specifications unique to the operation of each Physical Layer device are shown in Table 56–1.

Table 56–2 specifies the correlation between nomenclature and clauses for P2P systems, while Table 56–3 specifies the correlation between nomenclature and clauses for P2MP systems. A complete implementation conforming to one or more nomenclatures meets the requirements of the corresponding clauses.

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Table 56–1—Summary of EFM Physical Layer signaling systems

Name	Location	Rate[a]	Nominal reach (km)	Medium	Clause
100BASE-LX10	ONU/OLT[b]	100 Mb/s	10	Two single-mode fibers	58
100BASE-BX10-D	OLT	100 Mb/s	10	One single-mode fiber	58
100BASE-BX10-U	ONU				
1000BASE-LX10	ONU/OLT[b]	1000 Mb/s	10 0.55	Two single-mode fibers Two multimode fibers	59
1000BASE-BX10-D	OLT	1000 Mb/s	10	One single-mode fiber	59
1000BASE-BX10-U	ONU				
1000BASE-PX10-D	OLT	1000 Mb/s	10	One single-mode fiber PON	60
1000BASE-PX10-U	ONU				
1000BASE-PX20-D	OLT	1000 Mb/s	20	One single-mode fiber PON	60
1000BASE-PX20-U	ONU				
1000BASE-PX30-D	OLT	1000 Mb/s	20	One single-mode fiber PON	60
1000BASE-PX30-U	ONU				
1000BASE-PX40-D	OLT	1000 Mb/s	20	One single-mode fiber PON	60
1000BASE-PX40-U	ONU				
10/1GBASE-PRX-D1	OLT	10 Gb/s (tx) 1000 Mb/s (rx)	10	One single-mode fiber PON	75
10/1GBASE-PRX-U1	ONU	1000 Mb/s (tx) 10 Gb/s (rx)			
10/1GBASE-PRX-D2	OLT	10 Gb/s (tx) 1000 Mb/s (rx)	20	One single-mode fiber PON	75
10/1GBASE-PRX-U2	ONU	1000 Mb/s (tx) 10 Gb/s (rx)			
10/1GBASE-PRX-D3	OLT	10 Gb/s (tx) 1000 Mb/s (rx)	20	One single-mode fiber PON	75
10/1GBASE-PRX-U3	ONU	1000 Mb/s (tx) 10 Gb/s (rx)			
10/1GBASE-PRX-D4	OLT	10 Gb/s (tx) 1000 Mb/s (rx)	20	One single-mode fiber PON	75
10/1GBASE-PRX-U4	ONU	1000 Mb/s (tx) 10 Gb/s (rx)			
10GBASE-PR-D1	OLT	10 Gb/s	10	One single-mode fiber PON	75
10GBASE-PR-U1	ONU				
10GBASE-PR-D2	OLT	10 Gb/s	20	One single-mode fiber PON	75
10GBASE-PR-U1	ONU				

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Table 56–1—Summary of EFM Physical Layer signaling systems *(continued)*

Name	Location	Rate[a]	Nominal reach (km)	Medium	Clause
10GBASE-PR-D3	OLT	10 Gb/s	20	One single-mode fiber PON	75
10GBASE-PR-U3	ONU				
10GBASE-PR-D4	OLT	10 Gb/s	20	One single-mode fiber PON	75
10GBASE-PR-U4	ONU				
10PASS-TS-O	CO[c]	10 Mb/s[d]	0.75[e]	One or more pairs of voice grade copper cable	62
10PASS-TS-R	Subscriber[c]				
2BASE-TL-O	CO[c]	2 Mb/s[f]	2.7[g]	One or more pairs of voice grade copper cable	63
2BASE-TL-R	Subscriber[c]				

[a]For 10/1G-EPON Physical Layer signaling systems transmit rate is denoted with the abbreviation "(tx)" to the location whereas the receive rate is denoted with the abbreviation "(rx)".
[b]Symmetric
[c]In private networks, the network administrator designates one end of each link as the network end.
[d]Nominal rate stated at the nominal reach. Rate may vary depending on plant. Refer to Annex 62B for more information.
[e]Reach may vary depending on plant. Refer to Annex 62B for further information.
[f]Nominal rate stated at the nominal reach. Rate may vary depending on plant. Refer to Annex 63B for more information.
[g]Reach may vary depending on plant. Refer to Annex 63B for further information.

Table 56–2—Nomenclature and clause correlation for P2P systems

Nomenclature	Clause									
	57	58		59		61	62	63	66	
	OAM	100BASE-LX10 PMD	100BASE-BX10 PMD	1000BASE-LX10 PMD	1000BASE-BX10 PMD	Cu PCS	10PASS-TS PMA & PMD	2BASE-TL PMA & PMD	100BASE-X PCS, PMA	1000BASE-X PCS, PMA
2BASE-TL	O[a]					M		M		
10PASS-TS	O					M	M			
100BASE-LX10	O	M							M	
100BASE-BX10	O		M						M	
1000BASE-LX10	O			M						M
1000BASE-BX10	O				M					M

[a]O = Optional, M = Mandatory

56.1.4 Management

Managed objects, attributes, and actions are defined for all EFM components in Clause 30.

In addition to the management objects, attributes, and actions defined in Clause 30, EFM introduces Operations, Administration, and Maintenance (OAM) for subscriber access networks to Ethernet. OAM, as defined in Clause 57, includes a mechanism for communicating management information using OAM

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Table 56–3—Nomenclature and clause correlation for P2MP systems[a]

Nomenclature	Clause											
	57	60				64	65		66	75	76	77
	OAM	1000BASE-PX10 PMD	1000BASE-PX20 PMD	1000BASE-PX30 PMD	1000BASE-PX40 PMD	P2MP MPMC	P2MP RS, PCS, PMA	FEC	1000BASE-X PCS, PMA	10/1GBASE–PRX or 10GBASE-PR PMDs	P2MP RS, PCS, PMA, FEC	10G-EPON P2MP MPMC
1000BASE-PX10-D	O	M				M	M	O	M			
1000BASE-PX10-U	O	M				M	M	O				
1000BASE-PX20-D	O		M			M	M	O	M			
1000BASE-PX20-U	O		M			M	M	O				
1000BASE-PX30-D	O			M		M	M	O	M			
1000BASE-PX30-U	O			M		M	M	O				
1000BASE-PX40-D	O				M	M	M	O	M			
1000BASE-PX40-U	O				M	M	M	O				
10/1GBASE-PRX-D1	O			M		M				M	M	M
10/1GBASE-PRX-U1	O			M		M				M	M	M
10/1GBASE-PRX-D2	O				M	M				M	M	M
10/1GBASE-PRX-U2	O				M	M				M	M	M
10/1GBASE-PRX-D3	O					M				M	M	M
10/1GBASE-PRX-U3	O					M				M	M	M
10/1GBASE-PRX-D4	O					M				M	M	M
10/1GBASE-PRX-U4	O					M				M	M	M
10GBASE-PR-D1	O									M	M	M
10GBASE-PR-U1	O									M	M	M
10GBASE-PR-D2	O									M	M	M
10GBASE-PR-D3	O									M	M	M
10GBASE-PR-U3	O									M	M	M
10GBASE-PR-D4	O									M	M	M
10GBASE-PR-U4	O									M	M	M

[a]O = Optional, M = Mandatory

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frames, as well as functions for performing low-level diagnostics on a per link basis in an Ethernet subscriber access network.

56.1.5 Unidirectional transmission

In contrast to previous editions of IEEE Std 802.3, in certain circumstances a DTE is allowed to transmit frames while not receiving a satisfactory signal. It is necessary for a 1000BASE-PX-D OLT to do this to

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bring a PON into operation (although it is highly inadvisable for a 1000BASE-PX-U ONU to transmit without receiving). Clause 66 describes optional modifications to the 100BASE-X PHY, 1000BASE-X PHY and 10GBASE RS so that a DTE may signal remote fault using OAMPDUs. When unidirectional operation is not enabled, the sublayers in Clause 66 are precisely the same as their equivalents in Clause 24, Clause 36, and Clause 46.

56.2 State diagrams

State diagrams take precedence over text.

The conventions of 1.2 are adopted, along with the extensions listed in 21.5.

56.3 Protocol implementation conformance statement (PICS) proforma

The supplier of a protocol implementation that is claimed to conform to any part of IEEE 802.3, Clause 57 through Clause 66, demonstrates compliance by completing a protocol implementation conformance statement (PICS) proforma.

A completed PICS proforma is the PICS for the implementation in question. The PICS is a statement of which capabilities and options of the protocol have been implemented. A PICS is included at the end of each clause as appropriate. Each of the EFM PICS conforms to the same notation and conventions used in 100BASE-T (see 21.6).

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57. Operations, Administration, and Maintenance (OAM)

57.1 Overview

57.1.1 Scope

This clause defines the Operations, Administration, and Maintenance (OAM) sublayer, which provides mechanisms useful for monitoring link operation such as remote fault indication and remote loopback control. In general, OAM provides network operators the ability to monitor the health of the network and quickly determine the location of failing links or fault conditions. The OAM described in this clause provides data link layer mechanisms that complement applications that may reside in higher layers.

OAM information is conveyed in Slow Protocol frames (see Annex 57A) called OAM Protocol Data Units (OAMPDUs). OAMPDUs contain the appropriate control and status information used to monitor, test and troubleshoot OAM-enabled links. OAMPDUs traverse a single link, being passed between peer OAM entities, and as such, are not forwarded by MAC clients (e.g., bridges or switches).

OAM does not include functions such as station management, bandwidth allocation, or provisioning functions, which are considered outside the scope of this standard.

For the remainder of this clause, the term OAM is specific to the link level OAM described here.

57.1.2 Summary of objectives and major concepts

This subclause provides details and functional requirements for the OAM objectives:

a) Remote Failure Indication
   1) A mechanism is provided to indicate to a peer that the receive path of the local DTE is non-operational.
   2) Physical Layer devices using Clause 66 may support unidirectional operation that allows OAM remote failure indication during fault conditions.
   3) Subscriber access Physical Layer devices using Clause 65 support unidirectional operation in the direction from OLT to ONU that allows OAM remote failure indication from OLT during fault conditions.
   4) Physical Layer devices other than those listed above do not support unidirectional operation allowing OAM remote failure indication during fault conditions. Some Physical Layer devices have specific remote failure signaling mechanisms in the Physical Layer.

b) Remote Loopback—A mechanism is provided to support a data link layer frame-level loopback mode.

c) Link Monitoring
   1) A mechanism is provided to support event notification that permits the inclusion of diagnostic information.
   2) A mechanism is provided to support polling of any variable in the Clause 30 MIB.

d) Miscellaneous
   1) Implementation and activation of OAM is optional.
   2) A mechanism is provided that performs OAM capability discovery.
   3) An extension mechanism is provided and made available for higher layer management applications.

These objectives support a subset of the user-plane OAM requirements found in ITU-T Y.1730 [B51].

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57.1.3 Summary of non-objectives

This subclause explicitly lists certain functions that are not addressed by OAM. These functions, while valuable, do not fall within the scope of this standard.

a) Management functions not pertaining to a single link such as protection switching and station management are not covered by this clause. Such functions could be addressed using the extension mechanism.
b) Provisioning and negotiation functions such as bandwidth allocation, rate adaptation and speed/duplex negotiation are not supported by OAM.
c) Issues related to privacy of OAM data and authentication of OAM entities are beyond the scope of this standard.
d) The ability to set/write remote MIB variables is not supported.

57.1.4 Positioning of OAM within the IEEE 802.3 architecture

OAM comprises an optional sublayer between a superior sublayer (e.g., MAC client or optional Link Aggregation) and a subordinate sublayer (e.g., MAC or optional MAC Control sublayer). Figure 57–1 shows the relationship of the OAM sublayer to the ISO/IEC (IEEE) OSI reference model.

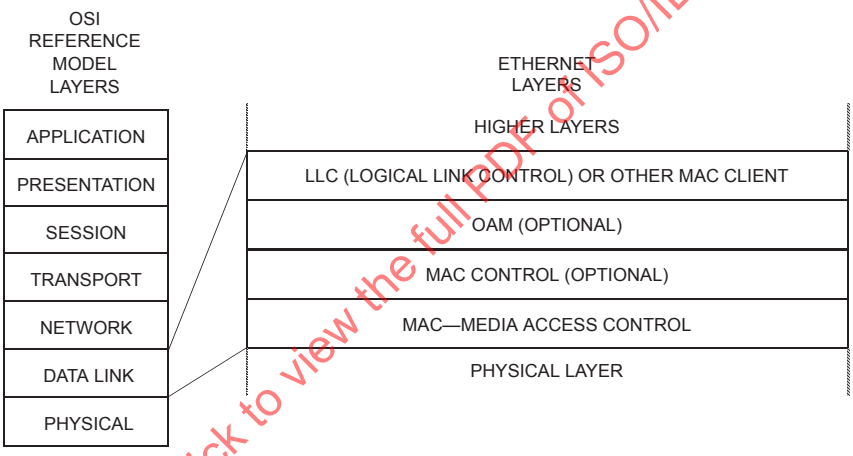

Figure 57–1—OAM sublayer relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

57.1.5 Compatibility considerations

57.1.5.1 Application

OAM is intended for point-to-point and emulated point-to-point IEEE 802.3 links. Implementation of OAM functionality is optional. A conformant implementation may implement the optional OAM sublayer for some ports within a system while not implementing it for other ports.

57.1.5.2 Interoperability between OAM capable DTEs

A DTE is able to determine whether or not a remote DTE has OAM functionality enabled. The OAM Discovery mechanism ascertains the configured parameters, such as maximum allowable OAMPDU size, and supported functions, such as OAM remote loopback, on a given link.

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57.1.5.3 MAC Control PAUSE

MAC Control PAUSE, commonly referred to as Flow Control as defined in Annex 31B, inhibits the transmission of all MA_DATA.request service primitives, including OAMPDUs. This may delay or prevent the signaling of critical events such as unrecoverable failure conditions and link faults.

57.1.5.4 Interface to MAC Control client

MAC Control clients that generate MA_CONTROL.request service primitives (and which expect MA_CONTROL.indication service primitives in response) are not acted upon by the OAM sublayer. They communicate directly with the MAC Control entity as though no OAM sublayer exists.

57.1.5.5 Frame loss during OAM remote loopback

Invocations of OAM remote loopback may result in frame loss. OAM remote loopback is an intrusive operation that prevents a link from passing frames between the MAC client of the local DTE and the MAC client of the remote DTE. Refer to 57.2.11 for a complete description of OAM remote loopback operation.

57.1.6 State diagram conventions

Many of the functions specified in this clause are presented in state diagram notation. All state diagrams contained in this clause use the notation and conventions defined in 21.5. In the event of a discrepancy between the text description and the state diagram formalization of a function, the state diagrams take precedence.

57.2 Functional specifications

57.2.1 Interlayer service interfaces

Figure 57–2 depicts the usage of interlayer interfaces by the OAM sublayer.

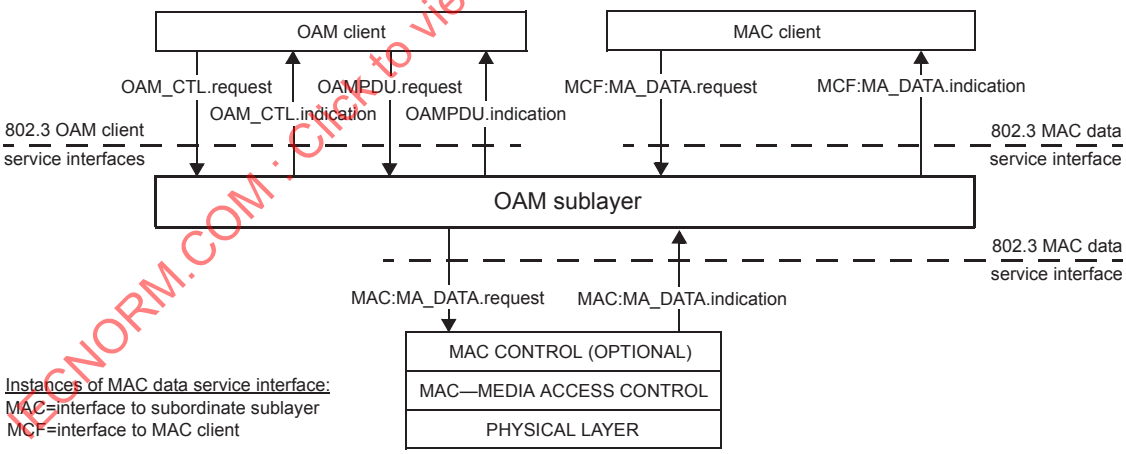

Figure 57–2—OAM sublayer support of interlayer service interfaces

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57.2.2 Principles of operation

OAM employs the following principles and concepts:

a) The OAM sublayer presents a standard IEEE 802.3 MAC service interface to the superior sublayer. Superior sublayers include MAC client and Link Aggregation.
b) The OAM sublayer employs a standard IEEE 802.3 MAC service interface to the subordinate sublayer. Subordinate sublayers include MAC and MAC Control.
c) Frames from superior sublayers are multiplexed within the OAM sublayer with OAMPDUs.
d) The OAM sublayer parses received frames and passes OAMPDUs to the OAM client. In general, non-OAMPDUs are passed to the superior sublayer. When in OAM remote loopback mode, non-OAMPDUs are looped back to the subordinate sublayer. When the peer OAM entity is in OAM remote loopback mode, non-OAMPDUs are discarded by the OAM sublayer so that higher layer functions (e.g., bridging) do not process the looped back frames.
e) Knowledge of the underlying Physical Layer device is not required by the OAM sublayer.
f) OAMPDUs traverse a single link and are passed between OAM client entities or OAM sublayer entities. OAMPDUs are not forwarded by OAM clients.
g) OAM is extensible through the use of an Organization Specific OAMPDU, Organization Specific Information TLV, and Organization Specific Event TLV. These can be used for functions outside the scope of this standard.

57.2.3 Instances of the MAC data service interface

A superior sublayer such as the MAC client communicates with the OAM sublayer using the standard MAC data service interface specified in Clause 2. Similarly, the OAM sublayer communicates with a subordinate sublayer such as the MAC Control or MAC using the same standard service interfaces.

Since this clause uses two instances of the MAC data service interface, it is necessary to introduce a notation convention so that the reader can be clear as to which interface is being referred to at any given time. A prefix is therefore assigned to each service primitive, indicating which of the two interfaces is being invoked, as depicted in Figure 57–2. The prefixes are as follows:

a) MCF:, for primitives issued on the interface between the superior sublayer and the OAM sublayer (MCF is an abbreviation for MAC client frame)
b) MAC:, for primitives issued on the interface between the underlying subordinate sublayer (e.g., MAC) and the OAM sublayer

57.2.4 Responsibilities of OAM client

The OAM client plays an integral role in establishing and managing OAM on a link. The OAM client enables and configures the OAM sublayer entity. During the OAM Discovery process (see 57.3.2.1), the OAM client monitors received OAMPDUs from the remote DTE and based upon local and remote state and configuration settings allows OAM functionality to be enabled on the link.

After OAM has been established, the OAM client is responsible for adhering to the OAMPDU response rules. For example, the OAM client does not respond to illegal requests such as Variable Request and Loopback Control OAMPDUs from Passive DTEs. The OAM client is also expected to manage the OAM remote loopback mode (see 57.2.11). It does so by reacting to particular OAMPDUs and altering local configuration parameters.

Link events are signalled between peer OAM client entities. The OAM client transfers events by sending and receiving particular OAMPDUs. To increase the likelihood that a specific event is received by the remote DTE, the OAM client may send the event multiple times.

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57.2.5 OAM client interactions

The OAM sublayer entity communicates with the OAM client using the following new interlayer service interfaces:

OAMPDU.request
OAMPDU.indication
OAM_CTL.request
OAM_CTL.indication

The OAMPDU.request, OAMPDU.indication, OAM_CTL.request and OAM_CTL.indication service primitives described in this subclause are mandatory.

57.2.5.1 OAMPDU.request

57.2.5.1.1 Function

This primitive defines the transfer of data from an OAM client entity to a peer OAM client entity.

57.2.5.1.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
OAMPDU.request      (
                    source_address,
                        flags,
                        code,
                        data
                        )
```

The source_address parameter specifies an individual MAC address. The flags parameter is used to create the Flags field within the OAMPDU to be transmitted. Only the indications corresponding to the Flags field bits 15:3 are contained in the flags parameter since the indications corresponding to Flags field bits 2:0 are contained in the OAM_CTL.request service primitive. The code parameter is used to create the Code field within the OAMPDU to be transmitted. The data parameter is used to create the Data field within the OAMPDU to be transmitted.

57.2.5.1.3 When generated

This primitive is generated by the OAM client entity whenever an OAMPDU is to be transferred to a peer entity. This can be in response to a request from the peer entity or from data generated internally to the OAM client.

57.2.5.1.4 Effect of receipt

The receipt of this primitive will cause the OAM sublayer entity to insert all OAMPDU specific fields, including DA, SA, Length/Type and Subtype, and pass the properly formed OAMPDU to the lower protocol layers for transfer to the peer OAM client entity according to the transmit rules as described in 57.3.2.2.6.

57.2.5.2 OAMPDU.indication

57.2.5.2.1 Function

This primitive defines the transfer of data from an OAM sublayer entity to an OAM client entity.

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57.2.5.2.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
OAMPDU.indication    (
                         source_address,
                         flags,
                         code,
                         data
                         )
```

The source_address parameter is the MAC source address of the incoming OAMPDU. The flags parameter is the entire Flags field of the incoming OAMPDU. The code parameter is the Code field of the incoming OAMPDU. The data parameter is the Data field of the incoming OAMPDU.

57.2.5.2.3 When generated

This primitive is passed from the OAM sublayer entity to the OAM client entity to indicate the arrival of an OAMPDU to the local OAM sublayer entity that is destined for the OAM client. Such OAMPDUs are reported only if they are validly formed and received without error.

57.2.5.2.4 Effect of receipt

The effect of receipt of this primitive by the OAM client is unspecified.

57.2.5.3 OAM_CTL.request

57.2.5.3.1 Function

This primitive defines the transfer of control information from an OAM client entity to an OAM sublayer entity.

57.2.5.3.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
OAM_CTL.request      (
                         local_unidirectional,
                         local_link_status,
                         local_dying_gasp,
                         local_critical_event,
                         local_satisfied,
                         remote_state_valid,
                         remote_stable,
                         local_mux_action,
                         local_par_action,
                         information_data
                              )
```

When set, the local_unidirectional parameter is used to indicate the sending station supports transmission of OAMPDUs on unidirectional links as supported by some physical coding layers (see 57.2.12).

The local_link_status, local_dying_gasp, and local_critical_event parameters are used to indicate immediate event situations that should be transmitted to the peer OAM entity. The local_link_status parameter is used

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to convey the status of the link as determined by the underlying Physical Layer. When set to FAIL, the local_link_status parameter will cause the OAM sublayer entity to transmit an Information OAMPDU with the Link Fault bit of the Flags field set and no Information TLVs. The local_dying_gasp parameter is used to signal a local unrecoverable failure condition. When set, the local_dying_gasp parameter will cause the OAM sublayer to transmit an Information OAMPDU with the Dying Gasp bit of the Flags field set. The local_critical_event parameter is used to signal an unspecified critical link event condition. When set, the local_critical_event parameter will cause the OAM sublayer to transmit an Information OAMPDU with the Critical Event bit of the Flags field set.

The local_satisfied, remote_state_valid, and remote_stable parameters are used in the Discovery process. The local_satisfied parameter is set by the OAM client as a result of comparing its local configuration and the remote configuration found in the received Local Information TLV (see 57.3.2.1).

The local_mux_action and local_par_action parameters are used to control the state of the Multiplexer and Parser functions of the OAM sublayer (see 57.3.3 and 57.3.4).

The information_data parameter contains the Local Information TLV fields, and, if available, the Remote Information and Organization Specific Information TLV fields, to be included in Information OAMPDUs generated by the Transmit process (see 57.3.2.2).

57.2.5.3.3 When generated

This primitive is passed from the OAM client entity to the OAM sublayer to update control information.

57.2.5.3.4 Effect of receipt

The receipt of this primitive will cause the OAM sublayer to generate Information OAMPDUs or update specific fields of future Information OAMPDUs. Also, OAM functions will be re-evaluated based upon any changing control information.

57.2.5.4 OAM_CTL.indication

57.2.5.4.1 Function

This primitive defines the transfer of control information from an OAM sublayer entity to an OAM client entity.

57.2.5.4.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
OAM_CTL.indication      (
                        local_pdu,
                        local_stable,
                        local_lost_link_timer_done
                            )
```

The local_pdu and local_stable parameters are used by the OAM sublayer to indicate to the OAM client state information in the Discovery process (see 57.3.2.1). The local_lost_link_timer_done parameter is used to convey the expiration of the local_lost_link_timer.

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57.2.5.4.3 When generated

This primitive is passed from the OAM sublayer entity to the OAM client entity to indicate local state information has changed.

57.2.5.4.4 Effect of receipt

The effect of receipt of this primitive by the OAM client is unspecified.

57.2.6 Instances of the OAM internal service interface

The OAM sublayer communicates internally using the OAM internal service interface. Since two instances of the OAM internal service interface are used, it is necessary to introduce a notation convention so that the reader can be clear as to which interface is being referred to at any given time. A prefix is therefore assigned to each service primitive, indicating which of the two interfaces is being invoked (see Figure 57–3). The prefixes are as follows:

a) LBF:, for primitives issued on the interface between the Parser and the Multiplexer (LBF is an abbreviation for loopback frame).
b) CTL:, for primitives issued on the interface between the Control and other OAM functions (CTL is an abbreviation for Control function).

57.2.7 Internal block diagram

Figure 57–3 depicts the major blocks within the OAM sublayer and their interrelationships.

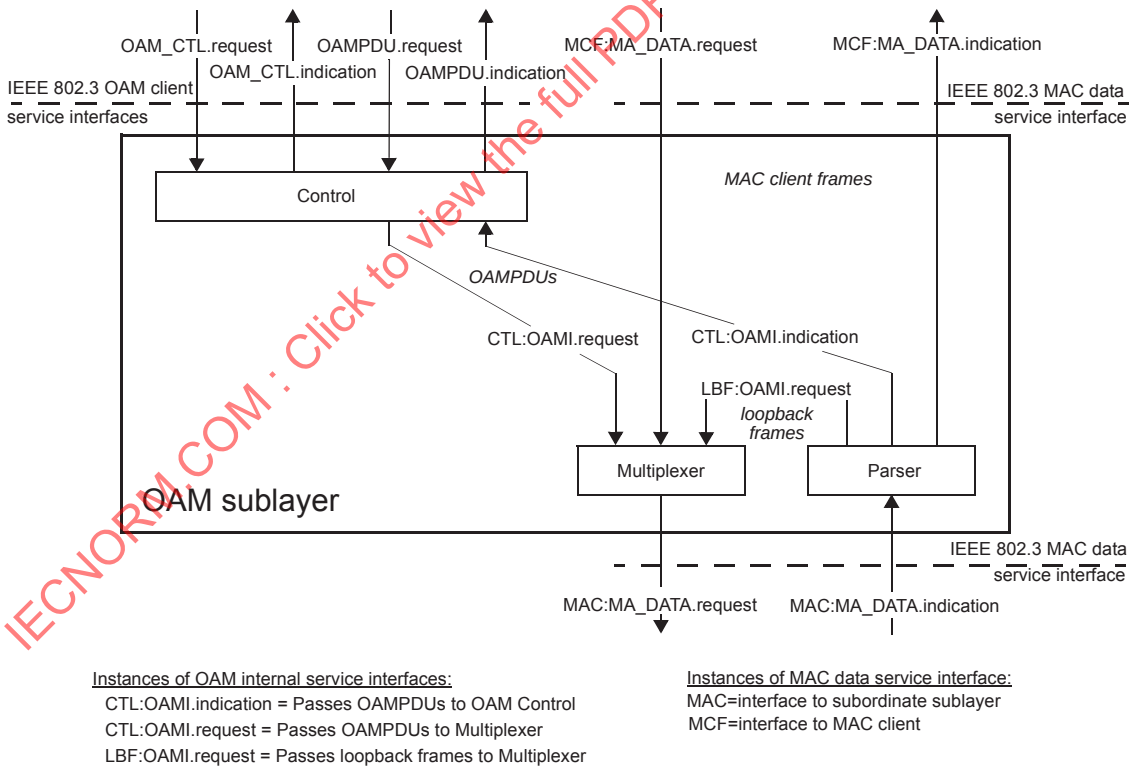

Figure 57–3—OAM sublayer block diagram

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57.2.8 OAM internal interactions

The OAM sublayer entity employs the following new internal service interfaces:
OAMI.request
OAMI.indication

The OAMI.request and OAMI.indication service primitives described in this subclause are mandatory.

57.2.8.1 OAMI.request

57.2.8.1.1 Function

This primitive defines the transfer of frames to the Multiplexer function internal to the OAM sublayer.

57.2.8.1.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
OAMI.request        (
                    destination_address,
                    source_address,
                    oam_service_data_unit,
                        frame_check_sequence
                        )
```

The destination_address parameter specifies the Slow Protocols Multicast Address. The source_address parameter must specify an individual MAC address. The oam_service_data_unit parameter specifies the OAM service data unit to be transmitted within the OAM sublayer entity. This parameter includes the Length/Type, Subtype, Flags, Code and Data/Pad fields. There is sufficient information associated with the oam_service_data_unit for the OAM sublayer entity to determine the length of the data unit. The frame_check_sequence parameter, if present, must specify the frame check sequence field for the frame (see 3.2.9).

57.2.8.1.3 When generated

This primitive is generated by the Parser function whenever a frame is intended to be looped back to the remote DTE via the Multiplexer function. This primitive is also generated by the Control function whenever an OAMPDU is to be conveyed to the peer OAM entity via the Multiplexer function, internal to the OAM sublayer.

57.2.8.1.4 Effect of receipt

The receipt of this primitive will cause the Multiplexer function to pass the properly formed frame, subject to Figure 57–7, to the subordinate sublayer via the MAC data service interface (see 57.2.3).

57.2.8.2 OAMI.indication

57.2.8.2.1 Function

This primitive defines the transfer of frames to the Control function internal to the OAM sublayer.

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57.2.8.2.2 Semantics of the service primitive

The semantics of the primitive are as follows:

```
OAMI.indication        (
                           destination_address,
                           source_address,
                           oam_service_data_unit,
                           frame_check_sequence,
                           reception_status
                           )
```

The destination_address parameter is the Slow Protocols Multicast Address as specified by the DA field of the incoming frame. The source_address parameter is an individual address as specified by the SA field of the incoming frame. The oam_service_data_unit parameter specifies the OAM service data unit as received by the internal OAM function. The frame_check_sequence parameter, if present, is the cyclic redundancy check value (see 3.2.9) as specified by the FCS field of the incoming frame. The reception_status parameter is used to pass status information to the internal OAM function. Values for the reception_status parameter can be found in 4.3.2.

57.2.8.2.3 When generated

This primitive is generated whenever the Parser function intends to pass a received OAMPDU to the Control function, internal to the OAM sublayer. Frames are reported only if they are validly formed and received without error.

57.2.8.2.4 Effect of receipt

The receipt of this primitive will cause the Control function to update internal state variables and pass the OAMPDU to the OAM client via the OAMPDU_indication service primitive (see 57.2.5.2).

57.2.9 Modes

DTEs incorporating the OAM sublayer support Active and/or Passive mode. When OAM is enabled, a DTE capable of both Active and Passive modes shall select either Active or Passive. Table 57–1 contains the behavior of Active and Passive mode DTEs.

Table 57–1—Active and passive mode behavior

Capability	Active DTE	Passive DTE
Initiates OAM Discovery process	Yes	No
Reacts to OAM Discovery process initiation	Yes	Yes
Required to send Information OAMPDUs	Yes	Yes
Permitted to send Event Notification OAMPDUs	Yes	Yes
Permitted to send Variable Request OAMPDUs	Yes	No
Permitted to send Variable Response OAMPDUs	Yes[a]	Yes
Permitted to send Loopback Control OAMPDUs	Yes	No
Reacts to Loopback Control OAMPDUs	Yes[a]	Yes
Permitted to send Organization Specific OAMPDUs	Yes	Yes

[a]Requires the peer DTE to be in Active mode.

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57.2.9.1 Active mode

DTEs configured in Active mode initiate the exchange of Information OAMPDUs as defined by the Discovery state diagram (see Figure 57–5). Once the Discovery process completes, Active DTEs are permitted to send any OAMPDU while connected to a remote OAM peer entity in Active mode. Active DTEs operate in a limited respect if the remote OAM entity is operating in Passive mode (see Table 57–1). Active devices should not respond to OAM remote loopback commands and variable requests from a Passive peer.

57.2.9.2 Passive mode

DTEs configured in Passive mode do not initiate the Discovery process. Passive DTEs react to the initiation of the Discovery process by the remote DTE. This eliminates the possibility of passive to passive links. Passive DTEs shall not send Variable Request or Loopback Control OAMPDUs.

57.2.10 OAM events

OAM defines a set of events that may impact link operation. OAM contains mechanisms to communicate such events to the remote DTE. The following sections provide an overview of these events and mechanisms.

57.2.10.1 Critical link events

Table 57–2 lists the defined critical link events. Critical link events are carried within the Flags field of each OAMPDU. Refer to 57.4.2.1 for the definition and encoding of the Flags field.

Table 57–2—Critical link event

Critical link event	Description
Link fault	The PHY has determined a fault has occurred in the receive direction of the local DTE.
Dying gasp	An unrecoverable local failure condition has occurred.
Critical event	An unspecified critical event has occurred.

NOTE—The definition of the specific faults comprising the Critical Event, Dying Gasp, and Link Fault flags is implementation specific and beyond the scope of this standard.

57.2.10.2 Link events

Link events are signaled via Link Event TLVs that are defined in 57.5.3. Examples of link events include Errored Symbol Period Event and Errored Frame Event.

57.2.10.3 Local event procedure

Local events are communicated to the remote DTE via one of two mechanisms described as follows:

a) Critical link events, defined in 57.2.10.1, are communicated to the OAM sublayer via the OAM_CTL.request service primitive. The OAM sublayer shall respond to critical link events by setting or clearing the appropriate bits within the Flags field on any subsequently generated OAMPDUs of any type.
b) The OAM client sends an Event Notification OAMPDU (see 57.4.3.2) containing a Link Event TLV (see Table 57–12) for every event not yet signaled to the remote DTE. The OAM client uses the OAMPDU.request service primitive to send Event Notification OAMPDUs. The OAM client may send duplicate Event Notification OAMPDUs to increase the probability of reception at the remote DTE on deteriorating links.

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57.2.10.4 Remote event procedure

Remote events are detected by the local OAM client via one of two mechanisms described as follows:

a) Critical link events, defined in 57.2.10.1, shall be detected by the local OAM sublayer via the Flags field of any received OAMPDU. The OAM sublayer signals the Flags field to the OAM client using the OAMPDU.indication service primitive. When receiving Information OAMPDUs indicating Link Fault from the remote DTE, it is recommended that the local OAM client set the local_link_status parameter in the OAM_CTL.request service primitive to OK. This avoids the situation where both ends of a link are in a deadlock condition where neither DTE will be capable of receiving frames.

b) All other link events shall be detected by the local OAM sublayer via the reception of an Event Notification OAMPDU and the subsequent passing of the OAMPDU to the OAM client via the OAMPDU.indication service primitive. The OAM client discards any duplicate received Event Notification OAMPDU.

57.2.11 OAM remote loopback

OAM provides an optional data link layer frame-level loopback mode, which is controlled remotely. OAM remote loopback can be used for fault localization and link performance testing. Statistics from both the local and remote DTE can be queried and compared at any time while the remote DTE is in OAM remote loopback mode. These queries can take place before, during or after loopback frames have been sent to the remote DTE. In addition, an implementation may analyze loopback frames within the OAM sublayer to determine additional information about the health of the link (i.e., determine which frames are being dropped due to link errors). Figure 57–4 shows the path of frames traversing the layer stack of both the local and remote DTEs.

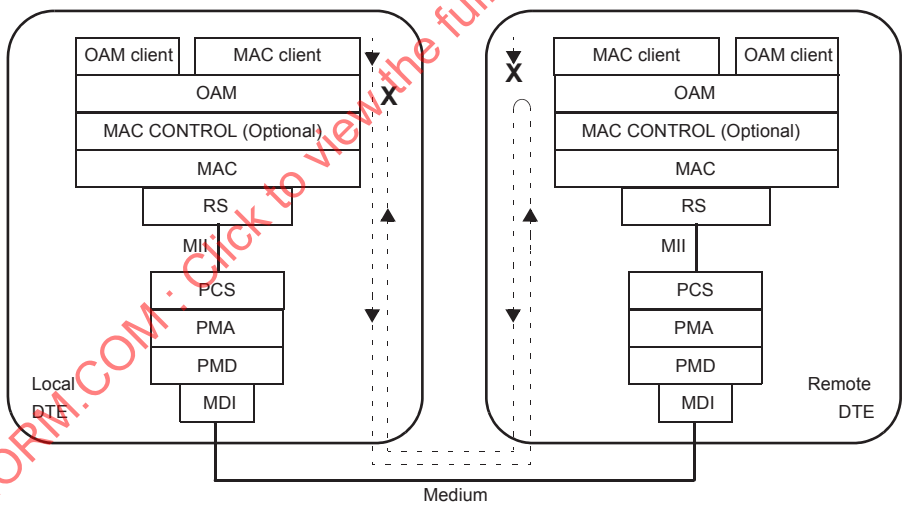

Figure 57–4—OAM remote loopback

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57.2.11.1 Initiating OAM remote loopback

To initiate OAM remote loopback, the local OAM client sets its local_mux_action parameter to DISCARD and the local_par_action parameter to DISCARD via the OAM_CTL.request service primitive. The local OAM client sends a Loopback Control OAMPDU (see 57.4.3.5) with the Enable OAM Remote Loopback command. After receiving the Loopback Control OAMPDU, the remote OAM client first sets its local_par_action parameter to LB and its local_mux_action parameter to DISCARD via the OAM_CTL.request service primitive, and then sends an Information OAMPDU with updated state

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information reflecting its local_par_action set to LB and its local_mux_action parameter set to DISCARD. On the reception of an Information OAMPDU from the remote OAM client with updated state information, the local OAM client sets the local_mux_action to FWD.

If an OAM client has sent a Loopback Control OAMPDU and is waiting for the peer DTE to respond with an Information OAMPDU that indicates it is in OAM remote loopback mode, and that OAM client receives an OAM remote loopback command from the peer device, the following procedures are recommended:

a) If the local DTE has a higher source_address than the peer, it should enter OAM remote loopback mode at the command of its peer.
b) If the local DTE has a lower source_address than the peer, it should ignore the OAM remote loopback command from its peer and continue as if it were never received.

If OAM clients do not follow these guidelines, it may be possible for two OAM clients to issue simultaneous OAM remote loopback commands with indeterminate results.

57.2.11.2 During OAM remote loopback

This section elaborates on Figure 57–4 and describes the flow of frames within the local and remote DTEs and across the link during OAM remote loopback mode. While in OAM remote loopback mode:

a) The local DTE transmits frames from the MAC client and OAMPDUs from the local OAM client or OAM sublayer.
b) Within the remote OAM sublayer entity, every non-OAMPDU, including other Slow Protocol frames, is looped back without altering any field of the frame.
c) OAMPDUs received by the remote DTE are passed to the remote OAM client.
d) Both DTEs are required to send OAMPDUs to the peer DTE in order to keep the Discovery process from re-starting. Both are also permitted to send other OAMPDUs to the peer DTE.
e) Frames received by the local DTE are parsed by the OAM sublayer. OAMPDUs are passed to the OAM client and all other frames are discarded.

57.2.11.3 Exiting OAM remote loopback

When the local DTE wishes to end the OAM remote loopback test, the local OAM client sets its local_mux_action parameter to DISCARD. The local OAM client then sends a Loopback Control OAMPDU with the Disable OAM Remote Loopback command. After receiving a Loopback Control OAMPDU with the Disable OAM Remote Loopback command, the remote OAM client first sets the local_par_action and local_mux_action parameters to FWD via the OAM_CTL.request service primitive and then sends an Information OAMPDU with updated state information reflecting the local_par_action and local_mux_action parameters set to FWD. After receiving an Information OAMPDU with local_par_action and local_mux_action set to FWD, the local OAM client sets its local_par_action and local_mux_action parameters to FWD via the OAM_CTL.request service primitive. The remote Parser resumes passing received non-OAMPDUs up to the MAC client and the local Multiplexer resumes forwarding any frames sourced by the local MAC client.

57.2.11.4 Loss of OAMPDUs during OAM remote loopback

There is the possibility of OAMPDU loss before, during and after OAM remote loopback tests. Of particular interest to the operation of OAM remote loopback is the loss of Loopback Control OAMPDUs and Information OAMPDUs. The local OAM client is able to determine whether or not the remote OAM client received Loopback Control OAMPDUs by examining all received Information OAMPDUs. Since Information OAMPDUs are continually sent to keep the OAM Discovery process from restarting, the occasional loss of an Information OAMPDU should not adversely impact the operation of OAM remote loopback mode.

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57.2.11.5 Loss of frames during OAM remote loopback

While the link is operating in OAM remote loopback mode, MAC client frames originating from the remote DTE are not transmitted by the remote OAM sublayer entity. Depending upon the remote DTE's implementation of OAM remote loopback, not every frame received is guaranteed to be looped back to the local DTE. Clock differences between the local and remote DTEs may also be a source of lost frames, as the delta in the rate of frames transmitted and received may overrun buffers within either DTE. As always, frames that incur errors during transit will be dropped by the MAC sublayer receiving the frame. Also, OAMPDUs inserted by the remote DTE impacts the bandwidth available to loopback frames. Implementations should take into account the topology (e.g., emulated point-to-point, asymmetrical links) when determining the rate at which to send frames during OAM remote loopback. When a bi-directional link has asymmetric data rates, frame loss may occur if the receive bandwidth is less than the transmit bandwidth.

Loopback frames that are discarded by the OAM sublayer within the remote DTE are counted and, if Clause 30 is present, are reflected in 30.3.6.1.46. This helps determine the health of the link by distinguishing between frames discarded due to link errors and those discarded within the OAM sublayer.

57.2.11.6 Timing considerations for OAM remote loopback

For effective OAM remote loopback operation, it is necessary to place an upper bound on the response time of the remote OAM client after receiving Loopback Control OAMPDUs.

To ensure correct operation, the OAM client needs to, within one second of receiving a Loopback Control OAMPDU with the Enable OAM Remote Loopback command

a) Set its local_par_action parameter to LB and the local_mux_action to DISCARD via the OAM_CTL.request service primitive.
b) Send an Information OAMPDU.

To ensure correct operation, the OAM client needs to, within one second of receiving a Loopback Control OAMPDU with the Disable OAM Remote Loopback command

c) Set its local_par_action and local_mux_action parameters to FWD via the OAM_CTL.request service primitive.
d) Send an Information OAMPDU.

It is possible for the remote MAC client to send frames before the remote OAM client can send the Information OAMPDU instructing the local DTE to change its local_par_action variable. As a result these remote MAC client frames will be discarded by the local DTE.

57.2.12 Unidirectional OAM operation

OAM provides an OAMPDU-based mechanism to notify the remote DTE when one direction of a link is non-operational and therefore data transmission is disabled. The ability to operate a link in a unidirectional mode for diagnostic purposes supports the maintenance objective of failure detection and notification.

Some Physical Layer devices support Unidirectional OAM operation (see 22.2.4.1.12, 22.2.4.2.8, and Clause 66). When a link is operating in Unidirectional OAM mode, the OAM sublayer ensures that only Information OAMPDUs with the Link Fault critical link event indication set and no Information TLVs are sent once per second across the link.

57.3 Detailed functions and state diagrams

As depicted in Figure 57–3, the OAM sublayer comprises the following functions:

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a) ***Multiplexer.*** This function is responsible for passing frames received from the superior sublayer (e.g., MAC client sublayer), OAMPDUs from the Control function and loopback frames from the Parser, to the subordinate sublayer (e.g., MAC sublayer).
b) ***Parser.*** This function distinguishes among OAMPDUs, MAC client frames and loopback frames and passes each to the appropriate entity (Control, superior sublayer and Multiplexer, respectively).
c) ***Control.*** This function is responsible for providing the interface between the OAM client entity and the functions internal to the OAM sublayer. It incorporates the Discovery process which detects the existence and capabilities of OAM at the remote DTE. Also, it includes the Transmit process, which governs the transmission of OAMPDUs to the Multiplexer function and a set of Receive rules, which govern the reception of OAMPDUs.

57.3.1 State diagram variables

57.3.1.1 Constants

OAM_subtype
The value of the Subtype field for OAMPDUs (see Table 57A–3).

Slow_Protocols_Multicast
The value of the Slow Protocols Multicast Address. (see Table 57A–1.)

Slow_Protocols_Type
The value of the Slow Protocols Length/Type field. (see Table 57A–2.)

57.3.1.2 Variables

BEGIN
A variable that resets the functions within OAM.
Values: TRUE; when the OAM sublayer is reset, or when local_oam_enable is set to DISABLE.
FALSE; When (re-)initialization has completed and local_oam_enable is set to ENABLE.

ind_DA
ind_SA
ind_mac_service_data_unit
ind_reception_status
The parameters of the MA_DATA.indication service primitive, as defined in Clause 2.

ind_subtype
The value of the octet following the Length/Type field in a Slow Protocol frame (see Annex 57A).
Value: Integer

local_critical_event
A parameter of the OAM_CTL.request service primitive, as defined in 57.2.5.3. This indicates the DTE has experienced an unspecified critical event condition.
Values: FALSE; A critical event condition has not occurred.
TRUE; A critical event condition has occurred.

local_dying_gasp
A parameter of the OAM_CTL.request service primitive, as defined in 57.2.5.3. This indicates the DTE has experienced an unrecoverable failure condition.
Values: FALSE; An unrecoverable local failure condition has not occurred.
TRUE; An unrecoverable local failure condition has occurred.

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local_link_status
A parameter of the OAM_CTL.request service primitive, as defined in 57.2.5.3. This indicates the status of the established link (see 67.6.3).
Values: FAIL; A link fault condition does exist.
OK; A link fault condition does not exist.

local_lost_link_timer_done
A parameter of the OAM_CTL.indication service primitive, as defined in 57.2.5.4. This is used to indicate the local_lost_link_timer has expired.
Values: TRUE; local_lost_link_timer has expired.
FALSE; local_lost_link_timer has not expired.

local_mux_action
A parameter of the OAM_CTL.request service primitive, as defined in 57.2.5.3. This governs the flow of frames from the MAC client through the Multiplexer function (see 57.3.3).
Values: FWD; Multiplexer passes MAC client frames to subordinate sublayer.
DISCARD; Multiplexer discards MAC client frames.

local_oam_enable
Used to enable and disable the OAM sublayer entity. If Clause 30 is present, this maps to 30.3.6.1.2 aOAMAdminState.
Values: DISABLE; The interface acts as it would if it had no OAM sublayer.
ENABLE; The interface employs the OAM sublayer and its functions.

local_oam_mode
Used to configure the OAM sublayer entity in either Active or Passive mode. If Clause 30 is present, this maps to 30.3.3.2 aOAMMode.
Values: PASSIVE; The OAM sublayer entity is configured in Passive mode.
ACTIVE; The OAM sublayer entity is configured in Active mode.

local_par_action
A parameter of the OAM_CTL.request service primitive, as defined in 57.2.5.3. This governs the flow of non-OAMPDUs through the Parser function (see 57.3.4).
Values: FWD; Parser passes received non-OAMPDUs to superior sublayer.
LB; Parser passes received non-OAMPDUs to Multiplexer during remote loopback test.
DISCARD; Parser discards received non-OAMPDUs.

local_pdu
This is used to govern the transmission and reception of OAMPDUs as part of the Discovery process (see 57.3.2.1).
Values: LF_INFO; Only Information OAMPDUs with the Link Fault critical link event set and without Information TLVs are allowed to be transmitted; only Information OAMPDUs are allowed to be received.
RX_INFO; No OAMPDUs are allowed to be transmitted; only Information OAMPDUs are allowed to be received.
INFO; Only Information OAMPDUs are allowed to be transmitted and received.
ANY; Any permissible OAMPDU is allowed to be transmitted and received (see Table 57–1).

local_satisfied
A parameter of the OAM_CTL.request service primitive, as defined in 57.2.5.3. This indicates the OAM client finds the local and remote OAM configuration settings are agreeable.
Values: FALSE; OAM client either has not seen or is not satisfied with local and remote settings.
TRUE; OAM client is satisfied with local and remote settings.

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local_stable
A variable set by the Discovery state diagram (see Figure 57–5). This is used to indicate local OAM client acknowledgment of and satisfaction with remote OAM state information.
Values: FALSE; Indicates that local DTE either has not seen or is unsatisfied with remote state information.
TRUE; Indicates that local DTE has seen and is satisfied with remote state information.

local_unidirectional
A parameter of the OAM_CTL.request service primitive, as defined in 57.2.5.3. This indicates the DTE is capable of sending OAMPDUs when the link in the receive direction is not operational.
Values: FALSE; DTE is unable to send OAMPDUs when receive path is not operational.
TRUE; DTE is capable of sending OAMPDUs when receive path is not operational.

pdu_req
This represents a request to send an OAMPDU and is used within the Transmit state diagram (see Figure 57–6).
Values: NONE: No OAMPDU.request
CRITICAL: OAMPDU.request with one or more critical link event OAM_CTL.request parameters set (local_dying_gasp, local_link_status, local_critical_event).
NORMAL: OAMPDU.request with no critical link event(s) set.

remote_stable
A parameter of the OAM_CTL.request service primitive, as defined in 57.2.5.3. OAM client extracts remote state information from received OAMPDUs. This is used to indicate remote OAM client acknowledgment of and satisfaction with local OAM state information.
Values: FALSE; Indicates that remote DTE either has not seen or is unsatisfied with local state information.
TRUE; Indicates that remote DTE has seen and is satisfied with local state information.

remote_state_valid
A parameter of the OAM_CTL.request service primitive, as defined in 57.2.5.3. This is used to indicate OAM client has received remote state information found within Local Information TLVs of received Information OAMPDUs.
Values: FALSE; Indicates that OAM client has not seen remote state information.
TRUE; Indicates that OAM client has seen remote state information.

req_DA
req_SA
req_mac_service_data_unit
req_frame_check_sequence
The parameters of the MA_DATA.request service primitive, as defined in Clause 2.

57.3.1.3 Messages

CTL:OAMI.indication
The service primitive used to pass a received frame to an internal OAM function with the specified parameters.

CTL:OAMI.request
LBF:OAMI.request
The service primitives used to transmit a frame with the specified parameters.

MAC:MA_DATA.indication

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MCF:MA_DATA.indication
The service primitives used to pass a received frame to a client with the specified parameters.

MAC:MA_DATA.request
MCF:MA_DATA.request
The service primitives used to transmit a frame with the specified parameters.

MADI
Alias for
MA_DATA.indication(ind_DA, ind_SA, ind_mac_service_data_unit, ind_reception_status)

MADR
Alias for
MA_DATA.request(req_DA, req_SA, req_mac_service_data_unit, req_frame_check_sequence)

OAMII
Alias for
OAMI.indication(DA, SA, oam_service_data_unit, frame_check_sequence, reception_status)

OAMIR
Alias for
OAMI.request(DA, SA, oam_service_data_unit, frame_check_sequence)

RxOAMPDU
Alias for ind_DA = Slow_Protocols_Multicast * ind_Length/Type = Slow_Protocols_Type * ind_subtype = OAM_subtype

rxOK
Alias for ind_reception_status = receiveOK

valid_pdu_req
Alias for the following term:
(local_pdu≠RX_INFO * pdu_req=NORMAL * pdu_cnt≠0)
+ (local_pdu=ANY * pdu_req=CRITICAL)

57.3.1.4 Counters

pdu_cnt
This counter is used to limit the number of OAMPDUs transmitted per second and ensure at least one OAMPDU is sent each second within the Transmit state diagram (see Figure 57–6).

57.3.1.5 Timers

All timers operate in the manner described in 14.2.3.2 with the following addition. A timer is reset and stops counting upon entering a state where 'stop x_timer' is asserted.

local_lost_link_timer
Timer used to reset the Discovery state diagram (see Figure 57–5).
Duration: 5 s ± 10%.

pdu_timer
Timer used to ensure OAM sublayer adheres to maximum number of OAMPDUs per second and emits at least one OAMPDU per second.
Duration: 1 s ± 10%.

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57.3.2 Control

The Control function provides the interfaces with the OAM client necessary to transmit and receive OAMPDUs and convey control and status parameters. The Control function also contains the Discovery process, which enables OAM to be established on a link, and the Transmit process, which governs the transmission of OAMPDUs to the Multiplexer block. Rules governing the reception of OAMPDUs are also contained within the Control function.

57.3.2.1 OAM Discovery

OAM provides a mechanism to detect the presence of an OAM sublayer at the remote DTE. This mechanism is called Discovery. OAM sublayer entities shall implement the OAM Discovery state diagram shown in Figure 57–5.

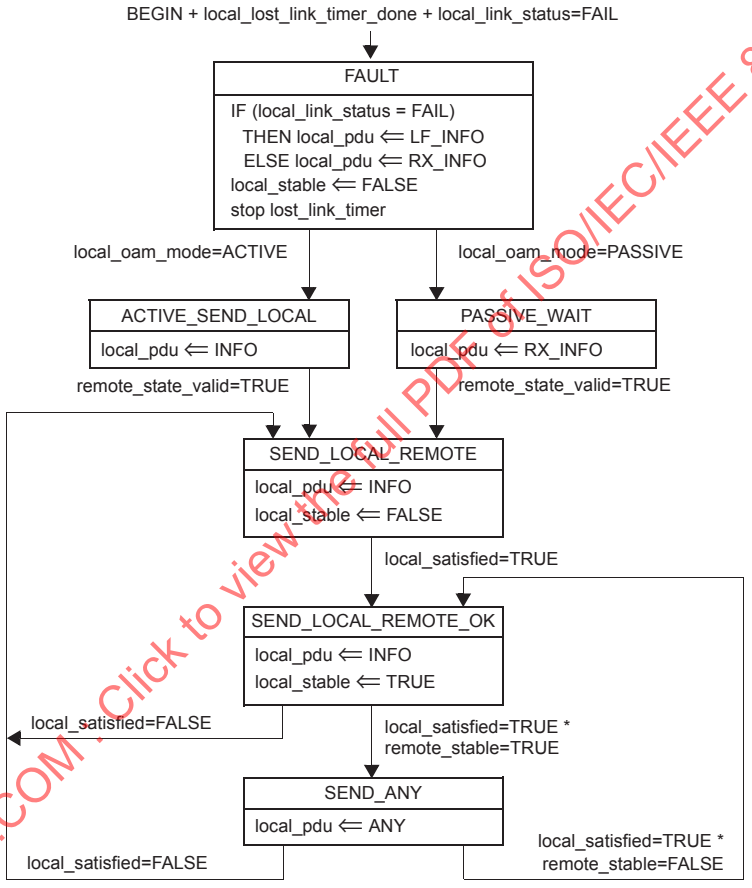

Figure 57–5—OAM Discovery state diagram

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In each state, the OAM sublayer sends specified OAMPDUs in a periodic fashion, normally once a second. When local_pdu is set to LF_INFO, the OAM sublayer sends Information OAMPDUs with the Link Fault bit of the Flags field set and without any Information TLVs. When local_pdu is set to RX_INFO, the OAM sublayer does not send any OAMPDUs. When local_pdu is set to INFO, only Information OAMPDUs are sent. When local_pdu is set to ANY, all permissible OAMPDUs may be sent, subject to the restrictions found in Table 57–1.

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57.3.2.1.1 FAULT state

Upon entering the FAULT state, local_pdu is set based on the value of local_link_status. If it is set to FAIL, local_pdu is set to LF_INFO, otherwise is it set to RX_INFO. Then, local_stable is set to FALSE and local_lost_link_timer is stopped. While local_link_status is set to FAIL, the DTE will remain in this state indicating to the remote DTE there is link fault. This is accomplished by sending Information OAMPDUs once per second with the Link Fault bit of the Flags field set and no Information TLVs in the Data field. The unidirectional transmission of Information OAMPDUs is supported by some physical coding sublayers (see 57.2.12).

If OAM is reset, disabled, the local_lost_link_timer expires or the local_link_status equals FAIL, the Discovery process returns to the FAULT state.

57.3.2.1.2 ACTIVE_SEND_LOCAL state

Once local_link_status is set to OK, the DTE evaluates local_oam_mode. A DTE configured in Active mode (see 57.2.9.1) sends Information OAMPDUs that only contain the Local Information TLV (see 57.5.2.1). This state is called ACTIVE_SEND_LOCAL. While in this state, the local DTE waits for Information OAMPDUs received from the remote DTE.

57.3.2.1.3 PASSIVE_WAIT state

A DTE configured in Passive mode (see 57.2.9.2) waits until receiving Information OAMPDUs with Local Information TLVs before sending any Information OAMPDUs with Local Information TLVs. This state is called PASSIVE_WAIT. By waiting until first receiving an Information OAMPDU with the Local Information TLV, a Passive DTE cannot complete the OAM Discovery process when connected to another Passive DTE.

57.3.2.1.4 SEND_LOCAL_REMOTE state

Once the local DTE has received an Information OAMPDU with the Local Information TLV from the remote DTE, the local DTE begins sending Information OAMPDUs that contain both the Local and Remote Information TLVs. This state is called SEND_LOCAL_REMOTE. If at any time the settings on either the local or remote DTE change resulting in the local OAM client becoming unsatisfied with the settings, the Discovery process returns to the SEND_LOCAL_REMOTE state.

57.3.2.1.5 SEND_LOCAL_REMOTE_OK state

If the local OAM client deems the settings on both the local and remote DTEs are acceptable, it enters the SEND_LOCAL_REMOTE_OK state. If at any time the settings on the local OAM client change resulting in the remote OAM client becoming unsatisfied with the settings, the OAM Discovery process returns to the SEND_LOCAL_REMOTE_OK state.

57.3.2.1.6 SEND_ANY state

Finally, once an OAMPDU has been received indicating the remote device is satisfied with the respective settings, the local device enters the SEND_ANY state. This is the expected normal operating state for OAM on fully operational links.

57.3.2.1.7 Sending Discovery status to peer

The Local Stable and Local Evaluating bits of the Flags field communicate the status of the local Discovery process to the peer. When the OAM Discovery process is started, the local DTE sets the Local Stable to 0 and Local Evaluating bits to 1 indicating OAM Discovery has not completed.

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If, after learning of the remote OAM settings, the local OAM client determines it is unsatisfied it sets the Local Stable and Local Evaluating bits to 0 indicating Discovery cannot successfully complete. If the local OAM client is satisfied, the local DTE sets the Local Stable bit to 1 and Local Evaluating bit to 0 indicating the local OAM client is satisfied.

When Local Stable is set to 1 and Local Evaluating is set to 0 and Remote Stable is set to 1 and Remote Evaluating is set to 0 indicating that both OAM clients are satisfied, the OAM Discovery process has successfully completed and local_pdu is set to ANY. See Table 57–3 for more information.

57.3.2.2 Transmit

OAM sublayer entities shall implement the Transmit state diagram shown in Figure 57–6.

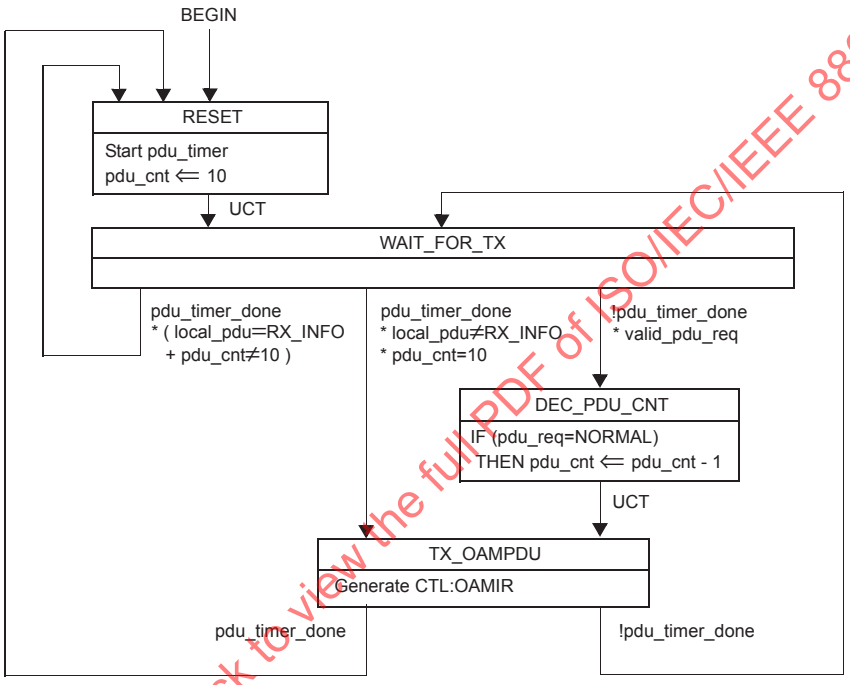

Figure 57–6—Transmit state diagram

57.3.2.2.1 RESET state

Upon initialization, the RESET state is entered. A one second timer is started called pdu_timer. The pdu_cnt variable is reset with a value of ten, the maximum number of OAMPDUs that may be sent in one second. Following RESET, the WAIT_FOR_TX state is entered.

57.3.2.2.2 WAIT_FOR_TX state

While in the WAIT_FOR_TX state, the Transmit process waits for the occurrence of one of three conditions. These three conditions are summarized as follows:

a) Expiration of pdu_timer:
   1) With one or more OAMPDUs sent within the last second
   2) Without any OAMPDUs being sent within the last second and without a valid pending request to send an OAMPDU

b) Valid request to send an OAMPDU present

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57.3.2.2.3 Expiration of pdu_timer

While in the WAIT_FOR_TX state, if the pdu_timer expires and one or more OAMPDUs have been sent within the last second, the Transmit process transitions to the RESET state. If, however, the pdu_timer expires and no OAMPDUs have been sent within the last second and there is no valid request to send an OAMPDU present, the Transmit process transitions to the TX_OAMPDU state sending an Information OAMPDU. This prevents the Discovery process from restarting. If local_pdu is set to LF_INFO, the Transmit process ensures the Information OAMPDU has the Link Fault bit of the Flags field set and has no Information TLVs in the Data field.

If, however, the OAM sublayer entity is configured to not send any OAMPDUs, as indicated by the local_pdu variable set to RX_INFO, the Transmit function will simply restart the pdu_timer by returning to the RESET state.

57.3.2.2.4 Valid request to send an OAMPDU

While in the WAIT_FOR_TX state, if a valid request to send an OAMPDU is present, the Transmit process transmits the requested OAMPDU in the TX_OAMPDU state. If the Flags field of the OAMPDU to be sent does not contain any critical link events, the pdu_cnt variable is decremented in the DEC_PDU_CNT state. A valid request is either one of the following:

a) An OAMPDU.request service primitive from the OAM client with the local_pdu variable set to INFO or ANY and pdu_cnt not equal to zero.
b) An OAM_CTL.request service primitive from the OAM client with one or more critical event parameters set and the local_pdu variable set to ANY. When the local_pdu variable is set to ANY, the Discovery process has completed and is in the SEND_ANY state. The Discovery process needs to complete before critical events, other than Link Fault, may be sent to the peer OAM entity.

57.3.2.2.5 TX_OAMPDU state

The TX_OAMDPU state generates the CTL:OAMI.request service primitive, which requests the transmission of an OAMPDU to the Multiplexer process. After generating the request, the Transmit process returns to the RESET state if the pdu_timer is expired or the WAIT_FOR_TX state if the pdu_timer has not expired.

57.3.2.2.6 Transmit rules

The following rules govern the generation of the CTL:OAMIR service primitive:

a) While local_pdu is set to LF_INFO, only Information OAMPDUs with the Link Fault bit of the Flags field set and without any Information TLVs shall be generated.
b) While local_pdu is set to RX_INFO, CTL:OAMIR service primitives shall not be generated.
c) While local_pdu is set to INFO, only Information OAMPDUs shall be generated.
d) While local_pdu is set to ANY:
    1) An OAM_CTL.request service primitive with one or more of the critical link event parameters set shall generate a CTL:OAMIR service primitive, requesting the transmission of an Information OAMPDU with the appropriate bit(s) of the Flags field set.
    2) An OAMPDU.request service primitive shall generate a CTL:OAMIR service primitive, requesting the transmission of the particular OAMPDU.

57.3.2.3 Receive rules

CTL:OAMII service primitives indicate a received OAMPDU and in turn generate an OAMPDU.indication service primitive to the OAM client entity subject to the following rules:

a) When local_pdu is not set to ANY, Information OAMPDUs shall be passed to the OAM client and non-Information OAMPDUs are discarded.

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b) When local_pdu is set to ANY, all OAMPDUs, including those with unknown Code fields shall be passed to the OAM client.[3] It is anticipated that the OAM client will ignore unknown or unsupported OAMPDUs.

57.3.3 Multiplexer

OAM sublayer entities shall implement the Multiplexer state diagram shown in Figure 57–7.

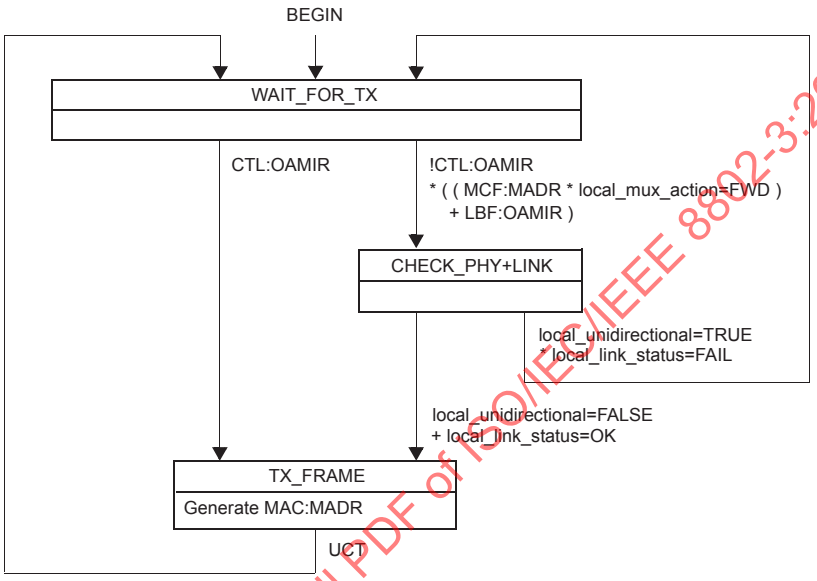

Figure 57–7—Multiplexer state diagram

57.3.3.1 WAIT_FOR_TX state

Upon initialization, the WAIT_FOR_TX state is entered. While in the WAIT_FOR_TX state, the Multiplexer waits for the occurrence of one of two conditions. These two conditions are summarized as follows:

a) Valid request to send an OAMPDU present
b) Valid request to forward a MAC client frame or loopback frame from Parser

57.3.3.1.1 Valid request to send an OAMPDU

While in the WAIT_FOR_TX state, if a request to send an OAMPDU is present, the Multiplexer function transmits the requested OAMPDU in the TX_FRAME state.

57.3.3.1.2 Valid request to forward or loopback frame

While in the WAIT_FOR_TX state, if a valid request to forward or loop back a frame is present and no request to send an OAMPDU is present, the Multiplexer will then check the status of the underlying Physical Layer and unidirectional configuration (in the CHECK_PHY+LINK state) and either transmit the frame in the TX_FRAME state or simply return to the WAIT_FOR_TX state.

[3]The behavior of the OAM sublayer is different in this regard from the behavior of the MAC Control sublayer (see Clause 31 and Clause 64).

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A valid request to forward a frame from the superior sublayer is indicated by the variable MCF:MADR with the Multiplexer configured to forward frames as indicated by the local_mux_action variable set to FWD. A request to loop back a frame from the Parser function is indicated by the variable LBF:OAMIR. When either request occurs, the local_unidirectional variable needs to be FALSE or the local_link_status variable needs to be OK in order for the frame to be sent to the subordinate sublayer via the TX_FRAME state. Since only Information OAMPDUs with the Link Fault critical link event indication set and no Information TLVs are sent on a unidirectional link, the status of the link is evaluated to ensure the same behavior as devices that do not support the optional Unidirectional OAM capability. When the local_link_status variable is OK, the MAC client frame will be transmitted regardless of the Unidirectional OAM capability or setting (see 57.2.12).

57.3.3.2 TX_FRAME state

Once the Multiplexer process reaches the TX_FRAME state, it shall provide transparent pass-through of frames submitted by the superior sublayer, the Transmit process and the Parser process. The transmission of an OAMPDU shall not affect the transmission of a frame that has been submitted to the subordinate sublayer (i.e., the MAC's TransmitFrame function is synchronous, and is never interrupted). After the frame has been sent to the subordinate sublayer, the Multiplexer process returns to the WAIT_FOR_TX state.

57.3.4 Parser

OAM sublayer entities shall implement the Parser state diagram shown in Figure 57–8.

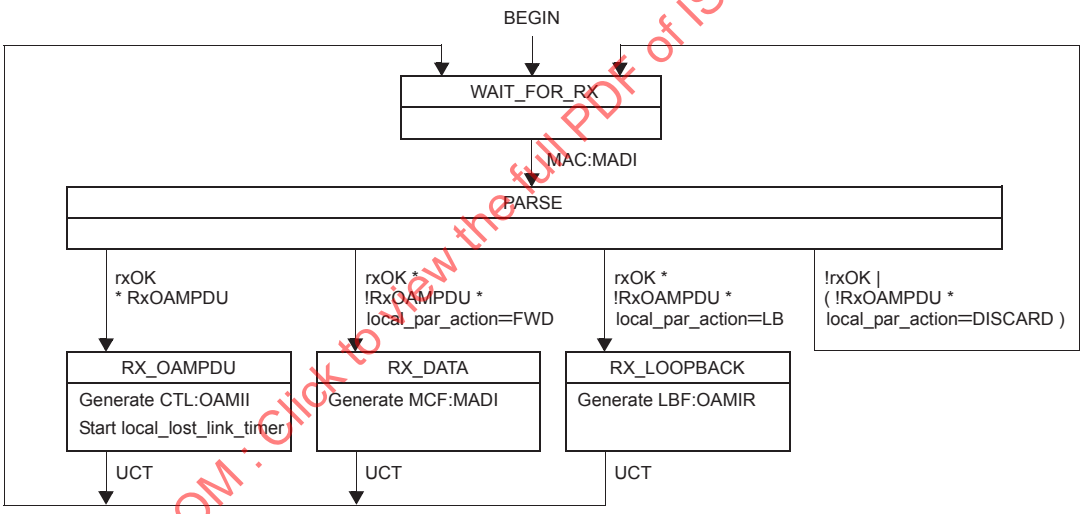

Figure 57–8—Parser state diagram

The Parser decodes frames received from the subordinate sublayer, passes OAMPDUs to the Control function, MAC client frames to the superior sublayer and loopback frames to the Multiplexer function. After reset, the Parser function enters the WAIT_FOR_RX state. The reception of a frame is detected when the MAC:MADI service primitive occurs. When a frame is received, the Parser function enters the PARSE state.

57.3.4.1 Reception of OAMPDU

The RX_OAMPDU state is entered when the receive frame is identified as an OAMPDU. Received OAMPDUs are sent to the OAM Control function via the CTL:OAMII service primitive. Following the receive rules in 57.3.2.3, the OAM Control function then passes the received OAMPDU to the OAM client. In addition, the local_lost_link_timer is reset. The Parser function then returns to the WAIT_FOR_RX state.

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57.3.4.2 Reception of non-OAMPDUs

Received non-OAMPDUs are handled according to the setting of the local_par_action parameter. Refer to 57.2.11 for a complete description of OAM remote loopback operation and the local_par_action variable.

57.3.4.2.1 Reception of non-OAMPDU in FWD mode

The RX_DATA state is entered if the frame is determined to not be an OAMPDU and the local_par_action variable is set to FWD. The received frame is passed up to the superior sublayer via the MCF:MADI service primitive. The Parser then returns to the WAIT_FOR_RX state.

57.3.4.2.2 Reception of non-OAMPDU in LB mode

The RX_LOOPBACK state is entered if the frame is determined to not be an OAMPDU and the local_par_action parameter is set to LB. The received loopback frame is passed to the Multiplexer function via the LBF:OAMIR service primitive to be looped back to the remote DTE. After the frame is passed to the Multiplexer function, the Parser function returns to the WAIT_FOR_RX state.

57.3.4.2.3 Reception of non-OAMPDU in DISCARD mode

If the local_par_action parameter is set to DISCARD, the Parser function simply returns to the WAIT_FOR_RX state.

57.4 OAMPDUs

57.4.1 Ordering and representation of octets

All OAMPDUs comprise an integral number of octets. When the encoding of (an element of) an OAMPDU is depicted in a diagram:

a) Octets are transmitted from top to bottom.
b) Within an octet, bits are shown with bit 0 to the left and bit 7 to the right.
c) When consecutive octets are used to represent a binary number, the octet transmitted first has the more significant value.
d) When consecutive octets are used to represent a MAC address, the least significant bit of the first octet is assigned the value of the first bit of the MAC address, the next most significant bit the value of the second bit of the MAC address, and so on for all the octets of the MAC address.

When the encoding of an element of an OAMPDU is depicted in a table, the least significant bit is bit 0.

The bit/octet ordering of any Organizationally Unique Identifier (OUI) or Company ID (CID) field within an OAMPDU is identical to the bit/octet ordering of the OUI portion of the DA/SA. Additional detail defining the format of OUIs and CIDs can be found in IEEE Std 802-2014.

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57.4.2 Structure

The OAMPDU structure shall be as shown in Figure 57–9.

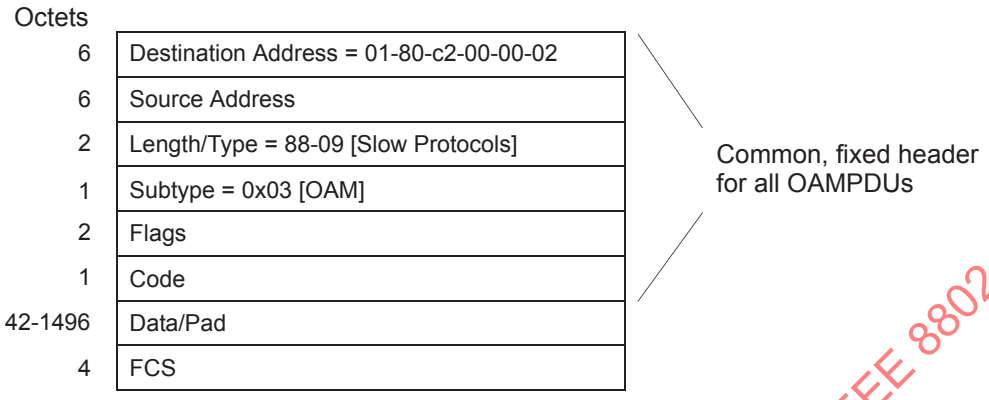

Figure 57–9—OAMPDU frame structure

OAMPDUs shall have the following fields:

a) ***Destination Address*** (DA). The DA in OAMPDUs is the Slow_Protocols_Multicast address. Its use and encoding are specified in Annex 57A.
b) ***Source Address*** (SA). The SA in OAMPDUs carries the individual MAC address associated with the port through which the OAMPDU is transmitted.
c) ***Length/Type***. The Length/Type in OAMPDUs carries the Slow_Protocols_Type field value as specified in 57A.4.
d) ***Subtype***. The Subtype field identifies the specific Slow Protocol being encapsulated. OAMPDUs carry the Subtype value 0x03.
e) ***Flags***. The Flags field contains status bits as defined in 57.4.2.1.
f) ***Code***. The Code field identifies the specific OAMPDU. The use and encoding of this field is specified in Table 57–4.
g) ***Data/Pad***. This field contains the OAMPDU data and any necessary pad. Implementations shall support OAMPDUs at least minFrameSize in length.
h) ***FCS***. This field is the Frame Check Sequence, as defined in Clause 4.

57.4.2.1 Flags field

The Flags field is encoded as individual bits within two octets as shown in Table 57–3. Additional diagnostic information may be sent using the Event Notification OAMPDU.

Table 57–3—Flags field

Bit(s)	Name	Description
15:7	*Reserved*	Reserved bits shall be set to zero when sending an OAMPDU, and should be ignored on reception for compatibility with future use of reserved bits.
6	Remote Stable	When remote_state_valid is set to TRUE, the Remote Stable and Remote Evaluating values shall be a copy of the last valid received Local Stable and Local Evaluating values from the remote OAM peer. Otherwise, the Remote Stable and Remote Evaluating bits shall be set to 0.
5	Remote Evaluating	

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Table 57–3—Flags field *(continued)*

Bit(s)	Name	Description
4	Local Stable	Local Stable and Local Evaluating form a two-bit encoding shown below: 4:3 0x0 = Local DTE Unsatisfied, Discovery can not complete 0x1 = Local DTE Discovery process has not completed 0x2 = Local DTE Discovery process has completed 0x3 = Reserved. This value shall not be sent. If the value 0x3 is received, it should be ignored and not change the last received value.
3	Local Evaluating	
2	Critical Event	1 = A critical event has occurred. 0 = A critical event has not occurred.
1	Dying Gasp	1 = An unrecoverable local failure condition has occurred. 0 = An unrecoverable local failure condition has not occurred.
0	Link Fault	The PHY has detected a fault has occurred in the receive direction of the local DTE (e.g., link, Physical Layer). 1 = Local device's receive path has detected a fault. 0 = Local device's receive path has not detected a fault.

NOTE—The definition of the specific faults comprising the Critical Event, Dying Gasp, and Link Fault flags is implementation specific and beyond the scope of this standard.

57.4.2.2 Code field

The value of the Code field is set by the Transmit process in the Control function for Information OAMPDUs it generates. The OAM client sets the Code field for all OAMPDUs it generates. Table 57–4 contains the defined OAMPDU codes.

Table 57–4—OAMPDU codes

Code	OAMPDU	Comment	Source
00	Information	Communicates local and remote OAM information.	OAM client / OAM sublayer
01	Event Notification	Alerts remote DTE of link event(s).	OAM client
02	Variable Request	Requests one or more specific MIB variables.	OAM client
03	Variable Response	Returns one or more specific MIB variables.	OAM client
04	Loopback Control	Enables/disables OAM remote loopback.	OAM client
05-FD	*Reserved*	*Reserved*	OAM client
FE	Organization Specific	Reserved for Organization Specific Extensions, distinguished by Organizationally Unique Identifier.	OAM client
FF	*Reserved*	*Reserved*	OAM client

57.4.3 OAMPDU descriptions

The local OAM sublayer communicates with the remote OAM sublayer via OAMPDUs. OAMPDUs are identified with a specific code. OAMPDUs are formatted as compliant IEEE 802.3 frames, where the IEEE 802.3 frame header format is described in Clause 3. OAMPDUs are further defined, as shown in Figure 57–9, to include a Subtype field, a Flags field, and a Code field following the IEEE 802.3 defined Length/Type field. The Data field begins in a fixed location within the OAMPDU. The Data field contents are unique to the particular OAMPDU. The following sections provide a detailed description of each OAMPDU and its corresponding Data field. All received OAMPDUs, including those with reserved Code fields, are passed to the OAM client. OAMPDUs with reserved Code field values shall not be transmitted.

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57.4.3.1 Information OAMPDU

The Information OAMPDU, identified by the Code field 0x00, is used to send OAM state information to the remote DTE. The Information OAMPDU frame structure shall be as depicted in Figure 57–10.

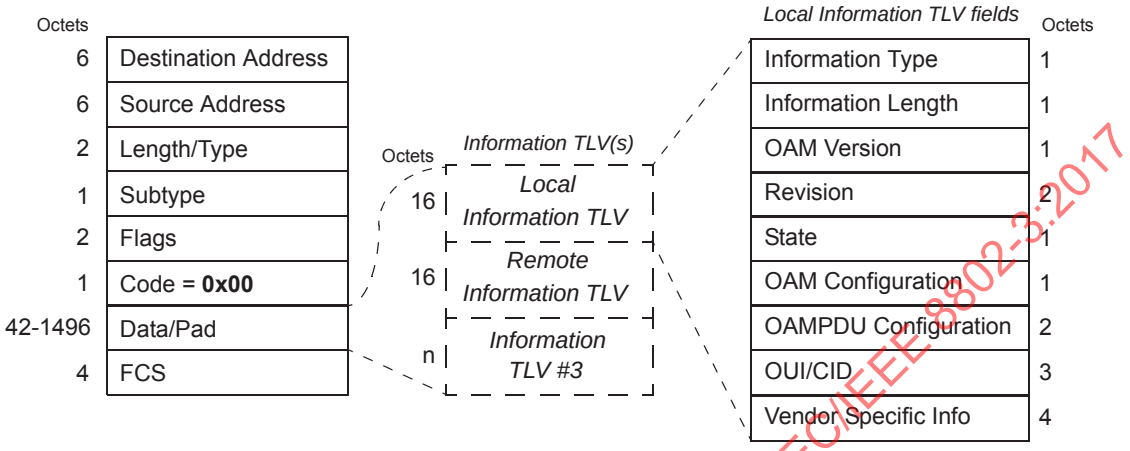

Figure 57–10—Information OAMPDU frame structure

When local_pdu is set to LF_INFO, the Information OAMPDU Data field shall not have any Information TLVs. When local_pdu is not set to LF_INFO, the Information OAMPDU Data field shall consist of the Local Information TLV (see 57.5.2.1) immediately following the Code field. In addition, if the Discovery state diagram variable remote_state_valid is TRUE, the Data field shall also contain the Remote Information TLV (see 57.5.2.2), immediately following the Local Information TLV and may also contain other Information TLVs found in Table 57–6.

57.4.3.2 Event Notification OAMPDU

The optional Event Notification OAMPDU, identified with the Code field set to 0x01, is used to alert the remote DTE of link events introduced in 57.2.10.2. The Event Notification OAMPDU frame structure shall be as depicted in Figure 57–11.

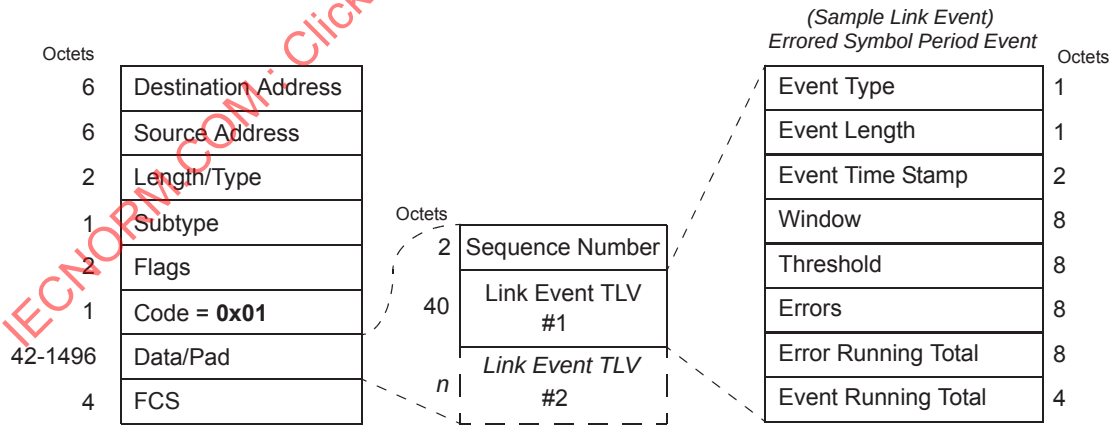

Figure 57–11—Event Notification OAMPDU frame structure

The first two octets of the Data field shall contain a Sequence Number, encoded as a 16-bit unsigned integer. As described in 57.2.3, the OAM client may send duplicate Event Notification OAMPDUs to increase the likelihood the remote DTE receives a particular event. The OAM client increments the Sequence Number

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for each unique Event Notification OAMPDU formed by the OAM client. A particular Event Notification OAMPDU may be sent multiple times with the same sequence number. It is recommended that any duplicate Event Notification OAMPDUs follow its original without a different, intervening Event Notification OAMPDU. A duplicate Event Notification OAMPDU should not be transmitted if a new Event Notification OAMPDU has already followed the original OAMPDU. Any particular event can be signaled in only one unique Event Notification OAMPDU (though that OAMPDU may be transmitted multiple times). Upon receiving an Event Notification OAMPDU, the OAM client compares the Sequence Number with the last received Sequence Number. If equal, the current event is a duplicate and is ignored by the OAM client.

Following the Sequence Number field, the Data field shall contain one or more optional Link Event TLVs which may provide useful information for troubleshooting events and faults. Link Event TLVs are defined in 57.5.3.

57.4.3.3 Variable Request OAMPDU

The optional Variable Request OAMPDU, identified with a Code field of 0x02, is used to request one or more MIB variables from the remote DTE. The Variable Request OAMPDU frame structure shall be as depicted in Figure 57–12.

The Variable Request OAMPDU Data field shall contain one or more Variable Descriptors. Variable Descriptors are defined in 57.6.1.

The Variable Request OAMPDU Data field may contain one or more Variable Containers, to determine the scope of subsequent Variable Descriptors, as described in 57.6.2.

.

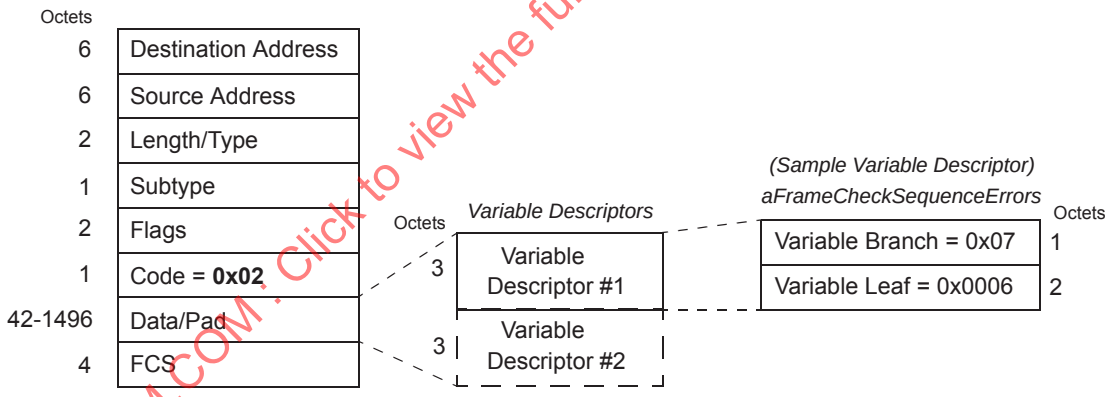

Figure 57–12—Variable Request OAMPDU frame structure

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57.4.3.4 Variable Response OAMPDU

The optional Variable Response OAMPDU, identified with the Code field of 0x03, is used to return one or more MIB variables. The Variable Response OAMPDU frame structure shall be as depicted in Figure 57–13.

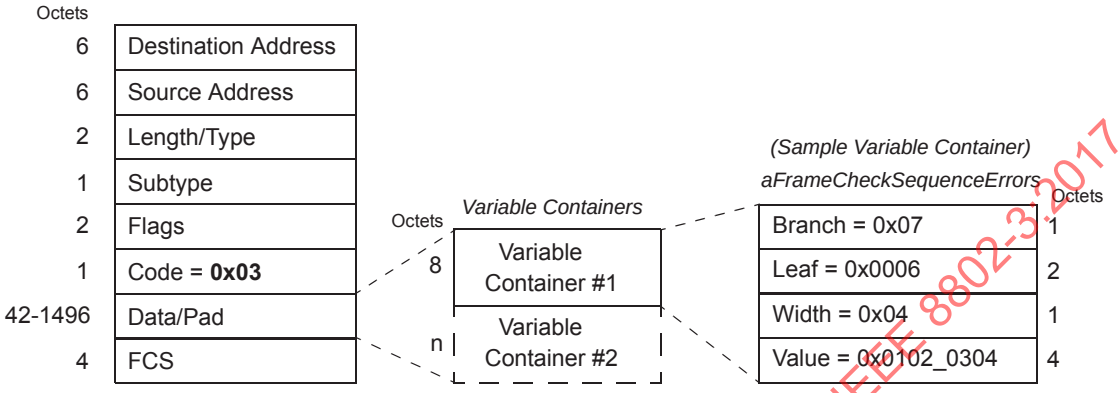

Figure 57–13—Variable Response OAMPDU frame structure

The Variable Response OAMPDU Data field shall contain one or more Variable Containers. Variable Containers are defined in 57.6.2. A Variable Response OAMPDU needs to be sent by the OAM client within one second of receipt of a Variable Request OAMPDU. If a DTE is unable to retrieve one or more variables, it needs to respond within one second and indicate the appropriate error(s) as found in Table 57–17. If a DTE is unable to retrieve one or more attributes within a package or object, it needs to either a) return the appropriate Variable Indication for the particular attribute(s) and return all other requested variables or b) return a Variable Indication for the entire package or object.

57.4.3.5 Loopback Control OAMPDU

The optional Loopback Control OAMPDU, identified with the Code field set to 0x04, is used to control the remote DTE's OAM remote loopback state. The Loopback Control OAMPDU frame structure shall be as depicted in Figure 57–14.

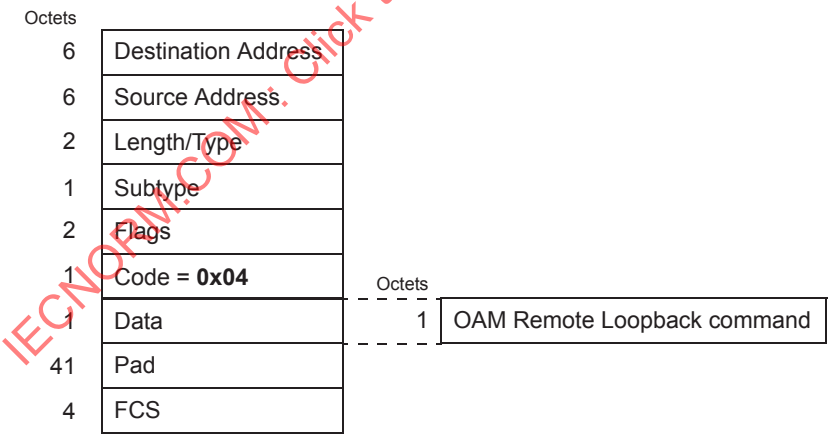

Figure 57–14—Loopback Control OAMPDU frame structure

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The Loopback Control OAMPDU Data field shall consist of an OAM remote loopback command. Table 57–5 lists the defined OAM remote loopback commands.

Table 57–5—OAM remote loopback commands

Command	Description
0x00	*Reserved — shall not be transmitted, should be ignored on reception by OAM client*
0x01	Enable OAM Remote Loopback
0x02	Disable OAM Remote Loopback
0x03–0xFF	*Reserved — shall not be transmitted, should be ignored on reception by OAM client*

For a complete description of OAM remote loopback refer to 57.2.11.

57.4.3.6 Organization Specific OAMPDU

The optional Organization Specific OAMPDU, identified with the Code field set to 0xFE, is used for organization specific extensions. The Organization Specific OAMPDU frame structure shall be as depicted in Figure 57–15.

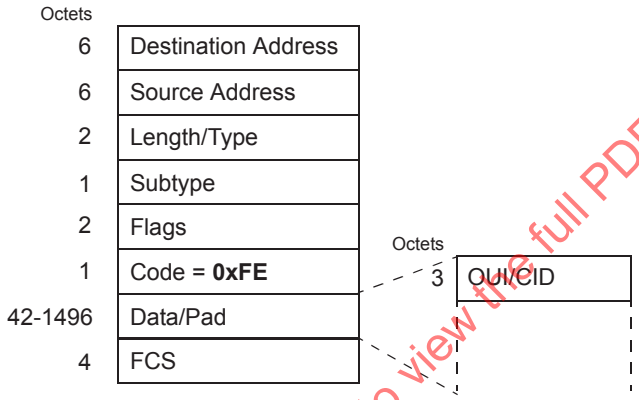

Figure 57–15—Organization Specific OAMPDU frame structure

The first three octets of the Organization Specific OAMPDU Data field shall contain the Organizationally Unique Identifier (OUI) or Company ID (CID).[4] The format and function of the rest of the Organization Specific OAMPDU Data field is dependent on OUI or CID value and is beyond the scope of this standard.

57.5 OAM TLVs

57.5.1 Parsing

The OAM client parses OAM TLVs. All OAM TLVs contain a single octet Type field and a single octet Length field. The Length field encompasses the entire TLV including the Type and Length fields. TLV processing should follow these recommendations:

a) Detection of a TLV type 0x00 should indicate there are no more TLVs to process (the length and value of the Type 0x00 TLV can be ignored).
b) TLVs with lengths 0x00 or 0x01 should be considered invalid, and the OAMPDU should be considered to have no more TLVs.
c) TLVs with unknown or unexpected types should be ignored.

[4]Interested applicants should contact the IEEE Standards Department, Institute of Electrical and Electronics Engineers, http://standards.ieee.org/regauth/index.html, 445 Hoes Lane, Piscataway, NJ 08854, USA.

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d) If the length of a TLV is less than that defined for the Type, that TLV should be ignored and the rest of the frame may be ignored. If the length of a TLV is greater than that defined for the Type, the expected fields of the TLV should be processed, and the remainder of the frame after the TLV should also be processed.
e) If a TLV length indicates that the TLV extends beyond the frame (e.g., the length cannot fit into the frame given its length and starting point), then the TLV should be ignored.

57.5.2 Information TLVs

This subclause contains the definitions for Information TLVs. Information TLVs are found in Information OAMPDUs. Table 57–6 contains the defined Information TLVs.

Table 57–6—Information TLV types

Type	Description
0x00	*End of TLV marker*
0x01	Local Information
0x02	Remote Information
0x03–0xFD	*Reserved —shall not be transmitted, should be ignored on reception by OAM client*
0xFE	Organization Specific Information
0xFF	*Reserved —shall not be transmitted, should be ignored on reception by OAM client*

The following subclauses describe the defined Information TLVs.

57.5.2.1 Local Information TLV

The Local Information TLV shall have the following fields:

a) ***Information Type*** = *Local Information*. This one-octet field indicates the nature of the data carried in this TLV-tuple. The encoding of this field is found in Table 57–6.
b) ***Information Length***. The one-octet field indicates the length (in octets) of this TLV-tuple. Local Information TLV uses a length value of 16 (0x10).
c) ***OAM Version***. This one-octet field indicates the version supported by the DTE. This field shall contain the value 0x01 to claim compliance with Version 1 of this protocol.
d) ***Revision***. This two-octet field indicates the current revision of the Information TLV. The value of this field shall start at zero and be incremented each time something in the Information TLV changes. Upon reception of an Information TLV from a peer, an OAM client may use this field to decide if it needs to be processed (an Information TLV that is identical to the previous Information TLV does not need to be parsed as nothing in it has changed).
e) ***State***. This one-octet field contains OAM state information and shall be as shown in Table 57–7.
f) ***OAM Configuration***. This one-octet field contains OAM configuration variables and shall be as shown in Table 57–8.
g) ***OAMPDU Configuration***. This two-octet field contains OAMPDU configuration variables and shall be as shown in Table 57–9 and encoded as specified in 57.4.1 c).
h) ***OUI/CID***. This three-octet field contains the 24-bit Organizationally Unique Identifier or Company ID and shall be as shown in Table 57–10.
i) ***Vendor Specific Information***. This four-octet field contains the Vendor Specific Information field and shall be as shown in Table 57–11.

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Table 57–7—State field

Bit(s)	Name	Description
7:3	*Reserved*	In Local Information TLVs, reserved bits shall be set to zero when sending an OAMPDU, and should be ignored on reception for compatibility with future use of reserved bits.
2	Multiplexer Action	0 = Device is forwarding non-OAMPDUs to the lower sublayer (local_mux_action = FWD). 1 = Device is discarding non-OAMPDUs (local_mux_action = DISCARD).
1:0	Parser Action	00 = Device is forwarding non-OAMPDUs to higher sublayer (local_par_action = FWD). 01 = Device is looping back non-OAMPDUs to the lower sublayer (local_par_action = LB). 10 = Device is discarding non-OAMPDUs (local_par_action = DISCARD). 11 = Reserved. In Local Information TLVs, this value shall not be sent. If the value 11 is received, it should be ignored and not change the last received value.

Table 57–8—OAM Configuration field

Bit(s)	Name	Description
7:5	*Reserved*	In Local Information TLVs, reserved bits shall be set to zero when sending an OAMPDU, and should be ignored on reception for compatibility with future use of reserved bits.
4	Variable Retrieval	1 = DTE supports sending Variable Response OAMPDUs. 0 = DTE does not support sending Variable Response OAMPDUs.
3	Link Events	1 = DTE supports interpreting Link Events. 0 = DTE does not support interpreting Link Events.
2	OAM Remote Loopback Support	1 = DTE is capable of OAM remote loopback mode. 0 = DTE is not capable of OAM remote loopback mode.
1	Unidirectional Support	1 = DTE is capable of sending OAMPDUs when the receive path is non-operational. 0 = DTE is not capable of sending OAMPDUs when the receive path is non-operational.
0	OAM Mode	1 = DTE configured in Active mode. 0 = DTE configured in Passive mode.

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Table 57–9—OAMPDU Configuration field

Bit(s)	Name	Description
15:11	*Reserved*	In Local Information TLVs, reserved bits shall be set to zero when sending an OAMPDU, and should be ignored on reception for compatibility with future use of reserved bits.
10:0	Maximum OAMPDU Size	11-bit field which represents the largest OAMPDU, in octets, supported by the DTE. This value is compared to the remote's Maximum OAMPDU Size and the smaller of the two is used. The minimum value of this field is minFrameSize / 8. The maximum value of this field is equal to maxBasicFrameSize, which is defined in 4.4.2. Prior to exchanging Maximum OAMPDU Size and agreeing upon a maximum OAMPDU size, a DTE sends OAMPDUs of length minFrameSize / 8. The OAMPDUs transmitted by a DTE are limited by both the local DTE's Maximum OAMPDU Size and the remote DTE's Maximum OAMPDU Size as indicated in received Information OAMPDUs. A DTE is not required to change the value transmitted in this field after negotiation to an agreed size as each end will dynamically determine the correct maximum OAMPDU size to use.

Table 57–10—OUI/CID field

Bit(s)	Name	Description
23:0	OUI/CID[a]	24-bit Organizationally Unique Identifier or Company ID of the vendor.

[a]Organizations that have previously received OUIs or CIDs from the IEEE Registration Authority should use one of their allocated OUIs or CIDs consistently in this field.

Table 57–11—Vendor Specific Information field

Bit(s)	Name	Description
31:0	Vendor Specific Information	32-bit identifier that may be used to differentiate a vendor's product models/versions.

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57.5.2.2 Remote Information TLV

The Remote Information TLV shall be a copy of the last received Local Information TLV from the remote OAM peer, with the exception of the Information Type field. The encoding of this field is found in Table 57–6.

57.5.2.3 Organization Specific Information TLV

The Organization Specific Information TLV shall have the following fields:

a) ***Information Type*** = *Organization Specific Information*. This one-octet field indicates the nature of the data carried in this TLV-tuple. The encoding of this field is found in Table 57–6.
b) ***Information Length.*** This one-octet field indicates the length (in octets) of this TLV-tuple. The length of an Organization Specific Information TLV is unspecified.
c) ***Organizationally Unique Identifier or Company ID.*** This three-octet field shall contain the 24-bit Organizationally Unique Identifier (OUI) or Company ID (CID).
d) ***Organization Specific Value.*** This field indicates the value of the Organization Specific Information TLV. This field's length and contents are unspecified.

57.5.3 Link Event TLVs

This subclause contains the definitions for Link Event TLVs. Link Event TLVs are found in Event Notification OAMPDUs. Table 57–12 contains the defined Link Event TLVs.

Table 57–12—Link Event TLV type value

Type	Description
0x00	*End of TLV marker*
0x01	Errored Symbol Period Event
0x02	Errored Frame Event
0x03	Errored Frame Period Event
0x04	Errored Frame Seconds Summary Event
0x05–0xFD	*Reserved—shall not be transmitted, should be ignored on reception by OAM client*
0xFE	Organization Specific Event
0xFF	*Reserved—shall not be transmitted, should be ignored on reception by OAM client*

The following subclauses describe the defined Link Event TLVs.

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57.5.3.1 Errored Symbol Period Event TLV

The Errored Symbol Period Event TLV counts the number of symbol errors that occurred during the specified period. The period is specified by the number of symbols that can be received in a time interval on the underlying Physical Layer. This event is generated if the symbol error count is equal to or greater than the specified threshold for that period.

The Errored Symbol Period Event TLV shall have the following fields:

a) ***Event Type*** = *Errored Symbol Period Event*. This one-octet field indicates the nature of the information carried in this TLV-tuple. The encoding of this field is found in Table 57–12.

b) ***Event Length.*** This one-octet field indicates the length (in octets) of this TLV-tuple. Errored Symbol Period Event uses a length value of 40 (0x28).

c) ***Event Time Stamp.*** This two-octet field indicates the time reference when the event was generated, in terms of 100 ms intervals, encoded as a 16-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.35. When received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.42.

d) ***Errored Symbol Window.*** This eight-octet field indicates the number of symbols in the period, encoded as a 64-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.35. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.42.
   1) The default value is the number of symbols in one second for the underlying Physical Layer.
   2) The lower bound is the number of symbols in one second for the underlying Physical Layer.
   3) The upper bound is the number of symbols in one minute for the underlying Physical Layer.

e) ***Errored Symbol Threshold.*** This eight-octet field indicates the number of errored symbols in the period is required to be equal to or greater than in order for the event to be generated, encoded as a 64-bit unsigned integer. When generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.35. When received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.42.
   1) The default value is one symbol error.
   2) The lower bound is zero symbol errors.
   3) The upper bound is unspecified.

f) ***Errored Symbols.*** This eight-octet field indicates the number of symbol errors in the period, encoded as a 64-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.35. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.42.

g) ***Error Running Total.*** This eight-octet field indicates the sum of symbol errors since the OAM sublayer was reset. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.35. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.42.

h) ***Event Running Total.*** This four-octet field indicates the number of Errored Symbol Period Event TLVs that have been generated since the OAM sublayer was reset, encoded as a 32-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.35. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.42.

This event is generated at the end of the event window rather than when the threshold is crossed.

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57.5.3.2 Errored Frame Event TLV

The Errored Frame Event TLV counts the number of errored frames detected during the specified period. The period is specified by a time interval. This event is generated if the errored frame count is equal to or greater than the specified threshold for that period. Errored frames are frames that had transmission errors as detected at the Media Access Control sublayer as communicated via the reception_status parameter of the MA_DATA.indication service primitive. Refer to 4.2.9 for the definition of detectable transmission errors during reception.

The Errored Frame Event TLV shall have the following fields:

a) ***Event Type*** = *Errored Frame Event*. This one-octet field indicates the nature of the information carried in this TLV-tuple. The encoding of this field is found in Table 57–12.
b) ***Event Length.*** This one-octet field indicates the length (in octets) of this TLV-tuple. Errored Frame Event uses a length value of 26 (0x1A).
c) ***Event Time Stamp.*** This two-octet field indicates the time reference when the event was generated, in terms of 100 ms intervals, encoded as a 16-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.37. When received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.43.
d) ***Errored Frame Window.*** This two-octet field indicates the duration of the period in terms of 100 ms intervals, encoded as a 16-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.37. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.43.
    1) The default value is one second.
    2) The lower bound is one second.
    3) The upper bound is one minute.
e) ***Errored Frame Threshold.*** This four-octet field indicates the number of detected errored frames in the period is required to be equal to or greater than in order for the event to be generated, encoded as a 32-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.37. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.43.
    1) The default value is one frame error.
    2) The lower bound is zero frame errors.
    3) The upper bound is unspecified.
f) ***Errored Frames.*** This four-octet field indicates the number of detected errored frames in the period, encoded as a 32-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.37. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.43.
g) ***Error Running Total.*** This eight-octet field indicates the sum of errored frames that have been detected since the OAM sublayer was reset. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.37. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.43.
h) ***Event Running Total.*** This four-octet field indicates the number of Errored Frame Event TLVs that have been generated since the OAM sublayer was reset, encoded as a 32-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.37. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.43.

This event is generated at the end of the event window rather than when the threshold is crossed.

57.5.3.3 Errored Frame Period Event TLV

The Errored Frame Period Event TLV counts the number of errored frames detected during the specified period. The period is specified by a number of received frames. This event is generated if the errored frame count is greater than or equal to the specified threshold for that period (for example, if the errored frame count is greater than or equal to 10 for the last 1 000 000 frames received). Errored frames are frames that had transmission errors as detected at the Media Access Control sublayer as communicated via the reception_status parameter of the MA_DATA.indication service primitive. Refer to 4.2.9 for the definition of detectable transmission errors during reception.

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The Errored Frame Period Event TLV shall have the following fields:

a) ***Event Type*** = *Errored Frame Period Event*. This one-octet field indicates the nature of the information carried in this TLV-tuple. The encoding of this field is found in Table 57–12.

b) ***Event Length.*** This one-octet field indicates the length (in octets) of this TLV-tuple. Errored Frame Period Event uses a length value of 28 (0 x 1C).

c) ***Event Time Stamp.*** This two-octet field indicates the time reference when the event was generated, in terms of 100 ms intervals, encoded as a 16-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.39. When received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.44.

d) ***Errored Frame Window.*** This four-octet field indicates the duration of period in terms of frames, encoded as a 32-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.39. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.44.
   1) The default value is the number of minFrameSize frames that can be received in one second on the underlying Physical Layer.
   2) The lower bound is the number of minFrameSize frames that can be received in 100 ms on the underlying Physical Layer.
   3) The upper bound is the number of minFrameSize frames that can be received in one minute on the underlying Physical Layer.

e) ***Errored Frame Threshold.*** This four-octet field indicates the number of errored frames in the period is required to be equal to or greater than in order for the event to be generated, encoded as a 32-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.39. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.44.
   1) The default value is one frame error.
   2) The lower bound is zero frame errors.
   3) The upper bound is unspecified.

f) ***Errored Frames.*** This four-octet field indicates the number of frame errors in the period, encoded as a 32-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.39. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.44.

g) ***Error Running Total.*** This eight-octet field indicates the sum of frame errors that have been detected since the OAM sublayer was reset. When this event is generated by the local DTE and if Clause 30 is present, this maps to 330.3.6.1.39. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.44.

h) ***Event Running Total.*** This four-octet field indicates the number of Errored Frame Period Event TLVs that have been generated since the OAM sublayer was reset, encoded as a 32-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.39. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.44.

This event is generated at the end of the event window rather than when the threshold is crossed.

57.5.3.4 Errored Frame Seconds Summary Event TLV

The Errored Frame Seconds Summary Event TLV counts the number of errored frame seconds that occurred during the specified period. The period is specified by a time interval. This event is generated if the number of errored frame seconds is equal to or greater than the specified threshold for that period. An errored frame second is a one second interval wherein at least one frame error was detected. Errored frames are frames that had transmission errors as detected at the Media Access Control sublayer and communicated via the reception_status parameter of the MA_DATA.indication service primitive. Refer to 4.2.9 for the definition of detectable transmission errors during reception.

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The Errored Frame Seconds Summary Event TLV shall have the following fields:

a) ***Event Type*** = *Errored Frame Seconds Summary Event*. This one-octet field indicates the nature of the information carried in this TLV-tuple. The encoding of this field is found in Table 57–12.
b) ***Event Length.*** This one-octet field indicates the length (in octets) of this TLV-tuple. Errored Frame Seconds Summary Event uses a length value of 18 (0x12).
c) ***Event Time Stamp.*** This two-octet field indicates the time reference when the event was generated, in terms of 100 ms intervals, encoded as a 16-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.41. When received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.45.
d) ***Errored Frame Seconds Summary Window.*** This two-octet field indicates the duration of the period in terms of 100 ms intervals, encoded as a 16-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.41. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.45.
    1) The default value is 60 seconds.
    2) The lower bound is 10 seconds.
    3) The upper bound is 900 seconds.
e) ***Errored Frame Seconds Summary Threshold.*** This two-octet field indicates the number of errored frame seconds in the period is required to be equal to or greater than in order for the event to be generated, encoded as a 16-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.41. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.45.
    1) The default value is one errored second.
    2) The lower bound is zero errored seconds.
    3) The upper bound is unspecified.
f) ***Errored Frame Seconds Summary.*** This two-octet field indicates the number of errored frame seconds in the period, encoded as a 16-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.41. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.45.
g) ***Error Running Total.*** This four-octet field indicates the sum of errored frame seconds that have been detected since the OAM sublayer was reset. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.41. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.45.
h) ***Event Running Total.*** This four-octet field indicates the number of Errored Frame Seconds Summary Event TLVs that have been generated since the OAM sublayer was reset, encoded as a 32-bit unsigned integer. When this event is generated by the local DTE and if Clause 30 is present, this maps to 30.3.6.1.41. When this event is received from the remote DTE and if Clause 30 is present, this maps to 30.3.6.1.45.

This event is generated at the end of the event window rather than when the threshold is crossed.

57.5.3.5 Organization Specific Event TLVs

The optional Organization Specific Event TLV may be used by organizations to define extensions to the Event mechanisms in this clause. Organization Specific Event TLVs shall have the following fields:

a) ***Event Type*** = *Organization Specific Event*. This one-octet field indicates the nature of the information carried in this TLV-tuple. The encoding of this field is found in Table 57–12.
b) ***Event Length.*** This one-octet field indicates the length (in octets) of this TLV-tuple. The length of the Organization Specific Event is unspecified.
c) ***Organizationally Unique Identifier.*** This three-octet field shall contain a 24-bit Organizationally Unique Identifier.
d) ***Organization Specific Value.*** This field indicates the value of the Organization Specific Event. This field's length and contents are unspecified.

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57.6 Variables

MIB variables are queried through the use of Variable Request OAMPDUs and returned through the use of Variable Response OAMPDUs. Variable Request OAMPDUs, defined in 57.4.3.3, use data structures called Variable Descriptors (see 57.6.1). An OAM client may request one or more variables in each Variable Request OAMPDU.

Variable Response OAMPDUs, defined in 57.4.3.4, use data structures called Variable Containers (see 57.6.2). Each returned Variable Container resides within a single Variable Response OAMPDU. If a Variable Container does not fit within a Variable Response OAMPDU, an error code is returned. In returning requested variables, an OAM client generates at least one and perhaps additional Variable Response OAMPDUs per received Variable Request OAMPDU. The following subclauses describe the format of Variable Descriptors and Variable Containers.

See 57.6.3 for a description of the parsing rules for Variable Descriptors and Variable Containers.

57.6.1 Variable Descriptors

A Variable Descriptor is used to request MIB attributes, objects and packages and uses the encodings found in Annex B of IEEE Std 802.3.1. The Variable Descriptor structure shall be as shown in Table 57–13.

Table 57–13—Variable Descriptor format

Octet(s)	Name	Description
1	Variable Branch	As defined in Annex B of IEEE Std 802.3.1, Variable Branches may reference attributes, objects or packages. If an object or package is referenced, only the attributes within the object or package shall be found within the Variable Container. Actions shall not be found within Variable Containers.
2	Variable Leaf	The Variable Leaf field is derived from the encodings found in Annex B of IEEE Std 802.3.1.

57.6.2 Variable Containers

Variable Containers are used to return MIB attributes, objects and packages. One or more Variable Containers may exist in the Data field of a Variable Response OAMPDU (see 57.4.3.4).

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57.6.2.1 Format of Variable Containers when returning attributes

The Variable Container structure for an attribute shall be as shown in Table 57–14.

Table 57–14—Variable Container format when returning an attribute

Octet(s)	Name	Description
1	Variable Branch	Derived from the encodings found in Annex B of IEEE Std 802.3.1, Variable Branches may reference attributes, objects or packages. If an object or package is referenced, only the attributes within the object or package shall be found within the Variable Container. Actions shall not be found within Variable Containers.
2	Variable Leaf	The Variable Leaf field is derived from the encodings found in Annex B of IEEE Std 802.3.1.
1	Variable Width	When bit 7 = 1, bits 6:0 represent a Variable Indication. Refer to Table 57–17 for the encoding of bits 6:0. There is no Variable Value field when bit 7 = 1. When bit 7 = 0, bits 6:0 represent the length of the Variable Value field in octets. An encoding of 0x00 equals 128 octets. All other encodings represent actual lengths.
varies	Variable Value	The Variable Value field may be 1 to 128 octets in length. Its width is determined by the Variable Width field.

The first field is the one-octet Variable Branch field. The second field is the two-octet Variable Leaf field. See Table 57–16 for examples of Variable Branch and Variable Leaves. The third field is the dual purpose one-octet Variable Width field. This field either contains the actual width of the attribute or a Variable Indication providing information as to the reason this particular attribute could not be returned. See Table 57–17 for the defined Variable Indications. If the Variable Width field contains a width value, the fourth field is the Variable Value field, which contains the attribute. This field may be up to 128 octets in length. Octets of the attribute are ordered most significant first, followed by each successive octet. If the Variable Width field contains a Variable Indication, the Variable Value field does not exist.

Additionally, a special Variable Container with Variable Branch and Leaf values corresponding to an object identification number (such as 7/330 for a PME ID, or 7/282 for an EPON LLID), Variable Width equal to 2, and Variable Value equal to a 2-octet identification number, may be used in a Variable Request OAMPDU to select a particular instance of a managed object of which multiple instances exist in the remote MIB.

The Variable Value identifies which instance is being addressed. Subsequent Variable Descriptors shall be understood to target the attributes of the selected instance until an other instance selector is received or the Variable Request OAMPDU ends. Each instance selector shall be acknowledged with a Variable Container indicating the same Branch/Leaf and the identifier that was selected, preceding the concerned variables. If no explicit instance selection has taken place, all instances of the concerned object are addressed. In this case, each subsequent Variable Descriptor shall be understood to consecutively target the attributes of all existing instances until an instance selector is received or the Variable Request OAMPDU ends.

The Variable Containers returned by the far-end OAM client may be transmitted in one or more OAMPDUs, respecting the OAMPDU size limitations.

NOTE—In the case of PME Aggregation, each PME is identified by a bit position in a 32-bit string during the Handshake process. This position should be transformed into a number between 0 and 31 before transmission in the Variable Value field.

57.6.2.2 Format of Variable Containers when returning packages and objects

The Variable Container structure for packages and objects shall be as shown in Table 57–15.

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Table 57–15—Variable Container format when returning packages and objects

Octet(s)	Name	Description
1	Variable Branch	Derived from the encodings found in Annex B of IEEE Std 802.3.1, Variable Branches may reference attributes, objects or packages. If an object or package is referenced, only the attributes within the object or package shall be found within the Variable Container. Actions shall not be found within Variable Containers.
2	Variable Leaf	The Variable Leaf field is derived from the encodings found in Annex B of IEEE Std 802.3.1.
1	Variable Width	When bit 7 = 1, bits 6:0 represent a Variable Indication. Refer to Table 57–17 for the encoding of bits 6:0. There is no Variable Value field when bit 7 = 1. When bit 7 = 0, bits 6:0 represent the length of the Variable Value field in octets. An encoding of 0x00 equals 128 octets. All other encodings represent actual lengths.
varies	Variable Value	The Variable Value field may be 1 to 128 octets in length. Its width is determined by the Variable Width field.

A package is defined as a set of MIB attributes and/or actions. An object is a set of packages, which in turn are made up of MIB attributes and/or actions. Variable Containers provide an efficient method for returning packages and objects. Objects are returned in the order they are listed in Annex B of IEEE Std 802.3.1.

The Variable Container structure for packages and objects is similar to the structure for attributes. The first field is the one-octet Variable Branch field for the specific package or object being returned. The second field is the two-octet Variable Leaf field for the specific package or object being returned. See Table 57–16 for examples of Variable Branch and Variable Leaves. The third field is the dual purpose one-octet Variable Width field of the first attribute within the package or object being returned. This field either contains the actual width of the attribute or a Variable Indication providing information as to the reason this particular attribute could not be returned. See Table 57–17 for the defined Variable Indications. If the Variable Width field contains a width value, the fourth field is the Variable Value field, which contains the first attribute of the package or object being returned. This field may be up to 128 octets in length. Octets of the attribute are ordered most significant first, followed by each successive octet. If the Variable Width field contains a Variable Indication, the Variable Value field does not exist.

For each successive attribute within the package, the third field (Variable Width) and fourth field (Variable Value), if applicable, are repeated.

For each successive attribute within each successive package of the object, the third field (Variable Width) and fourth field (Variable Value), if applicable, are repeated.

57.6.3 Parsing

The OAM client parses Variable Descriptors and Variable Containers. All Variable Descriptors/Containers contain a one-octet Variable Branch field and a two-octet Variable Leaf field. Variable Descriptor/Container processing should follow these recommendations:

a) Detection of a Variable Branch field equal to 0x00 should indicate there are no more Variable Descriptors/Containers to process (subsequent fields can be ignored).
b) Variable Branch or Variable Leaf fields with unknown or unexpected values should be ignored.
c) If a Variable Width field indicates Variable Container extends beyond the frame (e.g., the length cannot fit into the frame given its length and starting point), then the Variable Container should be ignored.

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d) Detection of a Variable Indication value equal to 0x40 should indicate there are no more attributes within the object to process.
e) Detection of a Variable Indication value equal to 0x60 should indicate there are no more objects within the package to process.
f) Detection of a Variable Container in a Variable Request OAMPDU indicates that subsequent Variable Descriptors shall be applied to the instance of the managed object corresponding to the identification number expressed in the Variable Value field of the Variable Container. In the corresponding Variable Response OAMPDU, a Variable Container indicating the selected instance shall immediately precede the Variable Containers pertaining to objects of which a particular instance was selected.

57.6.4 Variable Branch/Leaf examples

Table 57–16 contains a set of example branch and leaf values for attributes, packages and objects.

Table 57–16—Variable Branch/Leaf examples

Variable Type	Variable Name	Variable	
		Branch	Leaf
attribute	aFramesTransmittedOK	0x07	0x0002
attribute	aFramesReceivedOK	0x07	0x0005
package	pMandatory	0x04	0x0001
package	pRecommended	0x04	0x0002
object	oMACEntity	0x03	0x0001
object	oPHYEntity	0x03	0x0002

57.6.5 Variable Indications

If a DTE is unable to retrieve one or more variables, the Variable Container is used to return the appropriate Variable Indication for the particular variable(s). The Variable Indications are defined in Table 57–17.

Table 57–17—Variable indications

Coding	Indication
0x00	*Reserved—shall not be transmitted, should be ignored on reception by OAM client*
0x01	Length of requested Variable Container(s) exceeded OAMPDU data field.
0x02 to 0x1F	*Reserved—shall not be transmitted, should be ignored on reception by OAM client*
Attribute Indications	
0x20	Requested attribute was unable to be returned due to an undetermined error.
0x21	Requested attribute was unable to be returned because it is not supported by the local DTE.
0x22	Requested attribute may have been corrupted due to reset.
0x23	Requested attribute unable to be returned due to a hardware failure.
0x24	Requested attribute experienced an overflow error.
0x25 to 0x3F	*Reserved—shall not be transmitted, should be ignored on reception by OAM client*
Object Indications	
0x40	End of object indication.

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Table 57–17—Variable indications *(continued)*

Coding	Indication
0x41	Requested object was unable to be returned due to an undetermined error.
0x42	Requested object was unable to be returned because it is not supported by the local DTE.
0x43	Requested object may have been corrupted due to reset.
0x44	Requested object unable to be returned due to a hardware failure.
0x45 to 0x5F	*Reserved—shall not be transmitted, should be ignored on reception by OAM client*
Package Indications	
0x60	End of package indication.
0x61	Requested package was unable to be returned due to an undetermined error.
0x62	Requested package was unable to be returned because it is not supported by the local DTE.
0x63	Requested package may have been corrupted due to reset.
0x64	Requested package unable to be returned due to a hardware failure.
0x65 to 0x7F	*Reserved—shall not be transmitted, should be ignored on reception by OAM client*

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57.7 Protocol implementation conformance statement (PICS) proforma for Clause 57, Operations, Administration, and Maintenance (OAM)[5]

57.7.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 57, Operations, Administration, and Maintenance (OAM), shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

57.7.2 Identification

57.7.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

57.7.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 57, Operations, Administration, and Maintenance (OAM)
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	

Date of Statement	

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[5]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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57.7.2.3 Major capabilities/options

Item	Feature	Subclause/ Table	Value/Comment	Status	Support
OM	OAM object class	30.3.6		O	Yes [ ] No [ ]
CSI	OAM client service interfaces	57.2.5		M	Yes [ ]
ISI	Internal service interfaces	57.2.8		M	Yes [ ]
*ACTV	Active mode	57.2.9		O.1	Yes [ ] No [ ]
*PASS	Passive mode	57.2.9		O.1	Yes [ ] No [ ]
*LB	OAM remote loopback	57.2.11, Table 57–8		O	Yes [ ] No [ ]
UNI	Unidirectional operation	57.2.12, Table 57–8	Requires support for unidirectional operation as defined in Clause 66.	O	Yes [ ] No [ ]
*EVNT	Link Events	57.4.3.2, 57.5.3		O	Yes [ ] No [ ]
*VAR	Variable Retrieval	57.4.3.3, 57.4.3.4		O	Yes [ ] No [ ]
*OSP	Organization Specific OAMPDU	57.4.3.6		O	Yes [ ] No [ ]
*OSE	Organization Specific Events	57.5.3.5		O	Yes [ ] No [ ]
OSI	Organization Specific Information TLV	57.5.2.3		O	Yes [ ] No [ ]

57.7.3 PICS proforma tables for Operation, Administration, and Maintenance (OAM)

57.7.3.1 Functional specifications

Item	Feature	Subclause/ Table	Value/Comment	Status	Support
OFS1	Passive mode limited transmission	57.2.9.2	Cannot send Variable Request or Loopback Control OAMPDUs	PASS:M	Yes [ ] No [ ] N/A [ ]
OFS2	Discovery state diagram	57.3.2.1	Implemented as defined in Figure 57–5	M	Yes [ ]
OFS3	Transmit state diagram	57.3.2.2	Implemented as defined in Figure 57–6	M	Yes [ ]
OFS4	OAMPDU transmission when local_pdu is set to LF_INFO	57.3.2.2.6	Only Information OAMPDUs with Link Fault bit of Flags field and without Information TLVs can be transmitted	M	Yes [ ]
OFS5	OAMPDU transmission when local_pdu is set to RX_INFO	57.3.2.2.6	No OAMPDU transmission allowed	M	Yes [ ]
OFS6	OAMPDU transmission when local_pdu is set to INFO	57.3.2.2.6	Only Information OAMPDUs can be transmitted	M	Yes [ ]

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Item	Feature	Subclause/ Table	Value/Comment	Status	Support
OFS7	OAMPDU transmission when local_pdu is set to ANY: OAM_CTL.request service primitive with one or more critical link event parameters	57.3.2.2.6	Requests transmission of Information OAMPDU with appropriate bits of Flags field set	M	Yes [ ]
OFS8	OAMPDU.request service primitive	57.3.2.2.6	Requests transmission of OAMPDU	M	Yes [ ]
OFS9	OAMPDU Flags field reserved encodings Remote Stable and Remote Evaluating bits	Table 57–3	Encoding of 0x3 is not transmitted	M	Yes [ ]
OFS10	Local Stable and Local Evaluating bits	Table 57–3	Encoding of 0x3 is not transmitted	M	Yes [ ]
OFS11	Reserved bits	Table 57–3	Reserved bits are zero on transmission	M	Yes [ ]
OFS12	OAMPDU Code field	57.4.2.2	Only defined Code field values are permitted in transmitted OAMPDUs	M	Yes [ ]
OFS13	OAMPDU reception when local_pdu is not set to ANY	57.3.2.3	Only Information OAMPDUs are sent to OAM client entity	M	Yes [ ]
OFS14	OAMPDU reception when local_pdu is set to ANY	57.3.2.3	All OAMPDUs are sent to OAM client entity	M	Yes [ ]
OFS15	Multiplexer state diagram	57.3.3	Implemented as defined in Figure 57–7	M	Yes [ ]
OFS16	Multiplexer transparent pass-through	57.3.3.2	Provide transparent pass-through of frames from superior sublayer to subordinate sublayer	M	Yes [ ]
OFS17	Effect of OAMPDU on a frame already submitted to subordinate sublayer	57.3.3.2	Has no effect	M	Yes [ ]
OFS18	Parser state diagram	57.3.4	Implemented as defined in Figure 57–8	M	Yes [ ]

57.7.3.2 Event Notification Generation and Reception

Item	Feature	Subclause/ Table	Value/Comment	Status	Support
EV1	Response to Critical Events	57.2.10.3	Set/clear Flag bits based on OAM_CTL.request service primitive	M	Yes [ ]
EV2	Critical Event reception	57.2.10.4	Indicated via Flags field of OAMPDU.indication service primitive	M	Yes [ ]
EV3	Link Event reception	57.2.10.4	Indicated via OAMPDU.indication service primitive with all received Event Notification OAMPDUs	EVNT:M	Yes [ ] N/A [ ]

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57.7.3.3 OAMPDUs

Item	Feature	Subclause/ Table	Value/Comment	Status	Support
PDU2	OAMPDU structure	57.4.2	As defined in Figure 57–9 and field definitions	M	Yes [ ]
PDU3	Minimum OAMPDU size	57.4.2	Support OAMPDUs minFrame-Size in length	M	Yes [ ]
PDU4	Information OAMPDU frame structure	57.4.3.1	Shown in Figure 57–10	M	Yes [ ]
PDU5	Information OAMPDU when local_pdu set to LF_INFO	57.4.3.1	Data field contains zero Information TLVs	M	Yes [ ]
	Information OAMPDU when local _pdu not set to LF_INFO				
PDU6	remote_state_valid=FALSE	57.4.3.1	Data field contains Local Information TLV	M	Yes [ ]
PDU7	remote_state_valid=TRUE	57.4.3.1	Data field contains Local and Remote Information TLVs	M	Yes [ ]
PDU8	Type values 0x03-0xFD	Table 57–6	Not to be sent	M	Yes [ ]
PDU9	Type value 0xFF	Table 57–6	Not to be sent	M	Yes [ ]
PDU10	Event Notification OAMPDU frame structure	57.4.3.2	Shown in Figure 57–11	EVNT:M	Yes [ ] N/A [ ]
PDU11	Event Notification OAMPDU Sequence Number	57.4.3.2	The first two bytes of the Data field contain a Sequence Number encoded as an unsigned 16-bit integer	EVNT:M	Yes [ ] N/A [ ]
PDU12	Event Notification OAMPDU Event(s)	57.4.3.2	Data field containing one or more Link Event TLVs following the Sequence Number	EVNT:M	Yes [ ] N/A [ ]
PDU13	Variable Request OAMPDU frame structure	57.4.3.3	Shown in Figure 57–12	VAR * ACTV:M	Yes [ ] No [ ] N/A [ ]
PDU14	Variable Request OAMPDU Data field	57.4.3.3	Data field contains one or more Variable Descriptors	VAR * ACTV:M	Yes [ ] N/A [ ]
PDU15	Variable Response OAMPDU frame structure	57.4.3.4	Shown in Figure 57–13	VAR:M	Yes [ ] N/A [ ]
PDU16	Variable Response OAMPDU Data field	57.4.3.4	Data field contains one or more Variable Containers	VAR:M	Yes [ ] N/A [ ]
PDU17	Loopback Control OAMPDU frame structure	57.4.3.5	Shown in Figure 57–14	!PASS * LB:M	Yes [ ] N/A [ ]
PDU18	Loopback Control OAMPDU Data field	57.4.3.5	Data field contains a single OAM Remote Loopback command from Table 57–5	!PASS * LB:M	Yes [ ] N/A [ ]
PDU19	Command value 0x00	Table 57–5	Not to be sent	!PASS * LB:M	Yes [ ] N/A [ ]
PDU20	Command values 0x03–0xFF	Table 57–5	Not to be sent	!PASS * LB:M	Yes [ ] N/A [ ]
PDU21	Organization Specific OAMPDU frame structure	57.4.3.6	Shown in Figure 57–15	OSP:M	Yes [ ] N/A [ ]
PDU22	Organization Specific OAMPDU Organizationally Unique Identifier field	57.4.3.6	Contains 24-bit Organizationally Unique Identifier	OSP:M	Yes [ ] N/A [ ]

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57.7.3.4 Local Information TLVs

Item	Feature	Subclause/ Table	Value/Comment	Status	Support
LIT1	Local Information TLV	57.5.2.1	Contains the following fields: Information Type, Information Length, OAM Version, Revision, State, OAM Configuration, OAMPDU Configuration, OUI/CID, Vendor Specific Information	M	Yes [ ]
LIT2	Local Information TLV OAM Version field	57.5.2.1	Contains 0x01 to claim compliance to this specification	M	Yes [ ]
LIT3	Local Information TLV Revision Field	57.5.2.1	Starts at zero and incremented each time a Local Information TLV field changes	M	Yes [ ]
LIT4	Local Information TLV State field	57.5.2.1	As defined in Table 57–7	M	Yes [ ]
LIT5	Local Information TLV State field Parser Action 0x3 value	57.5.2.1	Is not transmitted	M	Yes [ ]
LIT6	Reserved bits	Table 57–7	Reserved bits are zero on transmission	M	Yes [ ]
LIT7	Local Information TLV OAM Configuration field	57.5.2.1	As defined in Table 57–8	M	Yes [ ]
LIT8	Reserved bits	Table 57–8	Reserved bits are zero on transmission	M	Yes [ ]
LIT9	Local Information TLV OAMPDU Configuration field	57.5.2.1	As defined in Table 57–9	M	Yes [ ]
LIT10	Local Information TLV OUI/ CID field	57.5.2.1	As defined in Table 57–10	M	Yes [ ]
LIT11	Reserved bits	Table 57–9	Reserved bits are zero on transmission	M	Yes [ ]
LIT12	Local Information TLV Vendor Specific Information field	57.5.2.1	As defined in Table 57–11	M	Yes [ ]

57.7.3.5 Remote Information TLVs

Item	Feature	Subclause	Value/Comment	Status	Support
RIT1	Remote Information TLV	57.5.2.2	Contains the Information Type field specifying the Remote Information TLV Type value and all remaining fields are copied from the last received Local Information TLV from remote OAM peer	M	Yes [ ]

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57.7.3.6 Organization Specific Information TLVs

Item	Feature	Subclause	Value/Comment	Status	Support
OIT1	Organization Specific Information TLV	57.5.2.3	Contains the following fields: Information Type, Information Length, OUI/CID, Organization Specific Value	M	Yes [ ]
OIT2	Organization Specific Information TLV OUI field	57.5.2.3	Contains 24-bit OUI/CID	M	Yes [ ]

57.7.4 Link Event TLVs

Item	Feature	Subclause/ Table	Value/Comment	Status	Support
ET1	Errored Symbol Period Event TLV structure	57.5.3.1	Contains the following fields: Event Type, Event Length, Event Time Stamp, Errored Symbol Window, Errored Symbol Threshold, Errored Symbols, Error Running Total, Event Running Total	EVNT:M	Yes [ ] N/A [ ]
ET2	Errored Frame Event TLV structure	57.5.3.2	Contains the following fields: Event Type, Event Length, Event Time Stamp, Errored Frame Window, Errored Frame Threshold, Errored Frames, Error Running Total, Event Running Total	EVNT:M	Yes [ ] N/A [ ]
ET3	Errored Frame Period Event TLV structure	57.5.3.3	Contains the following fields: Event Type, Event Length, Event Time Stamp, Errored Frame Window, Errored Frame Threshold, Errored Frames, Error Running Total, Event Running Total	EVNT:M	Yes [ ] N/A [ ]
ET4	Errored Frame Seconds Summary Event TLV structure	57.5.3.4	Contains the following fields: Event Type, Event Length, Event Time Stamp, Errored Frame Seconds Summary Window, Errored Frame Seconds Summary Threshold, Errored Frame Seconds Summary, Error Running Total, Event Running Total	EVNT:M	Yes [ ] N/A [ ]
ET5	Organization Specific Event TLV structure	57.5.3.5	Contains the following fields: Event Type, Event Length, Organizationally Unique Identifier, Organization Specific Value	EVNT * OSE:M	Yes [ ] N/A [ ]
ET6	Organization Specific Event Organizationally Unique Identifier field	57.5.3.5	Contains 24-bit Organizationally Unique Identifier	EVNT * OSE:M	Yes [ ] N/A [ ]
ET7	Type values 0x05 to 0xFD	Table 57–12	Not to be sent	EVNT:M	Yes [ ] N/A [ ]
ET8	Type value 0xFF	Table 57–12	Not to be sent	EVNT:M	Yes [ ] N/A [ ]

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57.7.5 Variables Descriptors and Containers

Item	Feature	Subclause/ Table	Value/Comment	Status	Support
VAR1	Variable Descriptor structure	57.6.1	As defined in Table 57–13	VAR * ACTV:M	Yes [ ] N/A [ ]
	Variable Descriptor / Variable Branch				
VAR2	references attributes	57.6.1	If an object or package is referenced, only attributes can be found within Variable Container	VAR * ACTV:M	Yes [ ] N/A [ ]
VAR3	does not reference actions	57.6.1	Actions are not found in Variable Containers	VAR * ACTV:M	Yes [ ] N/A [ ]
VAR4	Variable Container structure for an attribute	57.6.2	As defined in Table 57–14	VAR:M	Yes [ ] N/A [ ]
	Variable Container / Variable Branch				
VAR5	references attributes	57.6.2	If an object or package is referenced, only attributes can be found within Variable Container	VAR:M	Yes [ ] N/A [ ]
VAR6	does not reference actions	57.6.2	Actions are not found in Variable Containers	VAR:M	Yes [ ] N/A [ ]
VAR7	Type value 0x00	Table 57–16	Not to be sent	VAR:M	Yes [ ] N/A [ ]
VAR8	Type values 0x02 to 0x1F	Table 57–16	Not to be sent	VAR:M	Yes [ ] N/A [ ]
VAR9	Type values 0x25 to 0x2F	Table 57–16	Not to be sent	VAR:M	Yes [ ] N/A [ ]
VAR10	Type values 0x45 to 0x5F	Table 57–16	Not to be sent	VAR:M	Yes [ ] N/A [ ]
VAR11	Type values 0x65 to 0x7F	Table 57–16	Not to be sent	VAR:M	Yes [ ] N/A [ ]

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58. Physical Medium Dependent (PMD) sublayer and medium, type 100BASE-LX10 (Long Wavelength) and 100BASE-BX10 (BiDirectional Long Wavelength)

58.1 Overview

The 100BASE-LX10 and 100BASE-BX10 PMD sublayers provide point-to-point 100 Mb/s Ethernet links over a pair of single-mode fibers or an individual single-mode fiber, respectively, up to at least 10 km. They complement 100BASE-TX (twisted-pair cable, see Clause 25) and 100BASE-FX (multimode fiber, see Clause 26).

This clause specifies the 100BASE-LX10 PMD and the 100BASE-BX10 PMDs for operation over single-mode fiber. A PMD is connected to the 100BASE-X PMA of 66.1, and to the medium through the MDI. A PMD is optionally combined with the management functions that may be accessible through the management interface defined in Clause 22 or by other means.

Table 58–1 shows the primary attributes of each PMD type.

Table 58–1—Classification of 100BASE-LX10 and 100BASE-BX10

Description	100BASE-LX10	100BASE-BX10-D	100BASE-BX10-U	Unit
Fiber type	B1.1, B1.3 SMF[a]			
Number of fibers	2	1		
Typical transmit direction	Any	Downstream	Upstream	
Nominal transmit wavelength	1310	1550	1310	nm
Minimum range	0.5 m to 10 km			
Maximum channel insertion loss[b]	6.0	5.5	6.0	dB

[a]Specified in IEC 60793-2.
[b]At the nominal wavelength.

A 100BASE-LX10 link uses 100BASE-LX10 PMDs at each end while a 100BASE-BX10 link uses a 100BASE-BX10-D PMD at one end and a 100BASE-BX10-U PMD at the other. Typically, the 1550 nm band is used to transmit away from the center of the network (“downstream”) and the 1310 nm band towards the center (“upstream”), although this arrangement, or the notion of hierarchy, is not required. The suffixes “D” and “U” indicate the PMDs at each end of a link which transmit in these directions and receive in the opposite directions.

Two optional temperature ranges are defined; see 58.8.4 for further details. Implementations may be declared as compliant over one or both complete ranges, or not so declared (compliant over parts of these ranges or another temperature range).

58.1.1 Goals and objectives

The following are the objectives of 100BASE-LX10 and 100BASE-BX10:

a) Point-to-point on optical fiber
b) 100BASE-X up to at least 10 km over single-mode fiber (SMF)
c) BER better than or equal to 10^{-12} at the PHY service interface

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58.1.2 Positioning of this PMD set within the IEEE 802.3 architecture

Figure 58–1 depicts the relationships of the PMD (shown shaded) with other sublayers and the ISO/IEC Open System Interconnection (OSI) reference model.

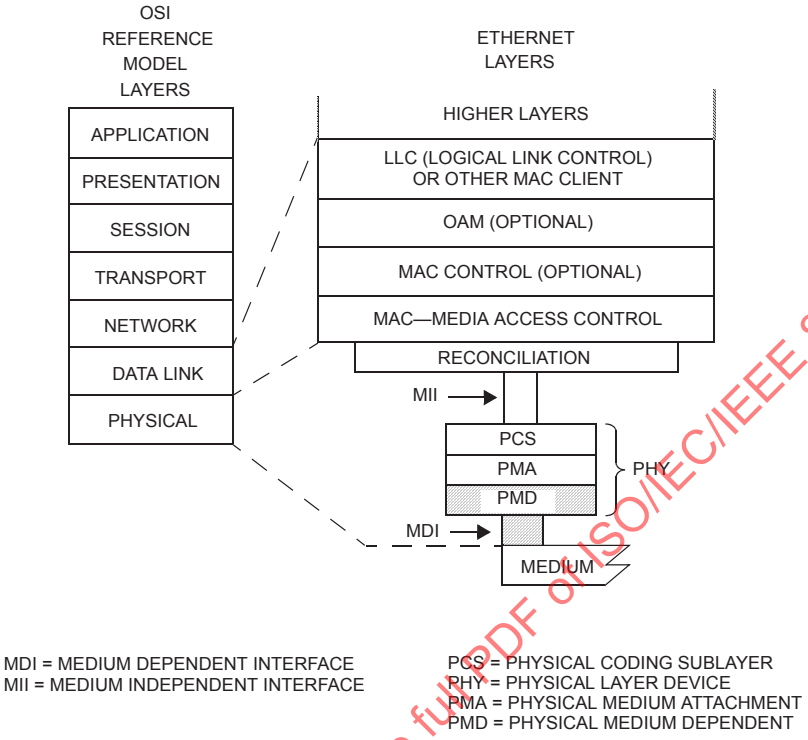

Figure 58–1—100BASE-LX10 and 100BASE-BX10 PMDs relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

58.1.3 Terminology and conventions

The following list contains references to terminology and conventions used in this clause:

Basic terminology and conventions, see 1.1 and 1.2.

Normative references, see 1.3.

Definitions, see 1.4.

Abbreviations, see 1.5.

Informative references shown referenced in the format [Bn], see Annex A.

Introduction to 100 Mb/s baseband networks, see Clause 21.

Introduction to Ethernet for subscriber access networks, see Clause 56

58.1.4 Physical Medium Dependent (PMD) sublayer service interface

The following specifies the services provided by the 100BASE-LX10 and 100BASE-BX10 PMDs. These PMD sublayer service interfaces are described in an abstract manner and do not imply any particular implementation.

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The PMD service interface supports the exchange of NRZI encoded 4B/5B bit streams between the PMA and PMD entities. The PMD translates the serialized data of the PMA to and from signals suitable for the specified medium.

The following primitives are defined:

PMD_UNITDATA.request

PMD_UNITDATA.indication

PMD_SIGNAL.indication

58.1.4.1 Delay constraints

Delay requirements which affect the PMD layer are specified in 24.6. Of the budget, up to 12 ns is reserved for each of the transmit and receive functions of the PMD to account for those cases where the PMD includes a pigtail.

58.1.4.2 PMD_UNITDATA.request

This primitive defines the transfer of a serial data stream from the PMA to the PMD.

The semantics of the service primitive are PMD_UNITDATA.request(tx_bit). The data conveyed by PMD_UNITDATA.request is a continuous stream of bits where the tx_bit parameter can take one of two values: ONE or ZERO. The PMA continuously sends the appropriate stream of bits to the PMD for transmission on the medium, at a nominal 125 MBd signaling speed. Upon receipt of this primitive, the PMD converts the specified stream of bits into the appropriate signals at the MDI.

58.1.4.3 PMD_UNITDATA.indication

This primitive defines the transfer of data from the PMD to the PMA.

The semantics of the service primitive are PMD_UNITDATA.indication(rx_bit). The data conveyed by PMD_UNITDATA.indication is a continuous stream of bits where the rx_bit parameter can take one of two values: ONE or ZERO. The PMD continuously sends a stream of bits to the PMA corresponding to the signals received from the MDI.

58.1.4.4 PMD_SIGNAL.indication

This primitive is generated by the PMD to indicate the status of the signal being received from the MDI.

The semantics of the service primitive are PMD_SIGNAL.indication(SIGNAL_DETECT). The SIGNAL_DETECT parameter can take on one of two values: OK or FAIL, indicating whether the PMD is detecting light at the receiver (OK) or not (FAIL). When SIGNAL_DETECT = FAIL, PMD_UNITDATA.indication(rx_bit) is undefined. The PMD generates this primitive to indicate a change in the value of SIGNAL_DETECT.

NOTE—SIGNAL_DETECT = OK does not guarantee that PMD_UNITDATA.indication(rx_bit) is known good. It is possible for a poor quality link to provide sufficient light for a SIGNAL_DETECT = OK indication and still not meet the specified bit error ratio.

58.2 PMD functional specifications

The 100BASE-X PMDs perform the transmit and receive functions that convey data between the PMD service interface and the MDI.

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58.2.1 PMD block diagram

The PMD sublayer is defined at the four reference points shown in Figure 58–2. Two points, TP2 and TP3, are compliance points. TP1 and TP4 are reference points for use by implementers. The optical transmit signal is defined at the output end of a patch cord (TP2), between 2 and 5 m in length, of single-mode fiber. Unless specified otherwise, all transmitter measurements and tests defined in 58.7 are made at TP2. The optical receive signal is defined at the output of the fiber optic cabling (TP3) connected to the receiver. Unless specified otherwise, all receiver measurements and tests defined in 58.7 are made at TP3.

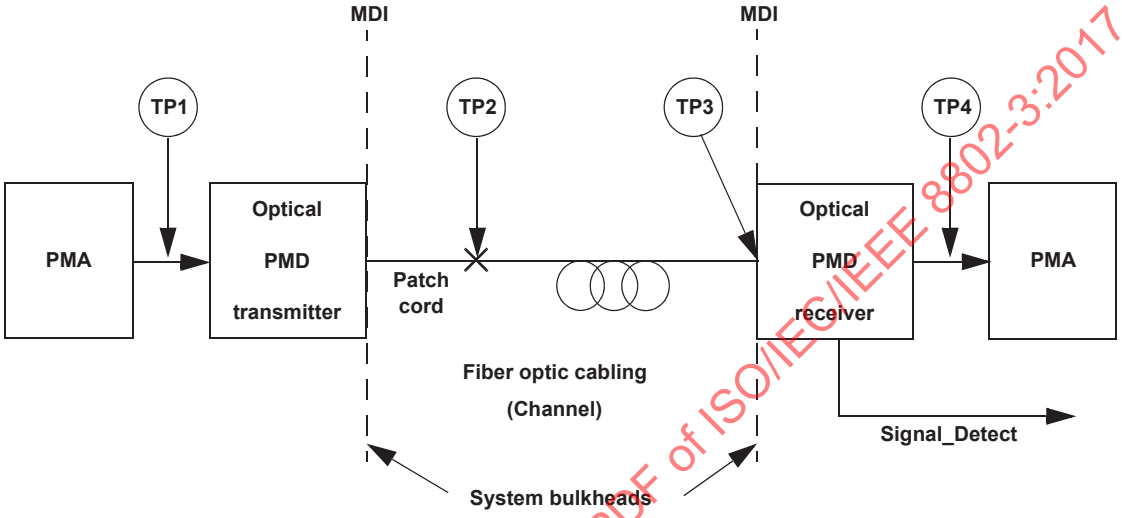

Figure 58–2—100BASE-X block diagram

The electrical specifications of the PMD service interface (TP1 and TP4) are not system compliance points (these are not readily testable in a system implementation). It is expected that in many implementations, TP1 and TP4 will be common between 100BASE-LX10, 100BASE-BX10-D, 100BASE-BX10-U, and 100BASE-FX (multimode fiber, see Clause 26).

58.2.2 PMD transmit function

The PMD transmit function shall convey the bits requested by the PMD service interface message PMD_UNITDATA.request(tx_bit) to the MDI according to the optical specifications in this clause. The higher optical power level should correspond to tx_bit = ONE.

NOTE—Because the NRZI coding distinguishes between a transition and no transition on the line, as opposed to 0 and 1, an inverted signal is usable.

58.2.3 PMD receive function

The PMD receive function shall convey the bits received from the MDI according to the optical specifications in this clause to the PMD service interface using the message PMD_UNITDATA.indication(rx_bit). The higher optical power level should correspond to rx_bit = ONE.

NOTE—Because the NRZI coding distinguishes between a transition and no transition on the line, as opposed to 0 and 1, an inverted signal is usable.

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58.2.4 100BASE-LX10 and 100BASE-BX10 signal detect function

The PMD signal detect function shall report to the PMD service interface, using the message PMD_SIGNAL.indication(SIGNAL_DETECT), which is signaled continuously. PMD_SIGNAL.indication is intended to be an indicator of optical signal presence.

The value of the SIGNAL_DETECT parameter for 100BASE-LX10 and 100BASE-BX10 shall be generated according to the conditions defined in Table 58–2. The PMD receiver is not required to verify whether a compliant 100BASE-LX10 signal or 100BASE-BX10 signal is being received. This standard imposes no response time requirements on the generation of the SIGNAL_DETECT parameter.

Table 58–2—100BASE-LX10 and 100BASE-BX10 SIGNAL_DETECT value definition

Receive conditions		SIGNAL_DETECT value
100BASE-LX10	**100BASE-BX10**	
Average input optical power ≤ Signal detect threshold (min) in Table 58–4	Average input optical power ≤ Signal detect threshold (min) in Table 58–6	FAIL
Average input optical power ≥ Receiver sensitivity (max) in Table 58–4 with a compliant 100BASE-LX10 signal input	Average input optical power ≥ Receiver sensitivity (max) in Table 58–6 with a compliant 100BASE-BX10 signal input at the specified receiver wavelength	OK
All other conditions		Unspecified

As an unavoidable consequence of the requirements for the setting of the SIGNAL_DETECT parameter, implementations must provide adequate margin between the input optical power level at which the SIGNAL_DETECT parameter is set to OK, and the inherent noise level of the PMD due to cross talk, power supply noise, etc.

Various implementations of the signal detect function are permitted by this standard, including implementations that generate the SIGNAL_DETECT parameter values in response to the amplitude of the modulation of the optical signal and implementations that respond to the average optical power of the modulated optical signal.

58.3 PMD to MDI optical specifications for 100BASE-LX10

The operating range for 100BASE-LX10 is defined in Table 58–1. A 100BASE-LX10 compliant transceiver operates over the media types listed in Table 58–1 according to the specifications described in 58.9. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant.

NOTE—In this subclause and 58.4, the specifications for OMA have been derived from extinction ratio and average launch power (minimum) or receiver sensitivity (maximum). The calculation is explained in 58.7.6.

58.3.1 Transmitter optical specifications

The 100BASE-LX10 transmitter's signaling speed, operating wavelength, spectral width, average launch power, extinction ratio, return loss tolerance, OMA, eye and TDP shall meet the specifications defined in Table 58–3 per measurement techniques described in 58.7. Its $RIN_{12}OMA$ should meet the value listed in Table 58–3 per measurement techniques described in 58.7.7.

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Table 58–3—100BASE-LX10 transmit characteristics

Description	Type B1.1, B1.3 SMF	Unit
Transmitter type[a]	Longwave laser	
Signaling speed (range)	125 ± 50 ppm	MBd
Operating wavelength range[b]	1260 to 1360	nm
RMS spectral width (max)	7.7	nm
Average launch power (max)	–8	dBm
Average launch power (min)	–15	dBm
Average launch power of OFF transmitter (max)	–45	dBm
Extinction ratio (min)	5	dB
$RIN_{12}OMA$[c] (max)	–110	dB/Hz
Optical return loss tolerance (max)	12	dB
Launch OMA (min)	–14.8 (33.1)	dBm (μW)
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3, Y4}	{0.18, 0.29, 0.35, 0.35, 0.38, 0.4, 0.55}	UI
Transmitter and dispersion penalty (max)	4.5	dB
Decision timing offsets for transmitter and dispersion penalty (min)	±1.6	ns

[a]The nominal transmitter type is not intended to be a requirement on the source type, and any transmitter meeting the transmitter characteristics specified may be substituted for the nominal transmitter type.
[b]The great majority of the transmitted spectrum must fall within the operating wavelength range, see 58.7.2.
[c]The $RIN_{12}OMA$ recommendation is informative not mandatory.

58.3.2 Receiver optical specifications

The 100BASE-LX10 receiver's signaling speed, operating wavelength, damage, overload, sensitivity, reflectance and signal detect shall meet the specifications defined in Table 58–4 per measurement techniques defined in 58.7. Its stressed receive characteristics should meet the values listed in Table 58–4 per measurement techniques described in 58.7.11. The receiver sensitivity includes the extinction ratio penalty.

A compliant receiver may be shown to deliver an error ratio lower than that in the table at the received power shown in the table, or shown to deliver an error ratio lower than 10^{-10} at a received power 1 dB lower than the value in the table. Sensitivity measurement is described in 58.7.10. Similarly, stressed receiver conformance may be shown for the error ratio and power shown in the table, or for 10^{-10} and 1 dB lower power. The 10^{-10} limits are more demanding but can be verified more accurately with reasonable test times.

Table 58–4—100BASE-LX10 receive characteristics

Description	Type B1.1, B1.3 SMF	Unit
Signaling speed (range)	125 ± 50 ppm	MBd
Operating wavelength range	1260 to 1360	nm
Bit error ratio (max)	10^{-12}	

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Table 58–4—100BASE-LX10 receive characteristics *(continued)*

Description	Type B1.1, B1.3 SMF	Unit
Average received power[a] (max)	–8	dBm
Receiver sensitivity (max)	–25	dBm
Receiver sensitivity as OMA (max)	–24.8 (3.3)	dBm (μW)
Receiver reflectance[b] (max)	–12	dB
Stressed receiver sensitivity[c]	–20.1	dBm
Stressed receiver sensitivity as OMA (max)	–19.9 (10.2)	dBm (μW)
Vertical eye-closure penalty[d] (min)	3.7	dB
Stressed eye jitter (min)	0.25	UI pk-pk
Jitter corner frequency	20	kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	0.05, 0.15	UI
Signal detect threshold (min)	–45	dBm

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having a power level equal to the average received power (max) plus at least 1 dB.
[b]See 1.4 for definition of reflectance.
[c]The stressed receiver sensitivity is optional.
[d]Vertical eye closure penalty and the jitter specifications are test conditions for measuring stressed receiver sensitivity. They are not required characteristics of the receiver.

58.4 PMD to MDI optical specifications for 100BASE-BX10

The operating range for 100BASE-BX10 is defined in Table 58–1. A 100BASE-BX10-D or 100BASE-BX10-U compliant transceiver operates over the media types listed in Table 58–1 according to the specifications described in 58.9. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant.

NOTE—In this subclause and 58.3, the specifications for OMA have been derived from extinction ratio and average launch power (minimum) or receiver sensitivity (maximum). The calculation is explained in 58.7.6.

58.4.1 Transmit optical specifications

The 100BASE-BX10 transmitters' signaling speed, operating wavelength, spectral width, average launch power, extinction ratio, return loss tolerance, OMA, eye and TDP shall meet the specifications defined in Table 58–5 per measurement techniques described in 58.7. Its $RIN_{12}OMA$ should meet the value listed in Table 58–5 per measurement techniques described in 58.7.7.

Table 58–5—100BASE-BX10 transmit characteristics

Description	100BASE-BX10-D	100BASE-BX10-U	Unit
Nominal transmitter type[a]	Longwave laser		
Signaling speed (range)	125 ± 50 ppm		MBd
Operating wavelength range[b]	1480 to 1580	1260 to 1360	nm
RMS spectral width (max)	4.6	7.7	nm

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Table 58–5—100BASE-BX10 transmit characteristics *(continued)*

Description	100BASE-BX10-D	100BASE-BX10-U	Unit
Average launch power (max)	–8		dBm
Average launch power (min)	–14		dBm
Average launch power of OFF transmitter (max)	–45		dBm
Extinction ratio (min)	6.6		dB
$RIN_{12}OMA$[c] (max)	–110		dB/Hz
Optical return loss tolerance (max)	12		dB
Launch OMA (min)	–12.9 (51.0)		dBm (μW)
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3, Y4}	{0.18, 0.29, 0.35, 0.35, 0.38, 0.4, 0.55}		UI
Transmitter and dispersion penalty (max)	4.5		dB
Decision timing offsets for transmitter and dispersion penalty (min)	±1.6		ns

[a]The nominal transmitter type is not intended to be a requirement on the source type, and any transmitter meeting the transmitter characteristics specified may be substituted for the nominal transmitter type.
[b]The great majority of the transmitted spectrum must fall within the operating wavelength range, see 58.7.2.
[c]The $RIN_{12}OMA$ recommendation is informative not mandatory.

58.4.2 Receiver optical specifications

The 100BASE-BX10 receivers' signaling speed, operating wavelength, damage, overload, sensitivity, reflectance and signal detect shall meet the specifications defined in Table 58–6 per measurement techniques defined in 58.7. Its stressed receive characteristics should meet the values listed in Table 58–6 per measurement techniques described in 58.7.11. The receiver sensitivity includes the extinction ratio penalty.

Table 58–6—100BASE-BX10 receive characteristics

Description	100BASE-BX10-D	100BASE-BX10-U	Unit
Signaling speed (range)	125 ± 50 ppm		MBd
Operating wavelength range[a]	1260 to 1360	1480 to 1600	nm
Bit error ratio (max)	10^{-12}		
Average received power[b] (max)	–8		dBm
Receiver sensitivity (max)	–28.2		dBm
Receiver sensitivity as OMA (max)	–27.1 (1.94)		dBm (μW)
Receiver reflectance[c] (max)	–12		dB
Stressed receiver sensitivity[d]	–23.3		dBm
Stressed receiver sensitivity as OMA (max)	–22.3 (6.0)		dBm (μW)
Vertical eye-closure penalty[e] (min)	3.8		dB

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Table 58–6—100BASE-BX10 receive characteristics *(continued)*

Description	100BASE-BX10-D	100BASE-BX10-U	Unit
Stressed eye jitter (min)	0.25		UI pk-pk
Jitter corner frequency	20		kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	0.05, 0.15		UI
Signal detect threshold (min)	–45		dBm

[a]The receiver wavelength range of 100BASE-BX10-U is wider than the associated transmitter to allow interoperation with existing implementations of 100 Mb/s bi-directional transceivers.
[b]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having a power level equal to the average received power (max) plus at least 1 dB.
[c]See 1.4 for definition of reflectance.
[d]The stressed receiver sensitivity is optional.
[e]Vertical eye closure penalty and jitter specifications are test conditions for measuring stressed receiver sensitivity. They are not required characteristics of the receiver.

A compliant receiver may be shown to deliver an error ratio lower than that in the table at the received power shown in the table, or shown to deliver an error ratio lower than 10^{-10} at a received power 1 dB lower than the value in the table. Sensitivity measurement is described in 58.7.10. Similarly, stressed receiver conformance may be shown for the error ratio and power shown in the table, or for 10^{-10} and 1 dB lower power. The 10^{-10} limits are more demanding but can be verified more accurately with reasonable test times.

58.5 Illustrative 100BASE-LX10 and 100BASE-BX10 channels and penalties (informative)

Illustrative channels and penalties for 100BASE-LX10 and 100BASE-BX10 are shown in Table 58–7.

NOTE—The budgets include an allowance for –12 dB reflection at the receiver.

Table 58–7—Illustrative 100BASE-LX10 and 100BASE-BX10 channels and penalties

Description	100BASE-LX10	100BASE-BX10-D	100BASE-BX10-U	Unit
Fiber type	B1.1, B1.3 SMF			
Measurement wavelength for fiber	1310	1550	1310	nm
Nominal distance	10			km
Available power budget	10	14.2		dB
Maximum channel insertion loss[a]	6.0	5.5	6.0	dB
Allocation for penalties[b]	4.0	8.7	8.2	dB

[a]The maximum channel insertion loss is based on the cable attenuation at the target distance and nominal measurement wavelength. The channel insertion loss also includes the loss for connectors, splices and other passive components.
[b]The allocation for penalties is the difference between the available power budget and the channel insertion loss; insertion loss difference between nominal and worst-case operating wavelength is considered a penalty. For 100BASE-X, it is possible for the allocation for penalties to be less than the TDP limit, as some penalties measured by TDP may arise in the receiver and need not be counted twice.

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58.6 Jitter at TP1 and TP4 for 100BASE-LX10 and 100BASE-BX10 (informative)

The entries in Table 58–8 represent high-frequency jitter (above 20 kHz) and do not include low frequency jitter or wander. The informative Table 58–8 shows jitter specifications which may be of interest to implementers. High probability jitter at TP2 is constrained by the eye mask. Total jitter at TP3 (and therefore at TP2 also) is constrained by the error detector timing offsets. High levels of high probability jitter at TP2, TP3 and TP4 are expected, caused by high probability baseline wander. The jitter difference between TP2 and TP3 is expected to be lower than for higher speed PMDs.

Table 58–8—100BASE-LX10 and 100BASE-BX10 jitter budget (informative)

[a]	Total jitter		High probability jitter (W)	
Reference point	UI	ns	UI	ns
TP1	0.09	0.72	0.05	0.40
TP2	0.40	3.2	0.305	2.44
TP3	0.43	3.54	0.305	2.44
TP4	0.51	4.04	0.305	2.44

[a]Informative jitter values are chosen to be compatible with the limits for eye mask and TDP (see 58.7.9). Because of the way the different components may interact, the differences in jitter between test points cannot be used to indicate a performance level of the intervening sections.

Total jitter in this table is defined at 10^{-12} BER. In a commonly used model,

$$TJ_{12} = 14.1\sigma + W \text{ at } 10^{12} \quad (58–1)$$

The total jitter at 10^{-10} BER may be calculated assuming

$$TJ_{10} = 12.7\sigma + W \quad (58–2)$$

NOTE—As an example, TJ_{10} at TP1 is 0.085 UI (0.69 ns).

W is similar but not necessarily identical to deterministic jitter (DJ). A jitter measurement procedure is described in 58.7.12. Jitter at TP2 or TP3 is defined with a receiver of the same bandwidth as specified for the transmitted eye.

58.7 Optical measurement requirements

The following subclauses describe definitive patterns and test procedures for certain PMDs of this standard. Implementers using alternative verification methods must ensure adequate correlation and allow adequate margin such that specifications are met by reference to the definitive methods.

All optical measurements, except TDP and RIN, shall be made through a short patch cable, between 2 m and 5 m in length.

NOTE—58.7.5, 58.7.6, 58.7.7, 58.7.9, 58.7.10, 58.7.11, and 58.7.12 apply to Clause 58, Clause 59, and Clause 60. Clause 59 (1000BASE-LX10) uses multimode fiber, although Clause 58 (100BASE-LX10 and 100BASE-BX10) and Clause 60 (1000BASE-PX10 and 1000BASE-PX20) do not.

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58.7.1 Test patterns

Compliance is to be achieved in normal operation. The definitive patterns for testing are shown in Table 58–9.

Table 58–9—List of test patterns and tests

Test pattern	Test	Related subclause
Valid 100BASE-X signal	Wavelength Spectral width	58.7.2
Valid balanced NRZI encoded 4B/5B bit stream	Optical power	58.7.3
Idle or far-end fault indication (see Clause 24)	Extinction ratio OMA RIN_xOMA	58.7.4 58.7.5 58.7.7
Optical frame-based test pattern of 58.7.1.1	Eye mask TDP Receiver sensitivity Stressed receiver sensitivity Jitter measurements	58.7.8 58.7.9 58.7.10 58.7.11 58.7.12

58.7.1.1 100BASE-X optical frame-based test pattern

Transmit eye mask, TDP and sensitivity are to be assured against the test pattern defined below. This represents an extremely untypical pattern. The BER in service can be expected to be lower than with the test pattern. In this clause, extinction ratio, OMA and RIN_xOMA are referred to the idle pattern (1010… for 4B/5B NRZI) or the nearly identical far-end fault indication.

The following test pattern is intended for frame-based testing of the 100BASE-LX10 and 100BASE-BX10 PMDs. It contains compliant Ethernet frames with adequate user defined fields to allow them to be passed through a system to the point of the test. Further information on frame-based testing is included in Annex 58A. The test suite and the recommended patterns are shown in Table 58–9.

NOTE—Users are advised to take care that the system under test is not connected to a network in service.

The test pattern shall be constructed as follows.

A test pattern for base line wander is composed of a sequence of three frames continuously repeated. Each frame has a 1500 octet length client data field and a zero length pad field. The contents of the destination address, source address, length/type fields and the first 32 octets of the client data field are at the discretion of the tester and may be implementation specific. The remaining 1468 octets of the client data field are filled with symbols with an even number of ones in the 4B/5B encoded data prior to NRZI transmission as shown in Table 58–10.

Frames are separated by a near minimum interpacket gap (IPG) of 14 octets.

Within the limits of the three bit maximum run length of the 4B/5B code this sequence gives a near worst case ISI pattern and provides alternating periods of high and low transition density to test clock and data recovery (CDR) performance.

The first 32 octets of the client data field are configured such that, after the frame check sequence (FCS) is added, there are an even number of ones in the first two packets and an odd number of ones in the third packet. This results in a six frame sequence on the line (after NRZI) with three frames containing near 40% ones density and three frames with near 60% ones density. Table 58–11 shows a pattern, nearly identical to the pattern in Table 58–10, that ends in 0 rather than 1 and can be used to join a 40% section to a 60% section. The “flipping” content causes a different frame check sequence which in turn causes the following idle to be inverted.

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When transmitted with a near minimum interpacket gap the resulting data stream has baseline wander at 1.35 kHz. In the example shown, IEEE Std 802.2 logical link control headers are used to form TEST command PDUs with null DSAP and SSAP addresses.

Table 58–10—Example unbalanced pattern

Item	Number of octets	Code-group name or hexa-decimal value	TXD<3:0>[a] (binary)		4B/5B encoded (binary)		NRZI encoded (binary)			
			1st nibble	2nd nibble	1st code-group[b]	2nd code-group	40% mark ratio		60% mark ratio	
Idle	13	I	Idle	Idle	11111	11111	10101	01010	01010	10101
Start-of-stream delimiter (SSD)	1	/J/K/			11000	10001	10000	11110	01111	00001
Remainder of preamble	6	55	0101	0101	01011	01011	01101	10010	10010	01101
Start of frame delimiter	1	D5	0101	1101	01011	11011	01101	01101	10010	10010
Destination address[c]	6	FF	1111	1111	11101	11101	01001	01001	10110	10110
Source address	6	00	0000	0000	11110	11110	01011	01011	10100	10100
Length/type	2	05	0101	0000	01011	11110	10010	10100	01101	01011
		DC	1100	1101	11010	11011	10011	01101	01100	10010
DSAP	1	00	0000	0000	11110	11110	01011	01011	10100	10100
SSAP	1	00	0000	0000	11110	11110	01011	01011	10100	10100
Control	1	F3	0011	1111	10101	11101	11001	01001	00110	10110
Implementation specific (example)	1	06	0110	0000	01110	11110	10100	10100	01011	01011
	28	00	0000	0000	11110	11110	10100	10100	01011	01011
Low transition density[d]	968	42	0010	0100	10100	01010	11000	01100	00111	10011
		24	0100	0010	01010	10100	01100	11000	10011	00111
Mixed	8	00	0000	0000	11110	11110	10100	10100	01011	01011
		D2	0010	1101	10100	11011	11000	10010	00111	01101
High transition density	484	07	0111	0000	01111	11110	01010	10100	10101	01011
		70	0000	0111	11110	01111	10100	01010	01011	10101
Mixed	8	00	0000	0000	11110	11110	10100	10100	01011	01011
		D2	0010	1101	10100	11011	11000	10010	00111	01101
Frame check sequence 1[e]	1	FF	1111	1111	11101	11101	10110	10110	01001	01001
Frame check sequence 2	1	13	0011	0001	10101	01001	00110	01110	11001	10001
Frame check sequence 3	1	9E	1110	1001	11100	10011	10111	00010	01000	11101
Frame check sequence 4	1	59	1001	0101	10011	01011	11101	10010	00010	01101
End-of-stream delimiter (ESD)	1	/T/R/			01101	00111	01001	11010	10110	00101

[a]See Table 24–2.
[b]The five bit code-groups are transmitted left most bit first.
[c]Use of the example broadcast address may cause problems in a system test; any unicast address is preferable. Other source and destination addresses may be chosen.
[d]The first row precedes the second row and the sub-sequence is repeated 16 times. This pattern can be varied to cause the disparity to remain the same or flip.
[e]The frame check sequence for another pattern may be calculated following 3.2.9 and Clause 24.

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Table 58–11—Example unbalanced pattern to flip polarity

Item	Number of octets	Code-group name or hexa-decimal value	TXD<3:0> (binary)		4B/5B encoded (binary)		NRZI encoded (binary)			
			1st nibble	2nd nibble	1st code-group	2nd code-group	40% mark ratio		60% mark ratio	
Idle, SSD, preamble, SFD, DA, SA, Length/ type, DSAP, SSAP, Control	38	As in Table 58–10								
Flipping	1	05	0101	0000	01011	11110	10010	10100	01101	01011
Implementation specific, and pattern	1496	As in Table 58–10								
Frame check sequence 1	1	0B	1011	0000	10111	11110	11010	10100	00101	01011
Frame check sequence 2	1	E2	0010	1110	10100	11100	11000	10111	00111	01000
Frame check sequence 3	1	08	1000	0000	10010	11110	00011	01011	11100	10100
Frame check sequence 4	1	3B	1011	0011	10111	10101	00101	11001	11010	00110
End-of-stream delimiter (ESD)	1	/T/R/			01101	00111	10110	00101	01001	11010

NOTE—While it is expected that these frames will be counted by a DTE under test, the likelihood of additional behavior means that the DTE should not be connected to a network in service while being tested.

58.7.2 Wavelength and spectral width measurements

The wavelength and spectral width (RMS) shall meet specifications according to TIA-455-127-A, under modulated conditions using a valid 100BASE-X signal.

NOTE—The great majority of the transmitted spectrum must fall within the operating wavelength range. The allowable range of central wavelengths is narrower than the operating wavelength range by the actual RMS spectral width at each extreme.

58.7.3 Optical power measurements

Optical power shall meet specifications according to the methods specified in ANSI/EIA-455-95. A measurement may be made with the port transmitting any valid balanced NRZI encoded 4B/5B bit stream.

58.7.4 Extinction ratio measurements

Extinction ratio shall meet specifications according to IEC 61280-2-2 with the port transmitting the NRZI encoded 4B/5B idle pattern (1010…) or far-end fault indication, that may be interspersed with OAM packets per 57A.2 and with minimal back reflections into the transmitter, lower than –20 dB. The extinction ratio is expected to be similar for other valid balanced NRZI encoded 4B/5B bit streams. The test receiver has the frequency response as specified for the transmitter optical waveform measurement.

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58.7.5 Optical modulation amplitude (OMA) measurements (informative)

The normative way of measuring transmitter characteristics is extinction ratio and mean power. The following clause is intended to inform on how the OMA measurement is performed.

In this clause, OMA is the difference in optical power for "1" and "0" levels of the optical signal in an idle (10101… for 100BASE-LX10 and 100BASE-BX10) sequence or far-end fault indication. It may be found using waveform averaging or histogram means. The measurement is recommended to be equivalent to that described below.

The recommended technique for measuring optical modulation amplitude is illustrated in Figure 58–3. A fourth-order Bessel-Thomson filter as specified for measuring the transmitter concerned is to be used with the O/E converter. The measurement system consisting of the O/E converter, the filter and the oscilloscope is calibrated at the appropriate wavelength for the transmitter under test.

With the device under test transmitting the idle pattern or far-end fault indication, use the following procedure to measure optical modulation amplitude:

a) Configure the test equipment as illustrated in Figure 58–3.
b) Measure the mean optical power P_1 of the logic "1" as defined over the center 20% of the time interval, here 1 UI long, where the signal is in the high state.
c) Measure the mean optical power P_0 of the logic "0" as defined over the center 20% of the time interval, here 1 UI long, where the signal is in the low state.
d) $OMA = P_1 - P_0$.

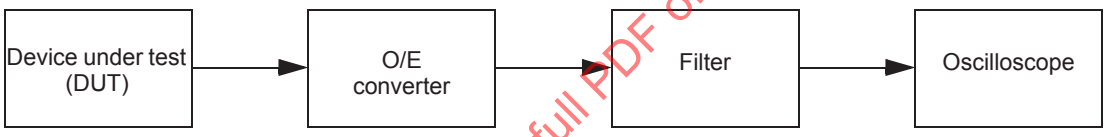

Figure 58–3—Recommended test equipment for measurement of optical modulation amplitude

A method of approximating OMA is shown in Figure 58–9.

Similarly, the optical power measure A_N is to be measured with a square wave pattern consisting of four to eleven consecutive ones followed by an equal run of zeros. Five ones followed by five zeros is convenient (the /H/ code-group in Clause 24, or K28.7 in 1000BASE-X which is the "Low-frequency test pattern" of 36A.2). The OMA of Clause 52 is A_N, and OMA here may differ.

NOTE—This OMA measurement procedure applies to Clause 58, Clause 59, and Clause 60.

58.7.6 OMA relationship to extinction ratio and power measurements (informative)

The normative way of measuring transmitter characteristics is extinction ratio and mean power. The following clause is intended to inform on how the three quantities OMA, extinction ratio, and mean power, are related to each other.

Optical modulation amplitude (OMA) is the difference between light levels for "1" and "0". Extinction ratio is the ratio between light levels for "1" and "0". If a signal contains equal density of "1" and "0" bits, and does not suffer from duty cycle distortion, the mean power is close to the mean of the light levels for "1" and "0".

$$OMA = P_1 - P_0 \tag{58–3}$$

OMA may be expressed in Watts or dBm.

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$$ER = \frac{P_1}{P_0} \tag{58–4}$$

Extinction ratio may be expressed in dB, as $10 \times \log_{10} (P_1 / P_0)$, or directly as a ratio. Sometimes extinction ratio is defined as P_0 / P_1.

$$P_{mean} \approx \frac{P_0 + P_1}{2} \tag{58–5}$$

Mean power may be expressed in Watts or dBm.

P_1 and P_0 are usually measured with a standardized instrument bandwidth to reduce the effects of overshoot. It should be noted that the values of P_1 and P_0 depend on the measurement technique and pattern to be used, which vary with PMD type. For some PMD types, e.g. 10GBASE, different patterns leading to different values of P_1 and P_0 are used for OMA on the one hand, and extinction ratio on the other.

Aside from these differences:

$$P_1 \approx 2 \times P_{mean} \times \frac{ER}{ER + 1} \tag{58–6}$$

$$P_0 \approx 2 \times \frac{P_{mean}}{ER + 1} \tag{58–7}$$

$$OMA \approx 2 \times P_{mean} \times \frac{ER - 1}{ER + 1} \tag{58–8}$$

Receiver sensitivity, which is an optical power, can be expressed in OMA or mean power terms according to the same relations.

NOTE—The OMA relationship to extinction ratio and power measurements applies to Clause 52, Clause 53, Clause 58, Clause 59, and Clause 60.

58.7.7 Relative intensity noise optical modulation amplitude ($RIN_x OMA$) measuring procedure

This procedure describes a component test that may not be appropriate for a system level test depending on the implementation. If used, the procedure is performed as described in 58.7.7.1, 58.7.7.2, and 58.7.7.3.

NOTE—This $RIN_x OMA$ measurement procedure applies to Clause 58, Clause 59, and Clause 60.

58.7.7.1 General test description

The test arrangement is shown in Figure 58–4. The optical path between the Device Under Test (DUT) and the detector has a single discrete reflection with the specified optical return loss as seen by the DUT.

Both the OMA power and noise power are measured by AC-coupling the O/E converter into the electrical power meter. If needed, an amplifier may be used to boost the signal to the power meter. A low-pass filter is used between the photo detector and the power meter to limit the noise measured to the passband appropriate to the data rate of interest. In order to measure the noise, the modulation to the DUT is turned off.

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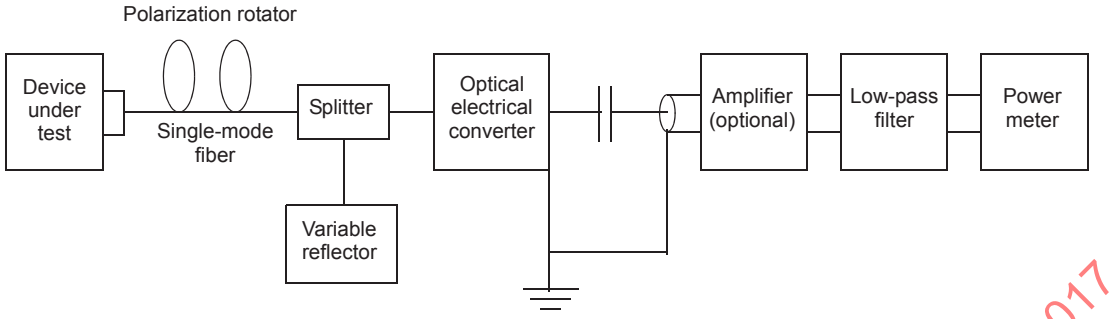

Figure 58–4—RIN$_x$OMA measurement setup

58.7.7.2 Component descriptions

The optical path and detector combination must be configured for a single dominant reflection with an optical return loss as specified in the appropriate transmitter table, e.g., Table 58–3. (The optical return loss may be determined by the method of FOTP-107.) The length of the fiber is not critical but should be in excess of 2 m.

The polarization rotator is capable of transforming an arbitrary orientation elliptically polarized wave into a fixed orientation linearly polarized wave.

If necessary, the noise may be amplified to a level consistent with accurate measurement by the power meter.

The upper –3 dB limit of the measurement apparatus is as specified for the transmitter optical waveform test. The bandwidth used in the RIN calculation takes the low-frequency cutoff of the DC-blocking capacitor into consideration. The low-frequency cutoff is recommended to be less than 1 MHz. The filter should be placed in the circuit as the last component before the power meter so that any high-frequency noise components generated by the detector/amplifier are eliminated. If the power meter used has a very wide bandwidth, care should be taken to ensure that the filter does not lose its rejection at extremely high frequencies.

The RMS electrical power meter should be capable of being zeroed in the absence of input optical power to remove any residual noise.

58.7.7.3 Test procedure

Use the following procedure to test relative intensity noise optical modulation amplitude:

a) With the DUT disconnected, zero the power meter;
b) Connect the DUT, turn on the laser, and ensure that the laser is not modulated;
c) Operate the polarization rotator while observing the power meter output to maximize the noise read by the power meter. Note the maximum power, P_N;
d) Turn on the modulation to the laser using the pattern specified for the PMD type (e.g., in 58.7.1 and 59.7.1) and note the power measurement, P_M. It may be necessary to change or remove the effective reflection to obtain an accurate reading;
e) Calculate RIN from the observed electrical signal power and noise power by use of Equation (58–9).

$$RIN_xOMA = 10 \times \log_{10}\frac{P_N}{BW \times P_M} \text{ [dB/Hz]} \quad (58–9)$$

where:

RIN_xOMA = Relative Intensity Noise referred to optical modulation amplitude measured with x dB

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reflection,
P_N = Electrical noise power in Watts with modulation off,
P_M = Electrical power in Watts with modulation on,
BW = Low-pass bandwidth of apparatus – high-pass bandwidth of apparatus due to DC-blocking capacitor [noise bandwidth of the measuring system (Hz)].

For testing multimode components or systems, the polarization rotator is removed from the setup and the single-mode fiber replaced with a multimode fiber. Step c) of the test procedure is eliminated.

58.7.8 Transmitter optical waveform (transmit eye)

The required transmitter pulse shape characteristics are specified in the form of a mask of the transmitter eye diagram as shown in Figure 58–5 for 100BASE-LX10 and 100BASE-BX10. Compliance is to be assured during system operation. The transmitter optical waveform of a port transmitting the test pattern specified for the PMD type, e.g., in 58.7.1, shall meet specifications according to the methods specified below.

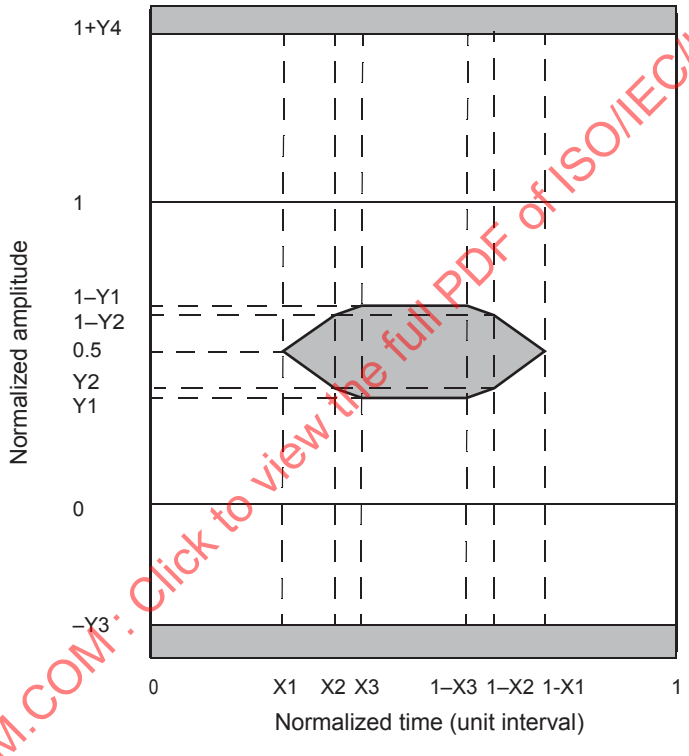

Figure 58–5—Transmitter eye mask definition

NOTE—This transmitter optical waveform measurement procedure applies to Clause 58, Clause 59, and Clause 60.

Normalized amplitudes of 0 and 1 represent the amplitudes of logic ZERO and ONE respectively. These are defined by the means of the lower and upper halves of the central 0.2 UI of the eye. 0 and 1 on the unit interval scale are to be determined by the eye crossing means. A clock recovery unit (CRU) may be used to trigger the scope for mask measurements as shown in Figure 58–6. It should have a high-frequency corner bandwidth of less than or equal to the jitter corner frequency in the appropriate table for the transmitter's peer receiver, e.g., Table 58–4 or Table 58–6, and a slope of –20 dB/decade. The CRU tracks acceptable levels of low frequency jitter and wander. The frequency response of the measurement instrument (e.g., oscilloscope) extends substantially lower than the test pattern repetition frequency. A DC-coupled instrument is convenient.

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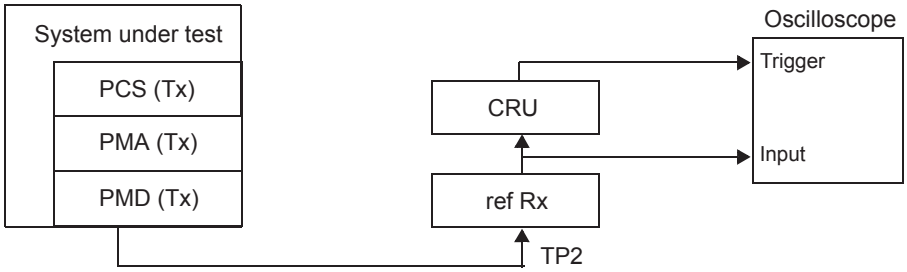

Figure 58–6—Transmitter optical waveform test block diagram

For 100BASE-LX10 and 100BASE-BX10, the eye is measured with respect to the mask of the eye using a receiver with a fourth-order Bessel-Thomson response with nominal f_r of 116.64 MHz as specified for STM-1 in ITU-T G.957, with the tolerances there specified. Receiver responses for other PMD types are specified in the appropriate clause. The Bessel-Thomson receiver is not intended to represent the noise filter used within a compliant optical receiver, but is intended to provide uniform measurement conditions at the transmitter.

The transmitter shall achieve a hit ratio lower than 5×10^{-5} hits per sample, where "hits" are the number of samples within the grey areas of Figure 58–5, and the sample count is the total number of samples from 0 UI to 1 UI.

NOTE—As an example, if an oscilloscope records 1350 samples/screen, and the timebase is set to 0.2 UI/div with 10 divisions across the screen, and the measurement is continued for 200 waveforms, then a transmitter with an expectation of less than 6.75 hits is compliant:

$$5 \times 10^{-5} \times 200 \times \frac{1350}{(0.2 \times 10)} = 6.75 \qquad (58\text{–}10)$$

Likewise, if a measurement is continued for 1000 waveforms, then an expectation of less than 33.75 hits is compliant. An extended measurement is expected to give a more accurate result, and a single reading of 6 hits in 200 waveforms would not give a statistically significant pass or fail. Measurements to "zero hits," which involve finding the position of the worst single sample in the measurement, have degraded reproducibility because random processes cause the position of such a single low-probability event to vary.

The hit ratio limit has been chosen to avoid misleading results due to transmitter and oscilloscope noise, and to give the best correlation to transmitter penalty; see 58.7.9.5.

Further information on optical eye pattern measurement procedures may be found in IEC 61280-2-2.

58.7.9 Transmitter and dispersion penalty (TDP) measurement

The TDP of a port transmitting the appropriate test pattern test shall meet specifications according to the methods specified below. The transmitter and dispersion penalty (TDP) measurement tests for transmitter impairments with chromatic effects for a transmitter to be used with single-mode fiber, and for transmitter impairments with modal (not chromatic) dispersion effects for a transmitter to be used with multimode fiber. Possible causes of impairment include intersymbol interference, jitter, RIN and mode partition noise. Meeting the separate requirements (e.g., eye mask, spectral characteristics) does not in itself guarantee the TDP. The procedure tests for pattern dependent effects; for 100BASE-LX10 and 100BASE-BX10, a standardized element of pattern dependent baseline wander is included in the reference channel.

Transmitter and dispersion penalty may be measured with apparatus shown in Figure 58–7, consisting of a reference transmitter, the transmitter under test, a controlled optical reflection, an optical attenuator, a test fiber, and a reference receiver system containing a reference receiver front end (optical to electrical converter), a transversal filter to emulate multimode fiber, if appropriate, and a bit error ratio tester. All BER and sensitivity measurements are made with the test patterns specified for the PMD type, e.g., in 58.7.1

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NOTE 1—This TDP measurement procedure applies to Clause 58, Clause 59, and Clause 60.

NOTE 2—Multimode fiber is not used with 100BASE-LX10 or 100BASE-BX10.

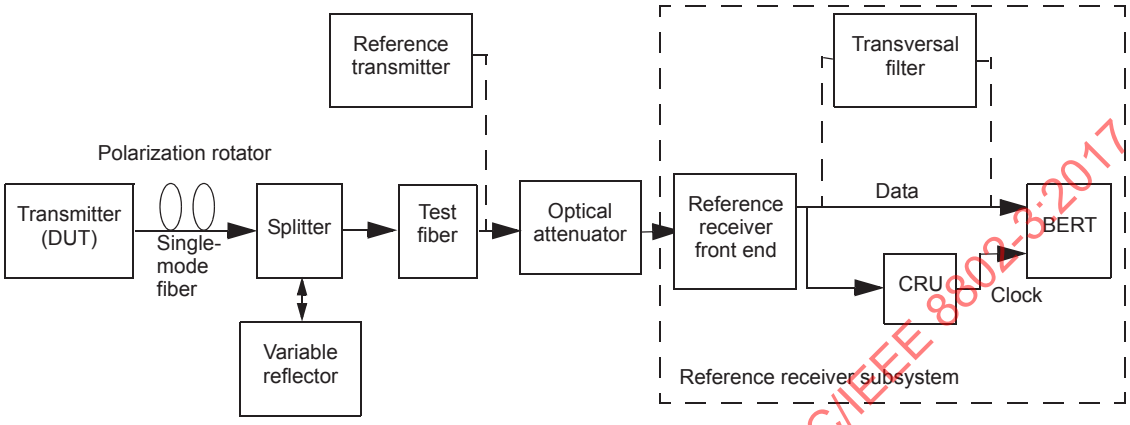

Figure 58–7—Test setup for measurement of transmitter and dispersion penalty

58.7.9.1 Reference transmitter requirements

The reference transmitter is a high-quality instrument-grade device, which can be implemented by a CW laser modulated by a high-performance modulator. It should meet the following basic requirements:

a) The rise/fall times should be less than 0.15 UI at 20% to 80%.
b) The output optical eye is symmetric and with good margin to the eye mask test for the transmitter (PMD) type under test.
c) In the center 20% region of the eye, the worst-case vertical eye closure penalty, as defined in 58.7.11.2, is less than 0.5 dB.
d) Jitter less than 0.20 UI peak-peak.
e) $RIN_{12}OMA$ should be minimized to less than –120 dB/Hz for 100BASE-X and –125 dB/Hz for 1000BASE-X.

58.7.9.2 Channel requirements

The transmitter is tested using an optical and electrical channel that meets the requirements specified for the PMD type listed in Table 58–12.A transmitter is to be compliant with a total dispersion at least as negative as the “minimum dispersion” and at least as positive as the “maximum dispersion” columns specified for the wavelength of the device under test. This may be achieved with a channel or channels consisting of fibers with lengths chosen to meet the dispersion requirements.

To verify that the fiber has the correct amount of dispersion, the measurement method defined in ANSI/TIA/EIA-455-175A-92 may be used. The measurement is made in the linear power regime of the fiber.

When emulating a multimode fiber link, the optical channel is a 2 m to 5 m patch cord meeting the appropriate specifications. In this case, the link bandwidth is emulated in the electrical domain.

The channel provides a maximum optical return loss specified as “Optical return loss tolerance (maximum)” in the specification of the transmitter under test. For a single-mode fiber channel, the state of polarization of the back reflection is adjusted to create the greatest RIN. The methods of 58.7.7.2 and 58.7.7.3 may be used.

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The BERT's receiver sensitivity must be adequate to meet the BER with the worst-case test signal and minimum attenuation.

Table 58–12—Transmitter compliance channel specifications

PMD transmitter wavelength, fiber type	Optical channel			Electrical channel
	Dispersion[a] (ps/nm)		Optical return loss[b] (max)	Differential delay (ps)
	Minimum	Maximum		
1310 nm band for SMF	$0.02325 \cdot L^{c} \cdot \lambda \cdot [1-(1324/\lambda)^4]$	$0.02325 \cdot L \cdot \lambda \cdot [1-(1300/\lambda)^4]$	See ORLT in Transmitter spec	N/A
1550 nm band for SMF	0	$0.02325 \cdot L \cdot \lambda \cdot [1-(1300/\lambda)^4]$		N/A

[a]The dispersion is specified for the actual wavelength of the device under test.
[b]The optical return loss is applied with respect to TP2.
[c]L is the upper operating range limit (reach) as defined e.g. in Table 58–1.

58.7.9.3 Reference receiver requirements

The reference receiver system should have the bandwidth specified for the transmitter optical waveform measurement for the transmitter under test. The sensitivity of the reference receiver system should be limited by Gaussian noise. The receiver system should have minimal threshold offset, deadband, hysteresis, deterministic jitter or other distortions. Decision sampling should be instantaneous with minimal uncertainty and setup/hold properties. When testing 100BASE-X optical transmitters, the receiver should have a passband not extending below 10 kHz at the –3 dBe (electrical) point, so as to emulate the pattern-induced baseline wander expected in a compliant receiver.

For all transmitter and dispersion penalty measurements, determination of the center of the eye is required. The center of the eye is defined as the time halfway between the left and right sampling points within the eye where the measured BERs are equal to each other, and greater than or equal to 10^{-3} (the BER at the eye center is much lower). The decision threshold is to occur at the average signal level.

For a transmitter to be used with multimode fiber the reference receiver is followed by a transversal filter with two equal amplitude paths with a differential delay as specified for the transmitter. In this case, the receiver front end should be operating in its linear regime (not clipping). For a transmitter to be used with single-mode fiber, the transversal filter is not used.

The clock recovery unit (CRU) used in the TDP measurement has a corner frequency of less than or equal to the jitter tolerance frequency specified for the appropriate receiver (the peer PMD to the transmitter under test), and a slope of 20 dB/decade. When using a clock recovery unit as a clock for BER measurements, passing of low-frequency jitter from the data to the clock removes this low-frequency jitter from the measurement.

The nominal sensitivity of the reference receiver system, S, is measured in OMA using the apparatus described above but with a short patchcord in place of the test fiber and without any transversal filter. The sensitivity S must be corrected for any significant reference transmitter impairments including any vertical eye closure. It should be measured while sampling at the eye center or corrected for off-center sampling. It is calibrated at the wavelength of the transmitter under test. For 100BASE-LX10 and 100BASE-BX10, TDP includes a pattern dependent penalty. It may be inconvenient or impossible to obtain reference transmitters and receivers which are immune to this penalty. For these cases, S may be measured with a benign pattern e.g., PRBS7.

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58.7.9.4 Test procedure

To measure the transmitter and dispersion penalty (TDP) the following procedure is used. The sampling instant is displaced from the eye center by the amount specified for decision timing offsets in e.g., Table 58–3 or Table 58–5. The following procedure is repeated for early and late decision and the larger TDP value is used:

a) Configure the test equipment as described above and illustrated in Figure 58–7.
b) Adjust the attenuation of the optical attenuator to obtain a BER of 10^{-12}. Extrapolation techniques may be used with care.
c) Record the optical power in OMA at the input to the reference receiver, P_DUT, in dBm.
d) If P_DUT is larger than S, the transmitter and dispersion penalty (TDP) for the transmitter under test is the difference between P_DUT and S, TDP = P_DUT – S. Otherwise the transmitter and dispersion penalty is zero, TDP = 0.

It is to be ensured that the measurements are made in the linear power regime of the fiber.

58.7.9.5 Approximate measures of TDP (informative)

Transmitter and dispersion penalty may be considered as a transmitter penalty (TP) followed by a dispersion penalty, which is also attributable to the transmitter. Measurements at TP2 can reveal the transmitter penalty. TP can be related to eye mask margin (MM) as follows.

In the absence of any noise or significant jitter,

$$TP = 10 \times \log_{10}\left(\frac{1}{H}\right) \tag{58–11}$$

$$MM = \frac{H - M}{1 - M} \tag{58–12}$$

where H is height of inner eye and M is the height of the central polygon of the mask.

Transmitter noise or noise-like impairments degrade both apparent MM and actual TP. To obtain a useful correlation between the two, MM is defined to an appropriate percentile of measured samples, to give the right weight to this noise; see 58.7.8. Oscilloscope noise degrades apparent MM only. This would distort the correlation, but in many measurement circumstances the error is reduced at the appropriate percentile. The one-dimensional statistics of MM measurement and the hit ratio are related by the frequency of relevant bit patterns in a stream (typically 1/4 of bits are flanked by two opposite bits) and by a factor related to mask dimensions.

This approach could be applied to a situation with combinations of noise of jitter.

It may be feasible to correlate TDP to eye measurements at TP3. However, the signal at TP3 is weaker, so oscilloscope noise is more of a concern.

The following suggestions apply to 100 Mb/s optical PMDs.

In practice it may be necessary to do without the clock recovery unit at 100 Mb/s. Experimentally, timing stability at this rate may be acceptable, and the jitter due to the CRU could be accounted for by adjusting the eye mask length and the TDP decision timing offsets.

A significant component of TDP is baseline wander. A wander of ± OMA/10 will be created by many receivers if it is not already present in the transmitted signal. Higher levels of pattern dependent penalty can in some cases be estimated from the mask margin (if necessary, by ignoring the upper and lower mask regions). The mask margin may also be measured with an AC-coupled measurement instrument with a high-

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pass filter of 10 kHz. It is likely that compliant implementations will pass the transmitter mask with both DC and AC-coupling. Certain implementations may be characterized by comparing the transmitted signal with the STM-1 mask, using a benign pattern such as PRBS7.

The accuracy of these approaches have not been established by the committee. Oscilloscope measurements at TP3 may be degraded by instrument noise.

58.7.10 Receiver sensitivity measurements

Receiver sensitivity is defined for an ideal input signal. The test signal should have negligible impairments such as intersymbol interference (ISI), jitter and RIN (but see the end of this subclause). The test pattern shall be as specified in 58.7.1, 59.7.1 or 60.9.1 as appropriate. Sensitivity is defined by the specified bit error ratio, which may be determined by counting bit or byte errors or errored frames. Extrapolation techniques may be used with care. Sensitivity is measured at a low but compliant extinction ratio, and correction made for any difference between the measurement extinction ratio and the specified minimum extinction ratio. This assurance should be met with asynchronous data flowing out of the optical transmitter of the system under test. The output data pattern from the transmitter of the system under test is the same pattern as defined for this measurement.

The sampling point is set by the system under test. While this standard applies to complete data terminal equipment (DTE), the test may be used as a diagnostic for testing components with appropriate margin, in which case the sampling point should be set at the average optical power level and at the specified timing offsets from the eye center, which may be found as the mid-point between the 10^{-3} BER points.

An implementer may use a combination of extrapolation and margin to assure compliance. This can entail a statistical analysis which could be implementation specific. As an example, with a small margin, it might not be advisable to extrapolate beyond a limited optical power difference; this represents an extrapolation in BER terms which varies according to circumstance.

In the case of 100BASE-X, systematic baseline wander of the input signal is to be expected. This may be generated with AC-coupling above 10 kHz within the transmitter, and/or with the interfering signal technique as described in 58.7.11.2. A standardized baseline wander of ± OMA/10 is defined for these PMD types. This causes some jitter in the test signal, which is acceptable.

For 100BASE-LX10 and 100BASE-BX10 only, sensitivities are defined for 10^{-12} and 10^{-10} bit error ratios. It is sufficient to show compliance to either of these. The 10^{-10} limit is the more demanding but can be verified more accurately with reasonable test times.

NOTE—This receiver sensitivity measurement applies to Clause 58, Clause 59, and Clause 60.

58.7.11 Stressed receiver conformance test

The stressed receiver conformance test is intended to screen against receivers with poor frequency response or timing characteristics that could cause errors when combined with a distorted but compliant signal at TP3. Modal (MMF) or chromatic (SMF) dispersion can cause distortion. Stressed receiver tolerance testing may be performed in accordance with the requirements of 58.7.11.1, 58.7.11.2, and 58.7.11.3. If this test is applied the receiver shall be compliant to for example Table 58–4.

A receiver should receive a conditioned input signal that combines vertical eye closure and jitter according to this clause with BER specified in the receiver tables. This assurance should be met with asynchronous data flowing out of the optical transmitter of the system under test. The output data pattern from the transmitter of the system under test is to be the same pattern as defined for this measurement.

NOTE 1—The length of the test pattern, low signaling rate and narrow rate tolerance of 100BASE-X means that the input and output patterns beat very slowly. Long test times or a slight modification to the length of one pattern may be appropriate.

NOTE 2—This stressed receiver conformance test applies to Clause 58, Clause 59, and Clause 60.

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58.7.11.1 Stressed receiver conformance test block diagram

A block diagram for the receiver conformance test is shown in Figure 58–8. A pattern generator continuously generates a signal or test pattern as specified for the receiver under test, e.g., in 58.7.1. The optical test signal is conditioned (stressed) using the methodology, as defined in 58.7.11.2, while applying sinusoidal jitter, as specified e.g., in 58.7.11.4. The receiver of the system under test is tested for conformance by counting bit or byte errors or errored frames. The optical power penalty for the stressed eye is intended to be similar to its vertical eye closure penalty. This is not necessarily the same as the highest TDP anticipated in service, but represents a standardized test condition for the receiver.

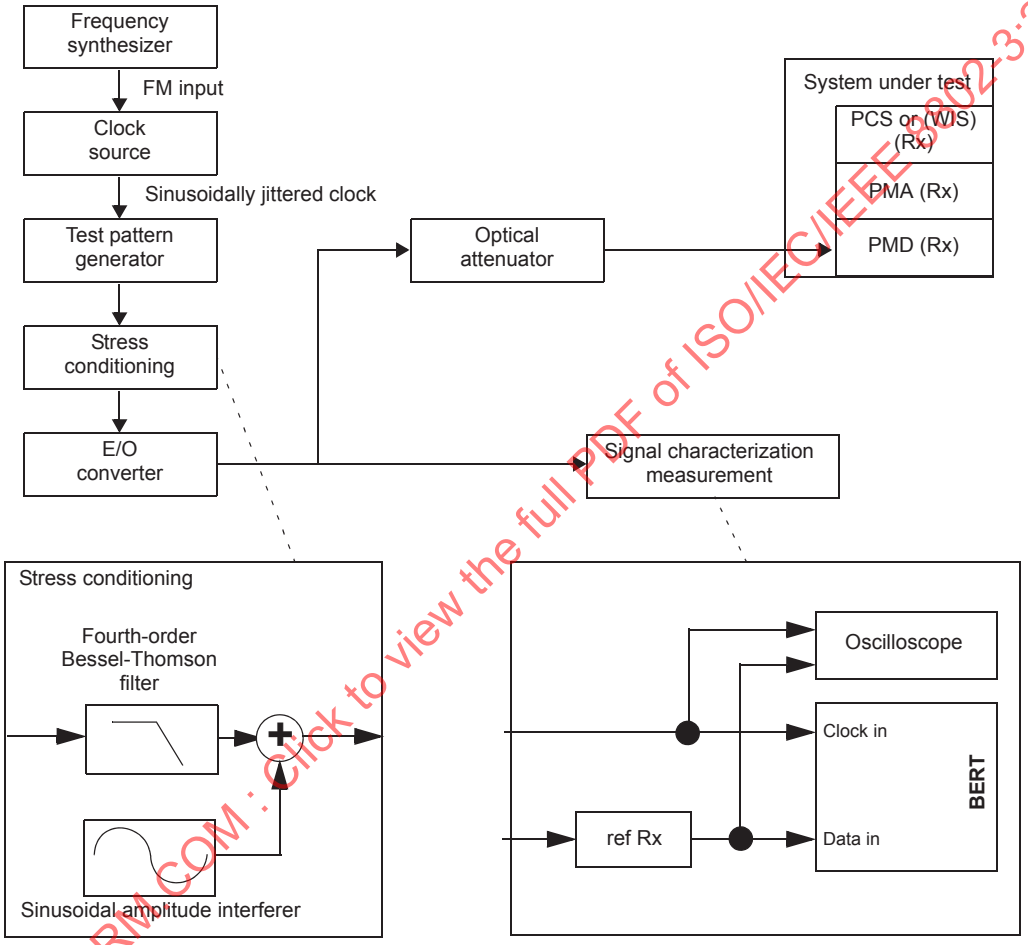

Figure 58–8—Stressed receiver conformance test block diagram

A suitable test set is needed to characterize and verify that the signal used to test the receiver has the appropriate characteristics. The test fiber called out for single-mode fiber based PMD layers and the transversal filter called out to emulate multimode fiber are not needed to characterize the receiver input signal; nor are they used during testing.

The fourth-order Bessel-Thomson filter is used to create ISI-induced vertical eye closure. The sinusoidal amplitude interferer causes additional eye closure, but in conjunction with the slowed edge rates from the filter, also causes jitter. The nature of the jitter is intended to emulate instantaneous bit shrinkage that can occur with DDJ. This type of jitter cannot be created by simple phase modulation. The sinusoidal phase modulation represents other forms of jitter and also verifies that the receiver under test can track low-frequency jitter.

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For improved visibility for calibration, it is imperative that the Bessel-Thomson filter and all other elements in the signal path (cables, DC blocks, E/O converter, etc.) have wide and smooth frequency response and linear phase response throughout the spectrum of interest. Overshoot and undershoot should be minimized. If this is achieved, then data dependent effects should be minimal, and short data patterns can be used for calibration with the benefit of providing much improved trace visibility on sampling oscilloscopes. Actual patterns for testing the receiver are specified in the appropriate clause.

To further improve visibility for calibration, random noise effects, such as RIN and random clock jitter, should also be minimized. A small amount of residual noise and jitter from all sources is unavoidable, but should be less than 0.25 UI peak-peak of jitter.

The test pattern generator, filter and E/O converter should together have a frequency response to result in the appropriate level of initial ISI eye closure before the sinusoidal terms are added. The E/O converter should have a linear response if electrical summing is used, linearity of all elements including the E/O modulator is critical. Summing with an optical coupler after the modulator is an option that eases linearity requirements, but requires a second source for the interfering signal, will complicate settings of extinction ratio, and will add more RIN. In either case, a typical optical transmitter with built-in driver is not linear and not suitable.

The vertical and horizontal eye closures to be used for receiver conformance testing are verified using an optical reference receiver with the response specified for the appropriate transmitter (the peer PMD to the receiver under test) e.g., in 58.7.8. Use of standard tolerance filters may significantly degrade this calibration. Care should be taken to ensure that all the light from the fiber is collected by the fast photo detector and (if using multimode fiber) that there is negligible mode selective loss, especially in the optical attenuator and the optical coupler, if used. The reference receiver and oscilloscope should achieve adequately low noise and jitter.

The clock output from the clock source in Figure 58–8 will be modulated with the sinusoidal jitter. To use an oscilloscope to calibrate the final stressed eye jitter that includes the sinusoidal jitter component, a separate clock source (clean clock of Figure 58–8) is required that is synchronized to the source clock, but not modulated with the jitter source.

58.7.11.2 Stressed receiver conformance test signal characteristics and calibration

The conformance test signal is used to validate that the PMD receiver meets BER requirements with near worst case waveforms at TP3 including pulse width shrinkage, power, simulated channel penalties, and a swept frequency sinusoidal jitter contribution.

Signal characteristics are described below along with a suggested approach for calibration.

The test signal includes vertical eye closure and high-probability jitter components. Vertical eye closure is measured at the time center of the eye (halfway between 0 and 1 on the unit interval scale as determined by the eye crossing means) and is the vertical eye closure penalty (VECP) when calculated relative to the measured A_N value. J is measured at the average optical power, which can be obtained with AC-coupling. The values of these components are defined as below by their histogram results. The vertical eye closure penalty is given in Equation (58–13):

$$\text{Vertical eye closure penalty [dB, optical]} = 10 \times \log_{10}\frac{A_N}{A_O} \tag{58–13}$$

where, A_O is the amplitude of the eye opening and A_N is the normal amplitude without ISI, as shown in Figure 58–9. A_N can be approximated with histograms as suggested in Figure 58–9. However, the definition for A_N is given in 58.7.5.

For this test, VECP is defined by the 99.95th percentile of the histogram of the lower half of the signal and the 0.05th percentile of the histogram of the upper half of the signal, and jitter is defined by the 0.5th and 99.5th percentiles of the jitter histogram. Histograms should include at least 10 000 hits, and should be about

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1%-width in the direction not being measured. Residual low-probability noise and jitter should be minimized—that is, the outer slopes of the final histograms should be as steep as possible down to very low probabilities.

The following steps describe a suggested method for calibrating a stressed eye generator:

a) Set the signaling speed of the test-pattern generator as specified for the appropriate transmitter. Sinusoidal interference and jitter signals should be turned off at this point.

b) Turn on the calibration pattern. A repetitive pattern may be used for calibration if the conditions described in 58.7.11.1 are met, but this increases the risk that the longer test pattern used during testing will overstress the device under test.

c) Set the extinction ratio to approximately the extinction ratio (minimum) value as specified for the appropriate transmitter. If optical summing is used, the extinction ratio may need to be adjusted after the sinusoidal interference signal is added below.

d) Measure the settled signal amplitude A_N of the test signal (without attenuation). A_N may be measured according to 58.7.5 using a square wave pattern, although for the purposes of this clause, OMA is to be measured with a different pattern; A_N and OMA are not likely to be equal.

e) The requirements for vertical eye closure and jitter of the stressed eye test signal are given by the vertical eye closure penalty (VECP) and stressed eye jitter (J) values given in the appropriate receiver specification table.

   There are three components involved in calibration for vertical closure and J. These are a linear phase filter, sinusoidal interference, and sinusoidal jitter.

   In general, the majority of the vertical eye closure penalty value should be created by use of a linear phase, low jitter filter (such as Bessel-Thomson). In the case of 100BASE-X, the majority of the vertical eye closure penalty value should be created by baseline wander or sinusoidal interference. The filter should be tested with the prescribed test patterns to verify that residual jitter is small, less than 0.25 UI peak-peak. If not, the stress may be more than desired, leading to conservative results. However, compensation is not allowed. Once done, revert to the calibration pattern, if different than the specified test pattern.

   Any remaining vertical eye closure required must be created with sinusoidal interference or sinusoidal jitter.

   To emulate the effects of DCD or data-dependent jitter, at least 0.05 but no more than 0.15 UI peak-peak of pulse shrinkage jitter should have been achieved. This imposes a limit of less than 1.2 dB of vertical closure from sinusoidal interference, applied after vertical closure created by filtering.

   The frequency of the sinusoidal interference may be set at any frequency between B / 100 and B / 5 where B is the signaling speed, although care should be taken to avoid a harmonic relationship between the sinusoidal interference, the sinusoidal jitter, the signaling speed and the pattern repetition rate.
   Sinusoidal jitter (phase modulation) must be added according to the appropriate jitter specification. For calibration purposes, sinusoidal jitter frequencies must be well within the flat portion of the template above the corner frequency.

   Iterate the filter bandwidth and the settings for sinusoidal interference and/or jitter until all constraints are met, including jitter (J), vertical eye closure penalty (VECP), and that sinusoidal jitter above the corner frequency is as specified.

   Verify that the optical power penalty for the stressed eye (relative to the reference transmitter per 58.7.9.1) is greater than or equal to VECP.

f) Decrease the amplitude with the optical attenuator until the OMA complies with the OMA values specified for the receiver under test.

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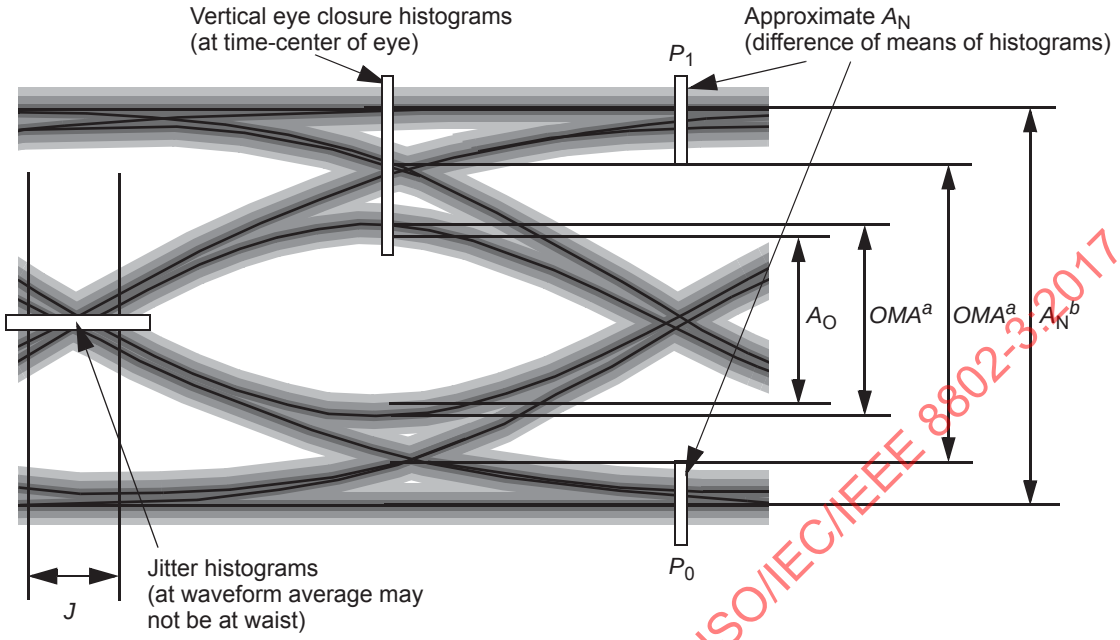
g) For testing, turn on the actual required test pattern(s).



[a]This measure of OMA on the eye of the conformance test signal differs between 100BASE-X, 1000BASE-X and 10GBASE-R/W.
[b]This is also OMA for 10GBASE-R/W.

Figure 58–9—Required characteristics of the conformance test signal at TP3

Care should be taken when characterizing the signal used to make receiver tolerance measurements. In the case of a transmit jitter measurement, excessive and/or uncalibrated noise/jitter in the test system makes it more difficult to meet the specification and may have a negative effect on yield but will not impact interoperability. Running the receiver tolerance test with a signal that is under-stressed may result in the deployment of non-compliant receivers. Care should be taken to minimize and/or correct for the noise/jitter introduced by the reference receiver, filters, oscilloscope, and BERT. While the details of measurement and test equipment are beyond the scope of this standard it is recommended that the implementers fully characterize their test equipment and apply appropriate guard bands to ensure that the receive input signal meets the specified requirements.

58.7.11.3 Stressed receiver conformance test procedure

The test apparatus is set up as described in 58.7.11.1 and 58.7.11.2. The sinusoidal jitter is then stepped across the specified frequency and amplitude range while monitoring errors at the receiver. The BER is to be compliant at all jitter frequencies in the specified frequency range. This method does not result in values for jitter contributed by the receiver. It does, however, ensure that a receiver meeting the requirements of this test will operate with the worst-case optical input.

58.7.11.4 Sinusoidal jitter for receiver conformance test

The sinusoidal jitter is used to test receiver jitter tolerance. Sinusoidal jitter may vary over a magnitude range as required to accurately calibrate a stressed eye per 58.7.11.2. The range is limited by the constraints of Table 58–13 as illustrated in Figure 58–10, where *f2*, *SJ1*, and *SJ2* are specified in the appropriate receiver table: Table 58–4, Table 58–6, Table 59–6, Table 59–8, Table 60–5, Table 60–6, or Table 60–14. The

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frequency *f2* is specified as "Jitter corner frequency" in the receiver tables. *SJ1* and *SJ2* are defined as "sinusoidal jitter limits for stressed receiver conformance test (min, max)" in e.g., Table 58–4.

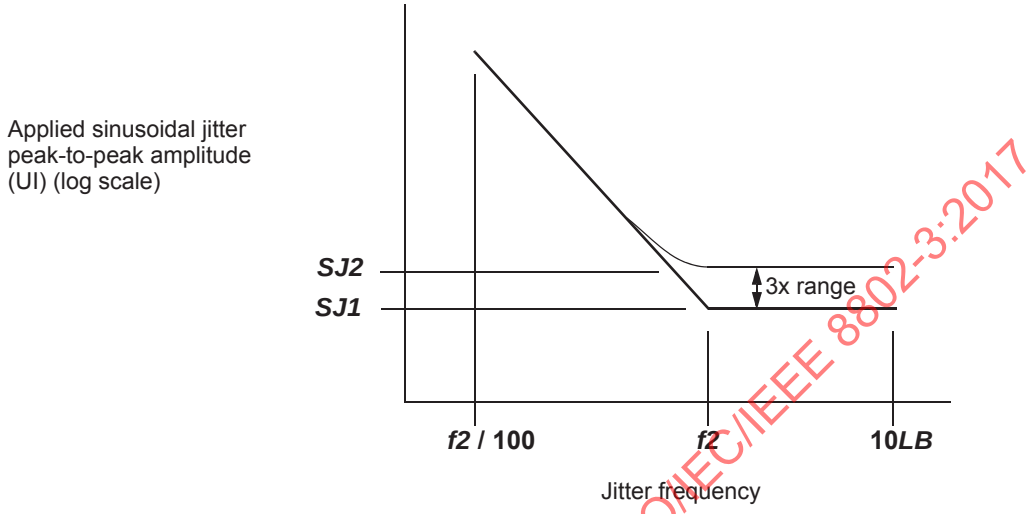

Figure 58–10—Mask of the sinusoidal component of jitter tolerance (informative)

Table 58–13—Applied sinusoidal jitter

Frequency range	Sinusoidal jitter (UI pk-pk)
$f < f2 / 100$	N/A
$f2 / 100 < f \le f2$	$0.05 \times f2 / f + S - 0.05$[a]
$f2 < f < 10 \times LB$[b]	$SJ1 \le S \le SJ2$[a]

[a] *S* is the magnitude of sine jitter actually used in the calibration of the stressed eye per the methods of 58.7.11.2.
[b] *LB* = Loop Bandwidth; Upper frequency bound for added sine jitter should be at least 10 times the loop bandwidth of the receiver being tested.

58.7.12 Jitter measurements (informative)

A jitter measurement method for use at 100 Mb/s or 1000 Mb/s is described in this subclause. The measurement is performed after any relevant fiber dispersion (at virtual TP3). The test pattern is specified in 58.7.1 or 59.7.1 as appropriate.

The transmit jitter is tested using a bit error ratio tester (BERT), where the tester scans the eye opening horizontally (varying the decision time) at the average optical power, at a virtual TP3 (hereafter referred to as simply TP3) and measures the bit error ratio at each point in time. The plot of BER as a function of sampling time is called the "bathtub curve." The channel and receiver are as specified in e.g., 58.7.9.2 and 58.7.9.3. The receiver includes a defined filter function. The test pattern is the same as for receiver sensitivity measurements.

NOTE—The parameter *W* may also be estimated from jitter histograms using an oscilloscope. Jitter of an optical signal is measured with a test optical receiver with the receiver bandwidth specified (e.g., for eye mask conformance) for the transmitter under test concerned.

The experimental curve is compared with a mask defined by Equation (58–14) and Equation (58–15) and illustrated in Figure 58–11:

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$$\log_{10}(BER) \le A - B\left(\frac{t - 0.5W}{\sigma}\right)^2 \quad (58\text{–}14)$$

$$\log_{10}(BER) \le A - B\left(\frac{1 - t - 0.5W}{\sigma}\right)^2 \quad (58\text{–}15)$$

where:

$$A = -1.75, B = \frac{\log_{10}(e)}{2} \approx 0.217$$

and t is the decision time specified in unit intervals (UI). $t = 0$ at the mean crossing time, which may be estimated as the mid-point between the 10^{-3} BER points.

The BER mask is defined for $10^{-12} < \text{BER} < 10^{-6}$. All points on the BER "bathtub curve" must fall within the white area or below. It can be seen that in the case of an asymmetric measured bathtub curve, the worse side determines W and σ.

W ("high probability jitter") and deterministic jitter (DJ) are not necessarily the same, but may be similar. The quantity σ can be similar to random jitter (RJ) although it is determined by low probability pattern dependent jitter also. "Total jitter" (TJ) is taken to be $W + 14\sigma$.

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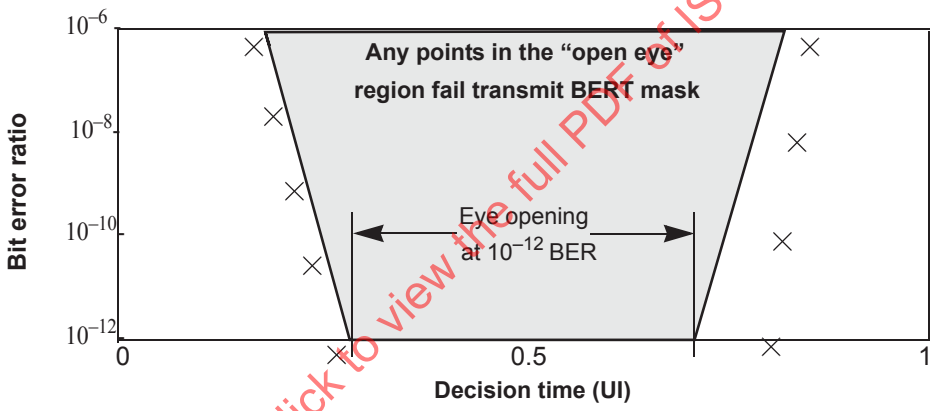

Figure 58–11—Example transmit BER mask at TP3

NOTE—This jitter measurement method applies to Clause 58, Clause 59, and Clause 60.

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58.8 Environmental, safety, and labeling

58.8.1 General safety

All equipment meeting this standard shall conform to IEC 60950-1.

58.8.2 Laser safety

100BASE-LX10 and 100BASE-BX10 optical transceivers shall conform to Hazard Level 1 laser requirements as defined in IEC 60825-1 and IEC 60825-2, under any condition of operation. This includes single fault conditions whether coupled into a fiber or out of an open bore. Conformance to additional laser safety standards may be required for operation within specific geographical regions.

Laser safety standards and regulations require that the manufacturer of a laser product provide information about the product's laser, safety features, labeling, use, maintenance, and service. This documentation shall explicitly define requirements and usage restrictions on the host system necessary to meet these safety certifications.

58.8.3 Installation

It is recommended that proper installation practices, as defined by applicable local codes and regulation, be followed in every instance in which such practices are applicable.

58.8.4 Environment

Two optional temperature ranges are defined in Table 58–14. Implementations shall be declared as compliant over one or both complete ranges, or not so declared (compliant over parts of these ranges or another temperature range).

Table 58–14—Component case temperature classes

Class	Low temperature (°C)	High temperature (°C)
Warm extended	–5	+85
Cool extended	–40	+60
Universal extended	–40	+85

Reference Annex 67A for additional environmental information.

58.8.5 PMD labeling requirements

It is recommended that each PHY (and supporting documentation) be labeled in a manner visible to the user, with at least the applicable safety warnings and the applicable port type designation (e.g., 100BASE-BX10-U).

Labeling requirements for Hazard Level 1 lasers are given in the laser safety standards referenced in 58.8.2.

Compliant systems and field pluggable components shall be clearly labeled with the operating temperature range over which their compliance is ensured.

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58.9 Characteristics of the fiber optic cabling

The 100BASE-LX10 and 100BASE-BX10 fiber optic cabling shall meet the dispersion specifications of IEC 60793-2 and ITU-T G.652, or the requirements of Table 58–15 where they differ. The fiber cable attenuation is for information only; the end-to-end channel loss shall meet the requirements of Table 58–1. The fiber optic cabling consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together. The fiber optic cabling spans from one MDI to another MDI, as shown in Figure 58–12.

58.9.1 Fiber optic cabling model

The fiber optic cabling model is shown in Figure 58–12.

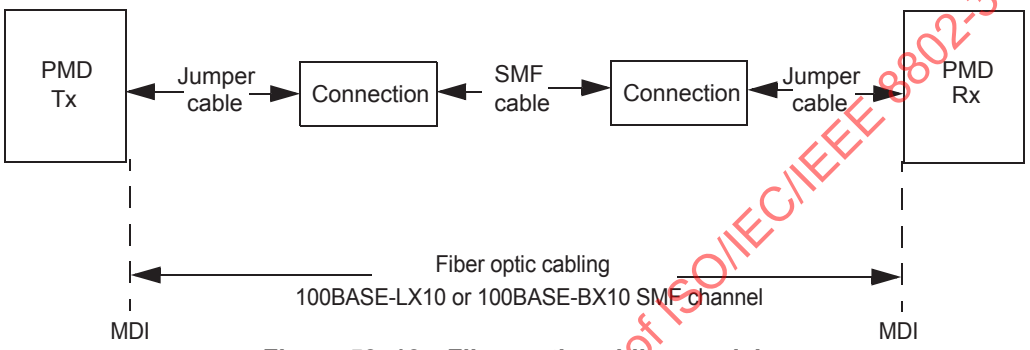

Figure 58–12—Fiber optic cabling model

The maximum channel insertion losses shall meet the requirements specified in Table 58–1. The minimum loss for 100BASE-LX10 and 100BASE-BX10 is zero. A channel may contain additional connectors or other optical elements as long as the optical characteristics of the channel, such as attenuation, dispersion and reflections, meet the specifications. Insertion loss measurements of installed fiber cables are made in accordance with ANSI/TIA/EIA-526-7 [B16], method A-1. The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment. The term channel is used here for consistency with generic cabling standards.

NOTE—In extreme cases with minimum length links (less than 2 m), care may be taken to avoid excess optical power delivered through cladding modes to the receiver.

58.9.2 Optical fiber and cable

The fiber optic cable requirements are satisfied by the fibers specified in IEC 60793-2, Types B1.1 (dispersion un-shifted single-mode) and B1.3 (low water peak single-mode) and ITU-T G.652, or by the requirements of Table 58–15 where they differ.

Table 58–15—Optical fiber and cable characteristics

Description[a]	B1.1, B1.3 SMF		Unit
Nominal fiber specification wavelength[b]	1310	1550	nm
Cabled optical fiber attenuation (max)[c]	0.4	0.35	dB/km
Zero dispersion wavelength (λ_0)[d]	$1300 \le \lambda_0 \le 1324$		nm
Dispersion slope (max) (S_0)	0.093		ps/nm^2km

[a]The fiber dispersion values are normative, all other values in the table are informative.
[b]Wavelength specified is the nominal fiber specification wavelength which is the typical measurement wavelength. Power penalties at other wavelengths are accounted for.
[c]Attenuation values are informative not normative. Attenuation for single-mode optical fiber cables is defined in ITU-T G.652.
[d]See IEC 60793 or G.652 for correct use of zero dispersion wavelength and dispersion slope.

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58.9.3 Optical fiber connection

The maximum link distances for single-mode fiber are calculated based on an allocation of 2 dB total connection and splice loss. Connections with different loss characteristics may be used provided the requirements of Table 58–1 are met.

The maximum discrete reflectance of e.g., a connection or splice shall be less than –26 dB.

58.9.4 Medium Dependent Interface (MDI)

The 100BASE-LX10, 100BASE-BX10-D or 100BASE-BX10-U PMD is coupled to the fiber optic cabling at the MDI. The MDI is the interface between the PMD and the "fiber optic cabling" (as shown in Figure 58–12). Examples of an MDI include the following:

a) Connectorized fiber pigtail
b) PMD receptacle

The MDI carries the signal in both directions. For 100BASE-BX10 it couples a single fiber and for 100BASE-LX10 it couples dual fibers.

When the MDI is a remateable connection it shall meet the interface performance specifications of IEC 61753-1.

NOTE—Compliance testing is performed at TP2 and TP3 as defined in 58.2.1, not at the MDI.

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58.10 Protocol implementation conformance statement (PICS) proforma for Clause 58, Physical Medium Dependent (PMD) sublayer and medium, type 100BASE-LX10 (Long Wavelength) and 100BASE-BX10 (BiDirectional Long Wavelength)[6]

58.10.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 58, Physical Medium Dependent (PMD) sublayer and medium, type 100BASE-LX10 and 100BASE-BX10, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

58.10.2 Identification

58.10.2.1 Implementation identification

Supplier[1]	
Contact point for inquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1, 3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

58.10.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 58, Physical Medium Dependent (PMD) sublayer and medium, type 100BASE-LX10 and 100BASE-BX10
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	

Date of Statement	

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[6]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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58.10.2.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
HT	High temperature operation	58.8.4	–5 °C to 85 °C	O	Yes [ ] No [ ]
LT	Low temperature operation	58.8.4	–40 °C to 60 °C	O	Yes [ ] No [ ]
*LX	100BASE-LX10 PMD	58.3	Device supports long wavelength (1310 nm) over dual single-mode fiber operation	O/1	Yes [ ] No [ ]
*BD	100BASE-BX10-D	58.4	Device operates with one single single-mode fiber and transmits at downstream wavelength (1550 nm)	O/1	Yes [ ] No [ ]
*BU	100BASE-BX10-U	58.4	Device operates with one single single-mode fiber and transmits at upstream wavelength (1310 nm)	O/1	Yes [ ] No [ ]
*INS	Installation / Cable	58.9	Items marked with INS include installation practices and cable specifications not applicable to a PHY manufacturer	O	Yes [ ] No [ ]

58.10.3 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and medium, type 100BASE-LX10 and 100BASE-BX10

58.10.3.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FN1	Transmit function	58.2.2	Conveys bits from PMD service interface to MDI	M	Yes [ ]
FN2	Transmitter optical signal	58.2.2	Higher optical power transmitted is a logic 1	O	Yes [ ] No [ ]
FN3	Receive function	58.2.3	Conveys bits from MDI to PMD service interface	M	Yes [ ]
FN4	Receiver optical signal	58.2.3	Higher optical power received is a logic 1	O	Yes [ ] No [ ]
FN5	Signal detect function	58.2.4	Mapping to PMD service interface	M	Yes [ ]
FN6	Signal detect behavior	58.2.4	Generated according to Table 58–2	M	Yes [ ]

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58.10.3.2 PMD to MDI optical specifications for 100BASE-LX10

Item	Feature	Subclause	Value/Comment	Status	Support
LX1	100BASE-LX10 transmitter	58.3.1	Meets specifications in Table 58–3	LX:M	Yes [ ] N/A [ ]
LX2	100BASE-LX10 receiver	58.3.2	Meets specifications in Table 58–4	LX:M	Yes [ ] N/A [ ]
LX3	100BASE-LX10 stressed receiver sensitivity	58.3.2	Meets specification in Table 58–4	LX:O	Yes [ ] No [ ] N/A [ ]

58.10.3.3 PMD to MDI optical specifications for 100BASE-BX10-D

Item	Feature	Subclause	Value/Comment	Status	Support
BD1	100BASE-BX10 transmitter	58.4.1	Meets specifications in Table 58–5	BD:M	Yes [ ] N/A [ ]
BD2	100BASE-BX10 receiver	58.4.2	Meets specifications in Table 58–6	BD:M	Yes [ ] N/A [ ]
BD3	100BASE-BX10 stressed receiver sensitivity	58.4.2	Meets specification in Table 58–6	BD:O	Yes [ ] No [ ] N/A [ ]

58.10.3.4 PMD to MDI optical specifications for 100BASE-BX10-U

Item	Feature	Subclause	Value/Comment	Status	Support
BU1	100BASE-BX10 transmitter	58.4.1	Meets specifications in Table 58–5	BU:M	Yes [ ] N/A [ ]
BU2	100BASE-BX10 receiver	58.4.2	Meets specifications in Table 58–6	BU:M	Yes [ ] N/A [ ]
BU3	100BASE-BX10 stressed receiver sensitivity	58.4.2	Meets specification in Table 58–6	BU:O	Yes [ ] No [ ] N/A [ ]

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58.10.3.5 Optical measurement requirements

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	Measurement cable	58.7	2 m to 5 m in length	M	Yes [ ]
OM2	Test pattern	58.7.1, 58.7.8, 58.7.10	For eye, sensitivity, TDP, stressed sensitivity, jitter	M	Yes [ ]
OM3	Wavelength and spectral width	58.7.2	Per TIA-455-127-A under modulated conditions	M	Yes [ ]
OM4	Average optical power	58.7.3	Per TIA/EIA-455-95	M	Yes [ ]
OM5	Extinction ratio	58.7.4	Per IEC 61280-2-2	M	Yes [ ]
OM6	Transmit eye	58.7.8	Per 58.7.8 with specified test pattern	M	Yes [ ]
OM7	Receiver sensitivity	58.7.10	With specified pattern	M	Yes [ ]
OM8	Transmitter and dispersion penalty	58.7.9	With dispersion, reflection and decision timing offsets	M	Yes [ ]
OM9	Stressed receiver conformance test	58.7.11	According to 58.7.11.1, 58.7.11.2, and 58.7.11.3	O	Yes [ ] No [ ]

58.10.3.6 Environmental specifications

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	General safety	58.8.1	Conforms to IEC-60950-1	M	Yes [ ]
ES2	Laser safety —IEC Hazard Level 1	58.8.2	Conform to Hazard Level 1 laser requirements defined in IEC 60825-1 and IEC 60825-2.	M	Yes [ ]
ES3	Documentation	58.8.2	Explicitly defines requirements and usage restrictions to meet safety certifications	M	Yes [ ]
ES4	Operating temperature range labeling	58.8.5	If required	M	Yes [ ] N/A [ ]

58.10.3.7 Characteristics of the fiber optic cabling and MDI

Item	Feature	Subclause	Value/Comment	Status	Support
FO1	Fiber optic cabling	58.9	Dispersion specifications of Table 58–15	INS:M	Yes [ ] N/A [ ]
FO2	End-to-end channel loss	58.1, 58.9	Meet the requirements of Table 58–1	INS:M	Yes [ ] N/A [ ]
FO3	Maximum discrete reflectance	58.9.3	Less than –26 dB	INS:M	Yes [ ] N/A [ ]
FO4	MDI requirements	58.9.4	IEC 61753-1 if remateable	INS:O	Yes [ ] No [ ] N/A [ ]

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59. Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-LX10 (Long Wavelength) and 1000BASE-BX10 (BiDirectional Long Wavelength)

59.1 Overview

The 1000BASE-LX10 and 1000BASE-BX10 PMD sublayers provide point-to-point (P2P) 1000BASE-X links over a pair of fibers or a single fiber, respectively, up to 10 km.

This clause specifies the 1000BASE-LX10 PMD for both single-mode and multimode fiber, and the 1000BASE-BX10 PMD for single-mode fiber. A PMD is connected to the 1000BASE-X PMA of 66.2, and to the medium through the MDI. A PMD is optionally combined with the management functions that may be accessible through the management interface defined in Clause 22 or by other means.

Table 59–1 shows the primary attributes of each PMD type.

Table 59–1—Classification of 1000BASE-LX10 and 1000BASE-BX10 PMDs

Description	1000BASE-LX10		1000BASE-BX10-D	1000BASE-BX10-U	Unit
Fiber type[a]	B1.1, B1.3 SMF	50, 62.5 µm MMF	B1.1, B1.3 SMF		
Number of fibers	2	2	1		
Typical transmit direction	N/A		Downstream	Upstream	
Nominal transmit wavelength	1310	1310	1490	1310	nm
Minimum range	0.5 m to 10 km	0.5 m to 550 m[b]	0.5 m to 10 km		
Maximum channel insertion loss[c]	6.0	2.4	5.5	6.0	dB

[a]Per IEC 60793-2.
[b]See Table 59–16 for fiber and cable characteristics.
[c]At the nominal operating wavelength

A 1000BASE-LX10 link uses 1000BASE-LX10 PMDs at each end while a 1000BASE-BX10 link uses a 1000BASE-BX10-D PMD at one end and a 1000BASE-BX10-U PMD at the other. Typically the 1490 nm band is used to transmit away from the center of the network (“downstream”) and the 1310 nm band towards the center (“upstream”), although this arrangement, or the notion of hierarchy, is not required. The suffixes “D” and “U” indicate the PMDs at each end of a link that transmit in these directions and receive in the opposite directions.

1000BASE-LX10 is interoperable with 1000BASE-LX (see Clause 38). If used on single-mode fiber, operation is not ensured by this standard beyond the reach given in Table 38–6.

Two optional temperature ranges are defined; see 59.8.4 for further details. Implementations may be declared as compliant over one or both complete ranges, or not so declared (compliant over parts of these ranges or another temperature range).

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59.1.1 Goals and objectives

The following are the objectives of 1000BASE-LX10 and 1000BASE-BX10:

a) Point-to-point on optical fiber
b) 1000BASE-LX extended temperature range optics
c) 1000BASE-X up to 10km over SM fiber
d) BER better than or equal to 10^{-12} at the PHY service interface

59.1.2 Positioning of 1000BASE-LX10 and 1000BASE-BX10 PMDs within the IEEE 802.3 architecture

Figure 59–1 depicts the relationships of the PMD (shown shaded) with other sublayers and the ISO/IEC Open System Interconnection (OSI) reference model.

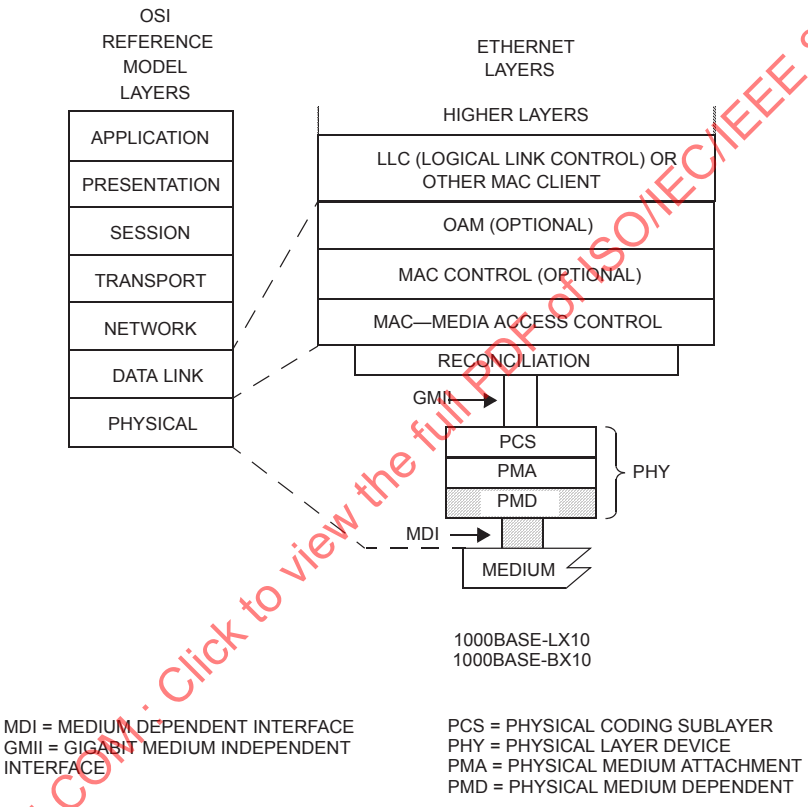

Figure 59–1—1000BASE-LX10 and 1000BASE-BX10 PMDs relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

59.1.3 Terminology and conventions

The following list contains references to terminology and conventions used in this clause:

Basic terminology and conventions, see 1.1 and 1.2.

Normative references, see 1.3.

Definitions, see 1.4.

Abbreviations, see 1.5.

Informative references, see Annex A.

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Introduction to 1000 Mb/s baseband networks, see Clause 34.

Introduction to Ethernet for subscriber access networks, see Clause 56.

59.1.4 Physical Medium Dependent (PMD) sublayer service interface

The following specifies the services provided by the 1000BASE-LX10 and 1000BASE-BX10 PMDs. These PMD sublayers are described in an abstract manner and do not imply any particular implementation. The PMD service interface supports the exchange of encoded 8B/10B code-groups between the PMA and PMD entities. The PMD translates the serialized data of the PMA to and from signals suitable for the specified medium.

The following primitives are defined:

PMD_UNITDATA.request

PMD_UNITDATA.indication

PMD_SIGNAL.indication

59.1.5 Delay constraints

Delay requirements from the MDI to the GMII which include the PMD layer are specified in Clause 36. Of the budget, up to 20 ns is reserved for each of the transmit and receive functions of the PMD to account for those cases where the PMD includes a pigtail.

59.1.5.1 PMD_UNITDATA.request

This primitive defines the transfer of a serial data stream from the PMA to the PMD.

The semantics of the service primitive are PMD_UNITDATA.request(tx_bit). The data conveyed by PMD_UNITDATA.request is a continuous stream of bits where the tx_bit parameter can take one of two values: ONE or ZERO. The PMA continuously sends the appropriate stream of bits to the PMD for transmission on the medium, at a nominal 1.25 GBd signaling speed. Upon receipt of this primitive, the PMD converts the specified stream of bits into the appropriate signals at the MDI.

59.1.5.2 PMD_UNITDATA.indication

This primitive defines the transfer of data from the PMD to the PMA.

The semantics of the service primitive are PMD_UNITDATA.indication(rx_bit). The data conveyed by PMD_UNITDATA.indication is a continuous stream of bits where the rx_bit parameter can take one of two values: ONE or ZERO. The PMD continuously sends a stream of bits to the PMA corresponding to the signals received from the MDI.

59.1.5.3 PMD_SIGNAL.indication

This primitive is generated by the PMD to indicate the status of the signal being received from the MDI.

The semantics of the service primitive are PMD_SIGNAL.indication(SIGNAL_DETECT). The SIGNAL_DETECT parameter can take on one of two values: OK or FAIL, indicating whether the PMD is detecting light at the receiver (OK) or not (FAIL). When SIGNAL_DETECT = FAIL, PMD_UNITDATA.indication(rx_bit) is undefined. The PMD generates this primitive to indicate a change in the value of SIGNAL_DETECT.

SIGNAL_DETECT = OK does not guarantee that PMD_UNITDATA.indication(rx_bit) is known good. It is possible for a poor quality link to provide sufficient light for a SIGNAL_DETECT = OK indication and still not meet the specified bit error ratio.

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59.2 PMD functional specifications

The 1000BASE-X PMDs perform the transmit and receive functions that convey data between the PMD service interface and the MDI.

59.2.1 PMD block diagram

The PMD sublayer is defined at the four reference points shown in Figure 59–2. Two points, TP2 and TP3, are compliance points. TP1 and TP4 are reference points for use by implementers. The optical transmit signal is defined at the output end of a patch cord (TP2), between 2 m and 5 m in length, of a fiber type consistent with the link type connected to the transmitter. If a single-mode fiber offset-launch mode-conditioning patch cord is used, the optical transmit signal is defined at the end of this single-mode fiber offset-launch mode-conditioning patch cord at TP2. Unless specified otherwise, all transmitter measurements and tests defined in 59.7 are made at TP2. The optical receive signal is defined at the output of the fiber optic cabling (TP3) connected to the receiver. Unless specified otherwise, all receiver measurements and tests defined in 59.7 are made at TP3.

The electrical specifications of the PMD service interface (TP1 and TP4) are not system compliance points (these are not readily testable in a system implementation). It is expected that in many implementations, TP1 and TP4 will be common between 1000BASE-X PMD types.

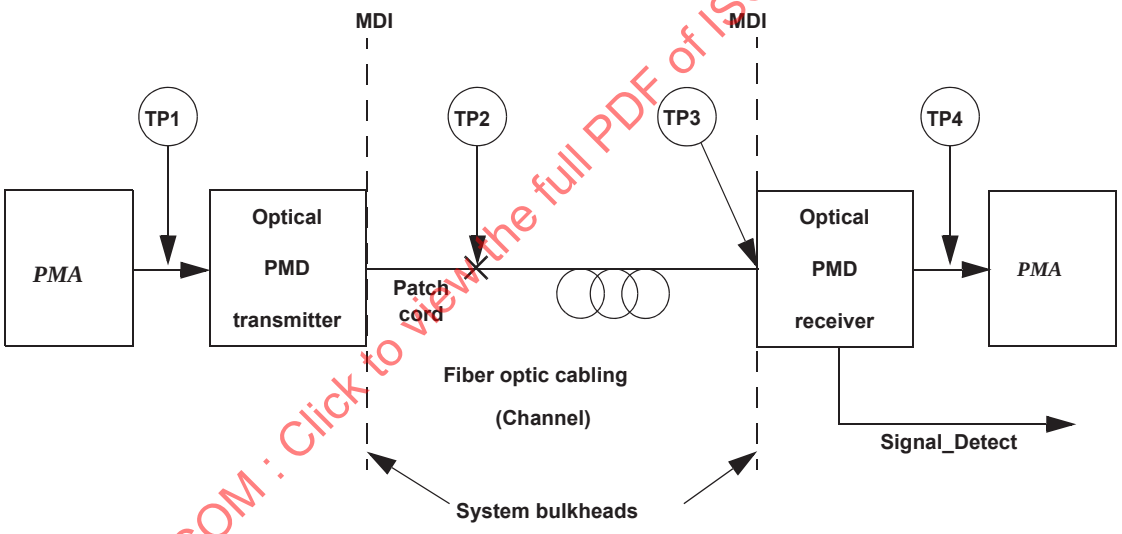

Figure 59–2—1000BASE-X block diagram

59.2.2 PMD transmit function

The PMD Transmit function shall convey the bits requested by the PMD service interface message PMD_UNITDATA.request(tx_bit) to the MDI according to the optical specifications in this clause. The higher optical power level shall correspond to tx_bit =ONE.

59.2.3 PMD receive function

The PMD receive function shall convey the bits received from the MDI according to the optical specifications in this clause to the PMD service interface using the message PMD_UNITDATA.indication(rx_bit). The higher optical power level shall correspond to rx_bit =ONE.

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59.2.4 PMD signal detect function

The PMD signal detect function shall report to the PMD service interface using the message PMD_SIGNAL.indication(SIGNAL DETECT) which is signaled continuously. PMD_SIGNAL.indication is intended to be an indicator of optical signal presence.

The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 59–2. The PMD receiver is not required to verify whether a compliant 1000BASE-X signal is being received. This standard imposes no response time requirements on the generation of the SIGNAL_DETECT parameter.

As an unavoidable consequence of the requirements for the setting of the SIGNAL_DETECT parameter, implementations must provide adequate margin between the input optical power level at which the SIGNAL_DETECT parameter is set to OK, and the inherent noise level of the PMD due to cross talk, power supply noise, etc.

Various implementations of the Signal Detect function are permitted by this standard, including implementations which generate the SIGNAL_DETECT parameter values in response to the amplitude of the 8B/10B modulation of the optical signal and implementations which respond to the average optical power of the 8B/10B modulated optical signal.

Table 59–2—1000BASE-LX10 and 1000BASE-BX10 SIGNAL_DETECT value definition

Receive conditions		Signal_detect value
1000BASE-LX10	**1000BASE-BX10**	
Average input optical power ≤ signal detect threshold (min) in Table 59–5	Average input optical power ≤ signal detect threshold (min) in Table 59–7	FAIL
Average input optical power ≥ receiver sensitivity (max) in Table 59–5 with a compliant 1000BASE-LX or 1000BASE-LX10 signal input	Average input optical power ≥ receiver sensitivity (max) in Table 59–7 with a compliant 1000BASE-BX10 signal input at the specified receiver wavelength	OK
All other conditions		Unspecified

59.3 PMD to MDI optical specifications for 1000BASE-LX10

The operating range for 1000BASE-LX10 is defined in Table 59–1. A 1000BASE-LX10 compliant transceiver operates over the media types listed in Table 59–1 according to the specifications described in 59.9. A transceiver that exceeds the operational range requirement while meeting all other optical specifications is considered compliant.

NOTE—In this subclause and Table 59–5, the specifications for OMA have been derived from extinction ratio and average launch power (minimum) or receiver sensitivity (maximum). The calculation is explained in 58.7.6.

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59.3.1 Transmitter optical specifications

The 1000BASE-LX10 transmitter's signaling speed, operating wavelength, spectral width, average launch power, extinction ratio, return loss tolerance, OMA, eye and TDP shall meet the specifications defined in Table 59–3 per measurement techniques described in 59.7. Its $RIN_{12}OMA$ should meet the value listed in Table 59–3 per measurement techniques described in 58.7.7. To ensure that the specifications of Table 59–3 are met with MMF links, the 1000BASE-LX10 transmitter output shall be coupled through a single-mode fiber offset-launch mode-conditioning patch cord, as defined in 59.9.5.The maximum RMS spectral width vs. center wavelength for 1000BASE-LX10 is shown in Table 59–4 and Figure 59–3. The equation used to generate these values is included in 59.7.2. The values in bold are normative, the others informative.

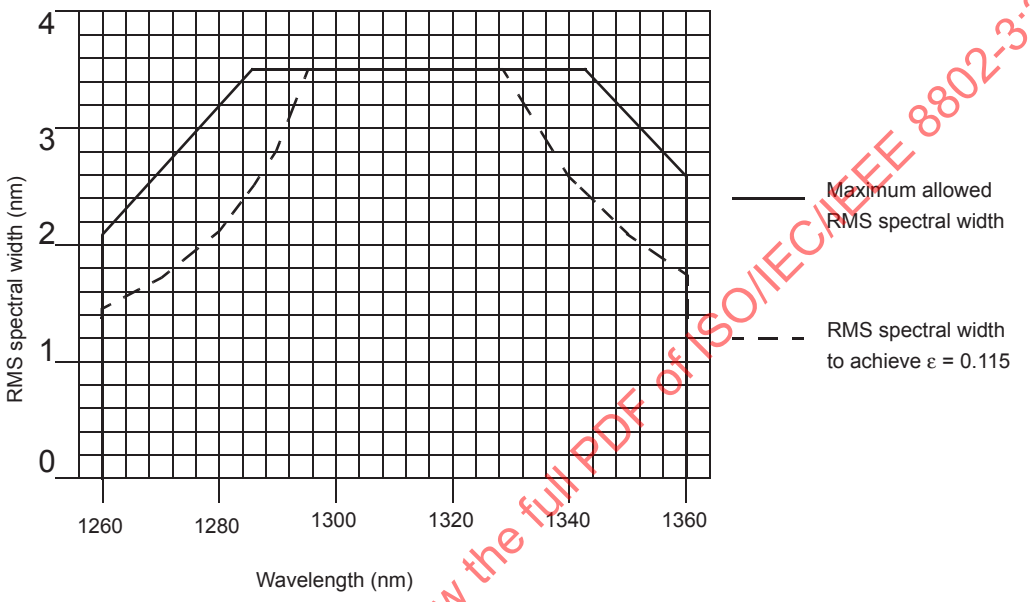

Figure 59–3—1000BASE-LX-10 Transmitter spectral limits

Table 59–3—1000BASE-LX10 transmit characteristics

Description	SMF	50 µm MMF	62.5 µm MMF	Unit
Nominal transmitter type[a]	Longwave Laser			
Signaling speed (range)	1.25 ± 100 ppm			GBd
Operating wavelength range[b]	1260 to 1360			nm
T rise /T fall (max, 20–80% response time)	0.30			ns
RMS spectral width (max)	See Table 59–4			nm
Average launch power (max)	–3			dBm
Average launch power (min)	–9	–11.0	–11.0	dBm
Average launch power of OFF transmitter (max)	–45			dBm
Extinction ratio (min)	6			dB
$RIN_{12}OMA$ (max)	–113			dB/Hz
Optical return loss tolerance (max)	12			dB
Launch OMA (min)	–8.7 (130)	–10.2 (100)	–10.2 (100)	dBm (µW)
Transmitter eye mask definition {X1, X2, Y1, Y2, Y3}	0.22, 0.375, 0.20, 0.20, 0.30			UI

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Table 59–3—1000BASE-LX10 transmit characteristics *(continued)*

Description	SMF	50 µm MMF	62.5 µm MMF	Unit
Decision timing offsets for transmitter and dispersion penalty (min)	±80			ps
Transmitter reflectance (max)	–6			dB
Transmitter and dispersion penalty, TDP (max)	3.3	3.5		dB
Differential delay, reference receiver for TDP (min)[c]	NA	367		ps

[a]The nominal device type is not intended to be a requirement on the source type, and any device meeting the transmitter characteristics specified may be substituted for the nominal device type.
[b]The great majority of the transmitted spectrum must fall within the operating wavelength range. The allowable range of central wavelengths is narrower than the operating wavelength range by the actual RMS spectral width at each extreme.
[c]Delay is calculated as Td = L/(3.BWf) where BWf is defined to –3 dB (optical). 1000BASE-LX is rated for 550 m of 500 MHz.km fiber while 1000BASE-LX also covered 550 m of 400 MHz.km fiber, but this is now seen as a historical bandwidth requirement.

Table 59–4—1000BASE-LX10 and 1000BASE-BX10 transmitter spectral limits

Center wavelength	RMS spectral width (max)[a]	RMS spectral width to achieve ε ≤0.115 (informative)
nm	**nm**	**nm**
1260	**2.09**	1.43
1270	**2.52**	1.72
1280	**3.13**	2.14
1286	**3.50**	2.49
1290		2.80
1297		3.50
1329		
1340		2.59
1343		2.41
1350	**3.06**	2.09
1360	**2.58**	1.76
1480 to 1500	**0.88**	0.60

[a]These limits for the 1000BASE-LX10 transmitter are illustrated in Figure 59–3. Limits at intermediate wavelengths may be found by interpolation.

59.3.2 Receiver optical specifications

The 1000BASE-LX10 receiver's signaling speed, operating wavelength, damage, overload, sensitivity, stressed receive characteristics, reflectance, and signal detect shall meet the specifications defined in Table 59–5 per measurement techniques defined in 59.7.

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Table 59–5—1000BASE-LX10 receive characteristics

Description	Value	Unit
Signaling speed (range)	1.25 ± 100 ppm	GBd
Wavelength (range)	1260 to 1360	nm
Average receive power (max)	–3	dBm
Receive sensitivity (max)	–19.5	dBm
Receiver sensitivity as OMA (max)	–18.7 (13.4)	dBm (μW)
Bit error ratio (max)	10^{-12}	
Receiver reflectance (max)[a]	–12	dB
Stressed receive sensitivity (max)	–15.4	dBm
Stressed receiver sensitivity as OMA (max)	–14.6 (35)	dBm (μW)
Vertical eye-closure penalty (min)	3.6	dB
Receive electrical 3 dB upper cutoff frequency (max)	1500	MHz
Signal detect threshold (min)	–45	dBm
Stressed eye jitter (min)[b]	0.3	UI pk-pk
Jitter corner frequency	637	kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	0.05, 0.15	UI

[a]See 1.4 for definition of reflectance.
[b]Vertical eye closure penalty and jitter specifications are test conditions for measuring stressed receiver sensitivity. They are not required characteristics of the receiver.

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59.4 PMD to MDI optical specifications for 1000BASE-BX10-D and 1000BASE-BX10-U

The operating range for 1000BASE-BX10-D and 1000BASE-BX10-U is defined in Table 59–1. A 1000BASE-BX10 compliant transceiver operates over all single-mode fibers listed in Table 59–1. A transceiver that exceeds the operational range requirement while meeting all other optical specifications is considered compliant.

NOTE—In this subclause and 59.3, the specifications for OMA have been derived from extinction ratio and average launch power (minimum) or receiver sensitivity (maximum). The calculation is explained in 58.7.6.

59.4.1 Transmit optical specifications

The 1000BASE-BX10-D and 1000BASE-BX10-U transmitter's signaling speed, operating wavelength, spectral width, average launch power, extinction ratio, return loss tolerance, OMA, eye and TDP shall meet the specifications defined in Table 59–6 per measurement techniques described in 59.7. Its $RIN_{12}OMA$ should meet the value listed in Table 59–6 per measurement techniques described in 59.7.7.

Table 59–6—1000BASE-BX10-D and 1000BASE-BX10-U transmit characteristics

Description	1000BASE-BX10-D	1000BASE-BX10-U	Unit
Nominal transmitter type[a]	Longwave Laser		
Signaling speed (range)	1.25 ± 100 ppm		GBd
Operating wavelength range[b]	1480 to 1500	1260 to 1360	nm
RMS spectral width (max)	See Table 59–4		nm
Average launch power (max)	–3		dBm
Average launch power (min)	–9		dBm
Average launch power of OFF transmitter (max)	–45		dBm
Extinction ratio (min)	6		dB
$RIN_{12}OMA$ (max)	–113		dB/Hz
Optical return loss tolerance (max)	12		dB
Launch OMA	–8.2 (151)		dBm (μW)
Transmitter eye mask definition {X1, X2, Y1, Y2, Y3}	0.22, 0.375, 0.20, 0.20, 0.30		UI
Transmitter reflectance (max)	–10	–6	dB
Transmitter and dispersion penalty, TDP (max)	3.3		dB
Decision timing offsets for transmitter and dispersion penalty (min)	± 80		ps

[a]The nominal device type is not intended to be a requirement on the source type, and any device meeting the transmitter characteristics specified may be substituted for the nominal device type.

[b]The great majority of the transmitted spectrum must fall within the operating wavelength range. The allowable range of central wavelengths is narrower than the operating wavelength range by the actual RMS spectral width at each extreme.

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59.4.2 Receiver optical specifications

The 1000BASE-BX10-D and 1000BASE-BX10-U receiver's signaling speed, operating wavelength, damage, overload, sensitivity, reflectance and signal detect shall meet the specifications defined in Table 59–7 per measurement techniques defined in 59.7. Its stressed receive characteristics should meet the values listed in Table 59–7 per measurement techniques described in 59.7.11.

Table 59–7—1000BASE-BX10-D and 1000BASE-BX10-U receive characteristics

Description	1000BASE-BX10-D	1000BASE-BX10-U	Unit
Signaling speed (range)	1.25 ± 100 ppm		GBd
Wavelength (range)	1260 to 1360	1480 to 1500	nm
Bit error ratio (max)	10^{-12}		
Average receive power (max)	–3		dBm
Receive sensitivity (max)	–19.5		dBm
Receiver sensitivity as OMA (max)	–18.7 (13.4)		dBm (μW)
Receiver reflectance (max)	–12		dB
Stressed receive sensitivity (max)[a]	–15.4		dBm
Stressed receiver sensitivity as OMA (max)	–14.6 (35)		dBm (μW)
Vertical eye-closure penalty (min)[b]	2.6		dB
Receive electrical 3 dB upper cutoff frequency (max)	1500		MHz
Signal detect threshold (min)	–45		dBm
Stressed eye jitter (min)	0.3		UI pk-pk
Jitter corner frequency	637		kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	0.05, 0.15		UI

[a]The stressed receiver sensitivity is optional.
[b]Vertical eye closure penalty and jitter specifications are test conditions for measuring stressed receiver sensitivity. They are not required characteristics of the receiver.

59.5 Illustrative 1000BASE-LX10 and 1000BASE-BX10 channels and penalties (informative)

The illustrative channel and penalties for 1000BASE-LX10 and 1000BASE-BX10 PMDs are shown in Table 59–8.

NOTE—The budgets include an allowance for –12 dB reflection at the receiver.

59.6 Jitter specifications

The entries for the 1000BASE-LX10 jitter budget on MMF in Table 59–9 and the 1000BASE-LX10 and 1000BASE-BX10 jitter budget on SMF in Table 59–10 represent high-frequency jitter (above 637 kHz) and do not include low frequency jitter or wander. All values are informative.

W is similar but not necessarily identical to deterministic jitter (DJ). A jitter measurement procedure is described in 58.7.12. Other jitter measurements are described in 59.7.12 and 59.7.13. Jitter at TP2 or TP3 is defined with a receiver of the same bandwidth as specified for the transmitted eye.

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Table 59–8—Illustrative 1000BASE-LX10 and 1000BASE-BX10 channel and penalties

PMD type	1000BASE-LX10		1000BASE-BX10-D	1000BASE-BX10-U	Unit
Fiber type	B1.1, B1.3 SMF	50µm, 62.5µm MMF	B1.1, B1.3 SMF		
Measurement wavelength for fiber	1310	1300	1550	1310	nm
Nominal distance	10	0.55	10		km
Available power budget	10.5	8.5	10.5		dB
Maximum channel insertion loss[a]	6.0	2.4	5.5	6.0	dB
Allocation for penalties[b]	4.5	6.1	5.0	4.5	dB

[a]The maximum channel insertion loss is based on the cable attenuation at the target distance and nominal measurement wavelength. The channel insertion loss also includes the loss for connectors, splices and other passive components.

[b]The allocation for penalties is the difference between the available power budget and the channel insertion loss; insertion loss difference between nominal and worse case operating wavelength is considered a penalty.

Table 59–9—1000BASE-LX10 jitter budget on MMF (informative)

	Total jitter		*W*	
Reference point	UI	ps	UI	ps
TP1	0.240	192	0.100	80
TP1 to TP2	0.284	227	0.100	80
TP2	0.431	345	0.200	160
TP2 to TP3	0.170	136	0.050	40
TP3	0.510	408	0.250	200
TP3 to TP4	0.332	266	0.212	170
TP4	0.749	599	0.462	370

Table 59–10—1000BASE-LX10 and 1000BASE-BX10 jitter budget on SMF (informative)

	Total jitter		*W*	
Reference point	UI	ps	UI	ps
TP1	0.240	192	0.100	80
TP1 to TP2	0.334	267	0.150	120
TP2	0.481	385	0.250	200
TP2 to TP3	0.119	95	0	0
TP3	0.510	408	0.250	200
TP3 to TP4	0.332	266	0.212	170
TP4	0.749	599	0.462	370

NOTE—Informative jitter values are chosen to be compatible with the limits for eye mask and TDP (see 58.7.9). A margin between the total jitter at TP4 and the eye opening imposed by the decision point offsets for TDP is intended to allow for the performance of test equipment used for TDP measurement, to avoid very involved jitter calibrations.

Total jitter in this table is defined at 10^{-12} BER. In a commonly used model,

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$$TJ = 14.1\sigma + DJ \text{ at } 10^{-12} \quad (59\text{–}1)$$

59.7 Optical measurement requirements

All optical measurements, except TDP and RIN, shall be made through a short patch cable, between 2 m and 5 m in length.

The following sections describe definitive patterns and test procedures for certain PMDs of this standard. implementers using alternative verification methods must ensure adequate correlation and allow adequate margin such that specifications are met by reference to the definitive methods.

59.7.1 Test patterns

The frame-based test patterns defined here are suitable for testing all Clause 59 and Clause 60 PMDs. Further information on frame-based testing in included in Annex 58A. The test suite and the patterns are shown in Table 59–11.

Table 59–11—List of test patterns and tests

Test pattern	Tests	Related subclauses
Any valid 8B/10B encoded signal	Eye mask Optical power Central wavelength Spectral width	59.7.8 59.7.3 59.7.2 59.7.2
Idles	Extinction ratio $RIN_{12}OMA$ OMA	59.7.4 59.7.7
Random pattern test frame	Receiver sensitivity Stressed receiver sensitivity Receiver 2dB upper cutoff frequency TDP	59.7.11 59.7.14 59.7.15 59.7.10
Jitter pattern test frame	All jitter tests	59.7.12

The following test patterns are intended for frame-based testing of the 1000BASE-X PMDs of Clause 59 and Clause 60. They are compliant Ethernet packets with adequate user defined fields to allow them to be routed through a system to the point of the test. The common portions of the frames are given in Table 59–12.

Table 59–12—Common portion of frame-based test pattern

Field	Number of octets	Hexadecimal	8B/10B encoded binary[a]	
			Starting disparity +	Starting disparity–
SPD (/S/)	1	N/A[b]	N/A[c]	110110 1000
Remainder of preamble	6	55	N/A[c]	101010 0101
SFD	1	D5	N/A[c]	101010 0110
Destination address	6	User defined	User defined	User defined
Source address	6	User defined	User defined	User defined
Length/Type	2	User defined	User defined	User defined
First portion of MAC client data	32	User defined	User defined	User defined
Second portion of MAC client data	456	See Table 59–13 or Table 59–14	See Table 59–13 or Table 59–14	See Table 59–13 or Table 59–14
Frame check sequence[d]	4	As required by frame	As required by frame	As required by frame

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Table 59–12—Common portion of frame-based test pattern *(continued)*

Field	Number of octets	Hexadecimal	8B/10B encoded binary[a]	
			Starting disparity +	Starting disparity–
EPD (/T/R/)[e]	2	N/A[b]	010001 0111 000101 0111	101110 1000 111010 1000
Idle (/I1/ or /I2/)[e]	2	N/A[b]	110000 0101 101001 0110	001111 1010 100100 0101
Idle (/I2/)[e]	10	N/A[b]	N/A[f]	001111 1010 100100 0101

[a]The binary bits are transmitted left most bit first.
[b]The SPD, EPD, and Idle code-groups are generated by the PCS and their hexadecimal octet values have no meaning without relation to the signals transmitted across the GMII.
[c]Except when operating in a half-duplex mode, it is not possible to transmit an SPD with a positive starting disparity. The first code-group that could begin with a positive running disparity would be the second octet of the destination address.
[d]The frame check sequence may be calculated using the method described in 3.2.9.
[e]The first row precedes the second row.
[f]The first idle code-group following the frame will be an /I1/ if the running disparity is positive and an /I2/ if the running disparity is negative. All subsequent idle code-groups will be /I2/.

NOTE—Users are advised to take care that the system under test is not connected to a network in service.

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Two payloads are defined. The first, which emulates a random pattern with broad spectral content and minimal peaking, is shown in Table 59–13.

Table 59–13—Payload for random pattern test frame

Number of octets	Hexadecimal	8B/10B encoded binary	
		Starting disparity +	Starting disparity –
Repeat 19 times for 228 bytes	BE	100001 1010	011110 1010
	D7	111010 0110	000101 0110
	23	110001 1001	110001 1001
	47	000111 0101	111000 0101
	6B	110100 0011	110100 1100
	8F	101000 1101	010111 0010
	B3	110010 1010	110010 1010
	14	001011 0100	001011 1011
	5E	011110 0101	100001 0101
	FB	001001 1110	110110 0001
	35	101010 1001	101010 1001
	59	100110 0101	100110 0101
Transmit once for 12 bytes	BC	001110 1010	001110 1010
	D7	000101 0110	111010 0110
	23	110001 1001	110001 1001
	47	111000 0101	000111 0101
	6B	110100 1100	110100 0011
	8F	010111 0010	101000 1101
	B3	110010 1010	110010 1010
	14	001011 1011	001011 0100
	5E	100001 0101	011110 0101
	FB	110110 0001	001001 1110
	35	101010 1001	101010 1001
	59	100110 0101	100110 0101
Repeat 18 times for 216 bytes	BE	011110 1010	100001 1010
	D7	000101 0110	111010 0110
	23	110001 1001	110001 1001
	47	111000 0101	000111 0101
	6B	110100 1100	110100 0011
	8F	010111 0010	101000 1101
	B3	110010 1010	110010 1010
	14	001011 1011	001011 0100
	5E	100001 0101	011110 0101
	FB	110110 0001	001001 1110
	35	101010 1001	101010 1001
	59	100110 0101	100110 0101

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The payload for the second pattern is shown in Table 59–14.

Table 59–14—Payload for jitter test frame

Field	Hexadecimal	8B/10B encoded binary	
		Starting disparity +	Starting disparity –
Low Transition Density, Repeat 96 times for 192 bytes	7E	100001 1100	011110 0011
	7E	011110 0011	100001 1100
Phase Jump, Repeat one time for 8 bytes	F4	001011 0001	001011 0111
	EB	110100 1110	110100 1000
	F4	001011 0001	001011 0111
	EB	110100 1110	110100 1000
	F4	001011 0001	001011 0111
	EB	110100 1110	110100 1000
	F4	001011 0001	001011 0111
	AB	110100 1010	110100 1010
High Transition Density, Repeat 20 times for 20 bytes	B5	101010 1010	101010 1010
Phase Jump, Repeat 4 times for 8 bytes	EB	110100 1110	110100 1000
	F4	001011 0001	001011 0111
Low Transition Density, Repeat 96 times for 192 bytes	7E	011110 0011	100001 1100
	7E	100001 1100	011110 0011
Phase Jump, Repeat one time for 8 bytes	F4	001011 0111	001011 0001
	EB	110100 1000	110100 1110
	F4	001011 0111	001011 0001
	EB	110100 1000	110100 1110
	F4	001011 0111	001011 0001
	EB	110100 1000	110100 1110
	F4	001011 0111	001011 0001
	AB	110100 1010	110100 1010
High Transition Density, Repeat 20 times for 20 bytes	B5	101010 1010	101010 1010
Phase Jump, Repeat 4 times for 8 bytes	EB	110100 1000	110100 1110
	F4	001011 0111	001011 0001

This pattern has areas of high and low transition density to aggravate jitter susceptibility.

Frames are separated by a near minimum interpacket gap (IPG) of 14 octets.

59.7.2 Wavelength and spectral width measurements

The wavelength and spectral width (RMS) shall meet the specifications according to TIA-455-127-A, under modulated conditions using a valid 1000BASE-X signal.

NOTE 1—The great majority of the transmitted spectrum must fall within the operating range. The allowable range of central wavelengths is narrower than the operating wavelength range by the actual RMS spectral width at each extreme.

NOTE 2—The 20 dB width for SLM lasers is taken as 6.07 times the RMS width.

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The interaction between the transmitter and the chromatic dispersion of the fiber is accounted for by a parameter ε (epsilon), which is defined as the product of 10^{-3} times the signaling speed (in GBd) times the path dispersion (in ps/nm) times the RMS spectral width (in nm).

$$\varepsilon = \text{dispersion} \times \text{length} \times \text{RMS spectral width} \times \text{signaling speed} \times 10^{-3} \quad (59\text{–}2)$$

A maximum ε close to 0.168 is imposed by column 2 of Table 59–5. If the spectral width is kept below the limits of column 3, ε will not exceed 0.115, and the chromatic dispersion penalty is expected to be below 2 dB. The chromatic dispersion penalty is a component of transmitter and dispersion penalty (TDP) which is specified in Table 59–3, Table 59–6 and described in 58.7.9.

59.7.3 Optical power measurements

Optical power shall meet specifications according to the methods specified in ANSI/EIA-455-95. A measurement may be made with the port transmitting any valid encoded 8B/10B data stream.

59.7.4 Extinction ratio measurements

Extinction ratio shall meet specifications according to IEC 61280-2-2 with the port transmitting a repeating idle pattern /I2/ ordered set (see 36.2.4.12) that may be interspersed with OAM packets per 57A.2, and with minimal back reflections into the transmitter, lower than –20 dB. The /I2/ ordered set is defined in Clause 36, and is coded as /K28.5/D16.2/, which is binary 001111 1010 100100 0101 within idles. The extinction ratio is expected to be similar for other valid 8B/10B bit streams. The test receiver has the frequency response as specified for the transmitter optical waveform measurement.

59.7.5 OMA measurements (informative)

58.7.5 provides a reference technique for performing OMA measurements.

59.7.6 OMA relationship to extinction ratio and power measurements (informative)

The normative way of measuring transmitter characteristics is extinction ratio and mean power. Clause 58 provides information on how OMA, extinction ratio, and mean power, are related to each other (see 58.7.6).

59.7.7 Relative intensity noise optical modulation amplitude ($RIN_{12}OMA$)

$RIN_{12}OMA$ is the ratio of noise to modulated optical signal in the presence of a back reflection. The measurement procedure is described in 58.7.7.

59.7.8 Transmitter optical waveform (transmit eye)

The required transmitter pulse shape characteristics are specified in the form of a mask of the transmitter eye diagram as shown in Figure 59–4.

The measurement procedure is described in 58.7.8 and references therein.

The eye shall comply to the mask of the eye using a fourth-order Bessel-Thomson receiver response with f_r= 0.9375 GHz, and where the relative response vs. relative frequency is defined in ITU-T G.957, Table B.2 (STM-16 values), along with the allowed tolerances for its physical implementation.

NOTE 1—This Bessel-Thomson filter is not intended to represent the noise filter used within an optical receiver, but is intended to provide uniform measurement conditions on the transmitter.

NOTE 2—The fourth order Bessel-Thomson filter is reactive. In order to suppress reflections, a 6 dB attenuator may be required at the filter input and/or output.

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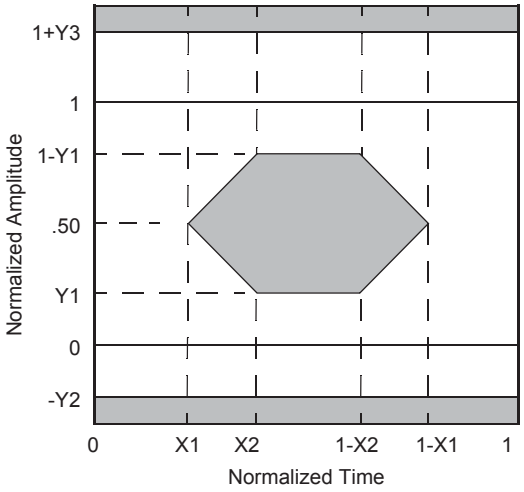

Figure 59–4—Transmitter eye mask definition

59.7.9 Transmit rise/fall characteristics

Optical response time specifications are based on unfiltered waveforms. Some lasers have overshoot and ringing on the optical waveforms, which, if unfiltered, reduce the accuracy of the 20–80% response times. For the purpose of standardizing the measurement method, measured waveforms shall conform to the mask defined in 59.7.8. If a filter is needed to conform to the mask, the filter response should be removed using Equation (59–3):

$$T_{\text{rise, fall}} = \sqrt{(T_{\text{rise, fall, measured}})^2 - (T_{\text{rise, fall, filter}})^2} \quad (59\text{–}3)$$

where the filter may be different for rise and fall. Any filter should have an impulse response equivalent to a fourth order Bessel-Thomson filter. The fourth order Bessel-Thomson filter describe in 59.7.8 may be a convenient filter for this measurement, however its low bandwidth adversely impacts the accuracy of the rise and fall time measurements.

59.7.10 Transmitter and dispersion penalty (TDP)

This measurement tests for transmitter impairments with modal (not chromatic) dispersion effects for a transmitter to be used with multimode fiber, and for transmitter impairments with chromatic effects for a transmitter to be used with single-mode fiber. Possible causes of impairment include intersymbol interference, jitter, RIN and mode partition noise. Meeting the separate requirements (e.g., eye mask, spectral characteristics) does not in itself guarantee the transmitter and dispersion penalty (TDP). The TDP limit shall be met. See 59.7.9 for details of the measurement.

59.7.11 Receive sensitivity measurements

Receiver sensitivity is defined for the random pattern test frame (see 59.7.1) and an ideal input signal quality with the specified extinction ratio. The measurement procedure is described in 58.7.10. The sensitivity shall be met for the bit error ratio defined in Table 59–5 or Table 59–7 as appropriate. Stressed sensitivity is described in 59.7.14 and 58.7.11.

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59.7.12 Total jitter measurements (informative)

Total jitter measurements may be made according to the method in ANSI X3.230 [B21](FC-PH), Annex A, A.4.2, or according to 58.7.12. Total jitter at TP2 should be measured utilizing a BERT (bit error ratio tester). References to use of the Bessel-Thomson filter should substitute use of the Bessel-Thomson filter defined in this clause (see 59.7.8). The test should utilize the mixed frequency test pattern specified in 59.7.1.

Total jitter at TP4 should be measured using the conformance test signal at TP3, as specified in 59.7.14. The optical power should be at the stressed receive sensitivity level in Table 59–5 for 1000BASE-LX10 and in Table 59–7 for 1000BASE-BX10. This power level should be corrected if the extinction ratio differs from the specified extinction ratio (minimum). Measurements at TP4 should be taken directly without additional Bessel-Thomson filters.

Jitter measurement may use a clock recovery unit (commonly referred to in the industry as a "golden PLL") to remove low-frequency jitter from the measurement as shown in Figure 59–5. The clock recovery unit has a low-pass filter with 20 dB/decade rolloff with –3 dB point of 637 kHz. For this measurement, the recovered clock will run at the signaling speed. The golden PLL is used to approximate the PLL in the deserializer function of the PMA. The PMA deserializer is able to track a large amount of low-frequency jitter (such as drift or wander) below its bandwidth. This low-frequency jitter would create a large measurement penalty, but does not affect operation of the link.

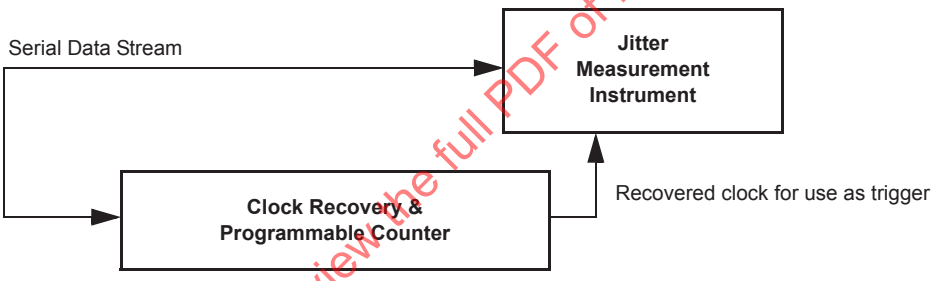

Figure 59–5—Utilization of clock recovery unit during measurement

59.7.13 Deterministic or high probability jitter measurement (informative)

Deterministic jitter may be measured according to ANSI X3.230-1994 [B21] (FC-PH), Annex A, A.4.3, DJ Measurement or high probability jitter may be measured according to 58.7.12. The test utilizes the mixed frequency test pattern specified in 36A.3. This method utilizes a digital sampling scope to measure actual vs. predicted arrival of bit transitions of the 36A.3 data pattern (alternating K28.5 code-groups).

It is convenient to use the clock recovery unit described in 59.7.12 for purposes of generating a trigger for the test equipment. This recovered clock should have a frequency equivalent to 1/20th of the signaling speed.

Measurements at TP2 and TP3 use the filter specified in 59.7.8, measurements at TP1 and TP4 do not use this filter.

59.7.14 Stressed receiver conformance test

The stressed receiver conformance test is intended to screen against receivers with poor frequency response or timing characteristics which could cause errors when combined with a distorted but compliant signal at TP3. Modal (MMF) or chromatic (SMF) dispersion can cause distortion. The conformance test signal uses the random pattern test frame and is conditioned by applying deterministic jitter and intersymbol

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interference. If the option for stressed receiver compliance is chosen, the receiver shall meet the specified bit error ratio at the power level and signal quality defined in Table 59–5 and Table 59–7 as appropriate, according to the measurement procedures of 58.7.11.

59.7.15 Measurement of the receiver 3 dB electrical upper cutoff frequency

The receiver 3 dB electrical upper cutoff frequency shall meet specifications according to the methods specified below. The test setup is shown in Figure 59–6. The test is performed with a laser that is suitable for analog signal transmission. The laser is modulated by a digital data signal. In addition to the digital modulation, the laser is modulated with an analog signal. The analog and digital signals should be asynchronous. The data pattern to be used for this test is the random pattern test frame defined in 59.7.1. The frequency response of the laser must be sufficient to allow it to respond to both the digital modulation and the analog modulation. The laser should be biased so that it remains linear when driven by the combined signals. Alternatively the two signals may be combined in the optical domain.

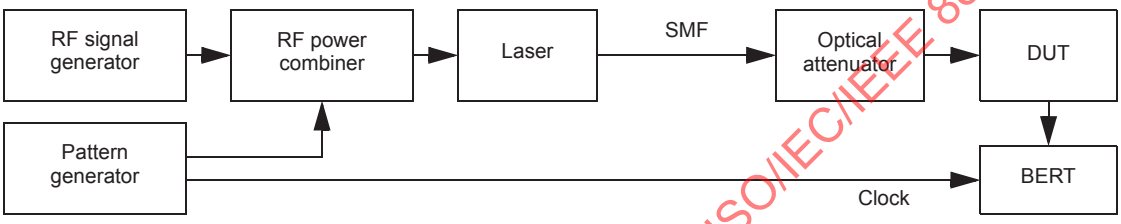

Figure 59–6—Test setup for receiver bandwidth measurement

The 3 dB upper cutoff frequency is measured using the following steps a) through e):

a) Calibrate the frequency response characteristics of the test equipment including the analog radio frequency (RF) signal generator, RF power combiner, and laser source. Measure the laser's extinction ratio according to 59.7.4. With the exception of extinction ratio, the optical source shall meet the requirements of Clause 59.
b) Configure the test equipment as shown in Figure 59–6. Take care to minimize changes to the signal path that could affect the system frequency response after the calibration in step a. Connect the laser output with no RF modulation applied to the receiver under test through an optical attenuator and taking into account the extinction ratio of the source, set the optical power to a level that approximates the stressed receive sensitivity level in Table 59–5 for 1000BASE-LX10 and in Table 59–7 for 1000BASE-BX10.
c) Locate the center of the eye with the BERT. Turn on the RF modulation while maintaining the same average optical power established in step b).
d) Measure the necessary RF modulation amplitude (in dBm) required to achieve a constant BER (e.g., 10^{-8}) for a number of frequencies.
e) The receiver 3 dB electrical upper cutoff frequency is that frequency where the corrected RF modulation amplitude (the measured amplitude in step d) corrected with the calibration data in step a) increases by 3 dB (electrical). If necessary, interpolate between the measured response values.

59.8 Environmental, safety, and labeling specifications

59.8.1 General safety

All equipment meeting this standard shall conform to IEC 60950-1.

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59.8.2 Laser safety

1000BASE-BX10 and 1000BASE-LX10 optical transceivers shall conform to Hazard Level 1 laser requirements as defined in IEC 60825-1 and IEC 60825-2, under any condition of operation. This includes single fault conditions whether coupled into a fiber or out of an open bore. Conformance to additional laser safety standards may be required for operation within specific geographical regions.

Laser safety standards and regulations require that the manufacturer of a laser product provide information about the product's laser, safety features, labeling, use, maintenance and service. This documentation shall explicitly define requirements and usage restrictions on the host system necessary to meet these safety certifications.

59.8.3 Installation

It is recommended that proper installation practices, as defined by applicable local codes and regulations, be followed in every instance in which such practices are applicable.

59.8.4 Environment

Reference Annex 67A for additional environmental information.

Two optional temperature ranges are defined in Table 59–15. Implementations shall be declared as compliant over one or both complete ranges, or not so declared (compliant over parts of these ranges or another temperature range).

Table 59–15—Component case temperature classes

Class	Low temperature (°C)	High temperature (°C)
Warm extended	–5	+85
Cool extended	–40	+60
Universal extended	–40	+85

59.8.5 PMD labeling requirements

It is recommended that each PHY (and supporting documentation) be labeled in a manner visible to the user, with at least the applicable safety warnings and the applicable port type designation (e.g., 1000BASE-BX10-U).

Labeling requirements for Hazard Level 1 lasers are given in the laser safety standards referenced in 59.8.2.

Compliant systems and field pluggable components shall be clearly labeled with the operating temperature range over which their compliance is ensured.

59.9 Characteristics of the fiber optic cabling

The 1000BASE-BX10 and 1000BASE-LX10 fiber optic cabling shall meet the dispersion and modal bandwidth specifications defined in IEC 60793-2 and ITU-T G.652, or the requirements of Table 59–16 where they differ. The fiber cable attenuation is shown for information only; the end-to-end channel loss shall meet the requirements of Table 59–1. The fiber optic cabling consists of one or more sections of fiber optic cable

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and any intermediate connections required to connect sections together. The fiber optic cabling spans from one MDI to another MDI, as shown in Figure 59–7.

59.9.1 Fiber optic cabling model

The fiber optic cabling model is shown in Figure 59–7.

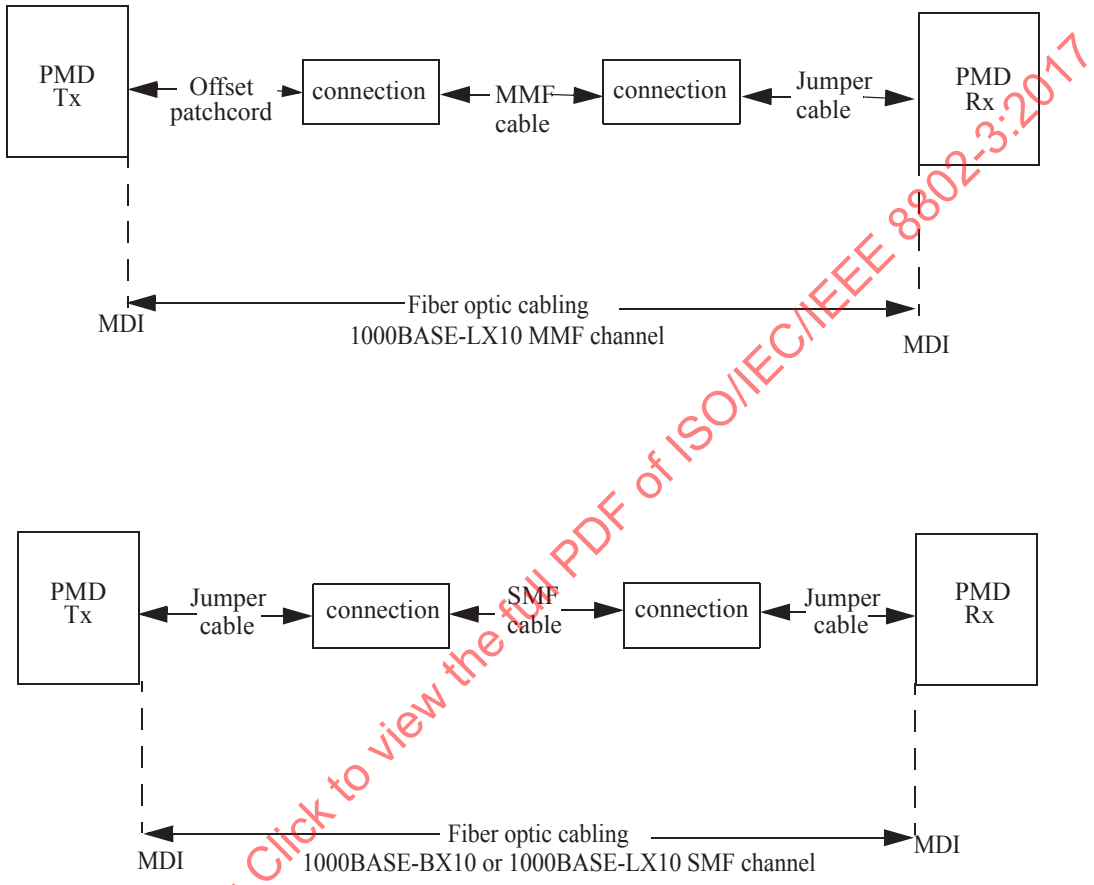

Figure 59–7—Fiber optic cable model

The maximum channel insertion loss shall meet the requirements specified in Table 59–1. The minimum loss for 1000BASE-BX10 and 100BASE-LX10 is zero. A channel may contain additional connectors or other optical elements as long as the optical characteristics of the channel, such as attenuation, dispersion and reflections, meet the specifications. Insertion loss measurements of installed fiber cables are made in accordance with ANSI/TIA/EIA-526-14A [B15], method B for multimode cabling and ANSI/TIA/EIA-526-7 [B16], method A-1 for single-mode cabling. The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment. The term channel is used here for consistency with generic cabling standards.

59.9.2 Optical fiber and cable

The fiber optic cable requirements are satisfied by the fibers specified in IEC 60793-2 Type B1.1 (dispersion un-shifted single-mode fiber) and Type B1.3 (low water peak single-mode fiber) and ITU-T G.652, or by the requirements of Table 59–16 where they differ.

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Table 59–16—Optical fiber and cable characteristics

Description[a]	B1.1, B1.3 SMF		50 µm MMF	62.5 µm MMF	Unit
Nominal fiber specification wavelength[b]	1310	1550	1300		nm
Cabled optical fiber attenuation (max)[c]	0.4	0.35	1.5		dB/km
Modal Bandwidth (min; overfilled launch)	N/A		500[d]		MHz· km
Zero dispersion wavelength[e]	$1300 \le \lambda_0 \le 1324$		$1295 \le \lambda_0 \le 1320$	$1320 \le \lambda_0 \le 1365$	nm
Dispersion slope (max)	0.093		0.11 for $1300 \le \lambda_0 \le 1320$ and $0.001(\lambda_0-1190)$ for $1295 \le \lambda_0 \le 1300$	0.11 for $1320 \le \lambda_0 \le 1348$ and $0.001(1458-\lambda_0)$ for $1348 \le \lambda_0 \le 1365$	ps /nm^2 · km

[a]The fiber dispersion values are normative, all other values in the table are informative.
[b]The wavelength specified is the nominal fiber specification wavelength which is the typical measurement wavelength. Power penalties at other wavelengths are accounted for.
[c]Attenuation values are informative. Attenuation for single-mode optical fiber cables is defined in ITU-T G.652 and for multimode fiber cables is defined in ISO/IEC 11801.
[d]1000BASE-LX10 is rated for 550 m of 500 MHz·km fiber, while 1000BASE-LX also covered 550 m of 400 MHz·km, but this now seen as a historical bandwidth requirement.
[e]See IEC 60793 or G.652 for correct use of zero dispersion wavelength and dispersion slope.

59.9.3 Optical fiber connection

The maximum link distances for multimode fiber are calculated based on the allocation of 1.5 dB total connection and splice loss. Connections with different loss characteristics may be used provided the requirements of Table 59–1 are met.

The maximum link distances for single-mode fiber are calculated based on the allocation of 2 dB total connection and splice loss for 1000BASE-LX10 and 1000BASE-BX10. Connections with different loss characteristics may be used provided the requirements of Table 59–1 are met.

The maximum discrete reflectance for multimode connections shall be less than –20 dB.

The maximum discrete reflectance for single-mode connections shall be less than –26 dB.

59.9.4 Medium Dependent Interface (MDI)

The 1000BASE-LX10 or 1000BASE-BX10 PMD is coupled to the fiber cabling at the MDI. The MDI is the interface between the PMD and the "fiber optic cabling" as shown in Figure 59–7. Examples of an MDI include the following:

a) Connectorized fiber pigtail
b) PMD receptacle

When the MDI is a remateable connection, it shall meet the interface performance specifications of IEC 61753-1. The MDI carries the signal in both directions. For 1000BASE-BX10 it couples a single fiber and for 1000BASE-LX10 it couples dual fibers.

NOTE—Compliance testing is performed at TP2 and TP3 as defined in 59.2.1, not at the MDI.

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59.9.5 Single-mode fiber offset-launch mode-conditioning patch cord for MMF operation of 1000BASE-LX10

This subclause specifies an example embodiment of a mode conditioner for 1000BASE-LX10 operation with MMF cabling. The mode conditioner consists of a single-mode fiber permanently coupled off-center to a graded index fiber. This example embodiment of a patch cord is not intended to exclude other physical implementations of offset-launch mode conditioners. However, any implementation of an offset-launch mode conditioner used for 1000BASE-LX10 shall meet the specifications of Table 59–17. The offset launch shall be contained within the patch cord assembly and is not adjustable by the user.

NOTE—The single-mode fiber offset-launch mode-conditioning patch cord described in Clause 38 may be used, although its labeling and coloring requirements are not mandatory here. See 38.11.4.

Table 59–17—Single-mode fiber offset-launch mode conditioner specifications

Description	62.5 µm MMF	50 µm MMF	Unit
Maximum insertion loss	0.5	0.5	dB
Coupled power ratio (CPR)	28 < CPR < 40	12 < CPR < 20	dB
Optical center offset between SMF and MMF	17 < Offset < 23	10 < Offset < 16	µm
Maximum angular offset	1	1	degree

Patch cord connectors and ferrules for the single-mode-to-multimode offset launch shall have single-mode tolerances, float, and other mechanical requirements according to IEC 61754-1.

The single-mode fiber used in the construction of the single-mode fiber offset-launch mode conditioner shall meet the requirements of 59.9.2. The multimode fiber used in the construction of the single-mode fiber offset-launch mode conditioner shall be of the same type as the cabling over which the 1000BASE-LX10 link is to be operated. If the cabling is 62.5 µm MMF then the MMF used in the construction of the mode conditioner is of type 62.5 µm MMF. If the cabling is 50 µm MMF, then the MMF used in the construction of the mode conditioner is of type 50 µm MMF.

Figure 59–8 shows an example of an embodiment of the single-mode fiber offset-launch mode-conditioning patch cord. This patch cord consists of duplex fibers including a single-mode-to-multimode offset launch fiber connected to the transmitter MDI and a second conventional graded index MMF connected to the receiver MDI. The preferred configuration is a plug-to-plug patch cord since it maximizes the power budget margin of the 1000BASE-LX10 link. The single-mode end of the patch cord is labeled “To Equipment”. The multimode end of the patch cord is labeled “To Cable”. The recommended color identifier of the single-mode fiber connector is blue. The recommended color identifier of all multimode fiber connector plugs is beige. The patch cord assembly is labeled “Offset-launch mode-conditioning patch cord assembly”. Labeling identifies which size multimode fiber is used in the construction of the patch cord. The keying of this duplex optical plug ensures that the single-mode fiber end is automatically aligned to the transmitter MDI.

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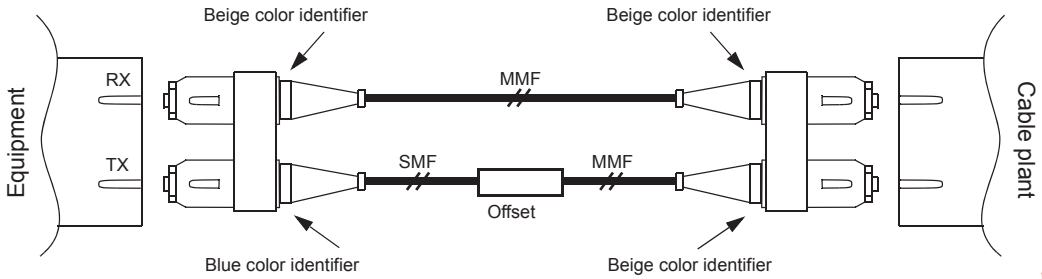

Figure 59–8—1000BASE-LX10 single-mode fiber offset-launch mode-conditioning patch cord assembly

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59.10 Protocol implementation conformance statement (PICS) proforma for Clause 59, Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-LX10 (Long Wavelength) and 1000BASE-BX10 (BiDirectional Long Wavelength)[7]

59.10.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 59, Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-LX10 and type 1000BASE-LX10, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

59.10.2 Identification

59.10.2.1 Implementation identification

Supplier[1]	
Contact point for inquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1, 3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

59.10.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 59, Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-LX10 and 1000BASE-BX10
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	

Date of Statement	

[7] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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59.10.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
HT	High temperature operation	59.8.4	–5 to 85°C	O	Yes [ ] No [ ]
LT	Low temperature operation	59.8.4	–40 to 60°C	O	Yes [ ] No [ ]
*LX	1000BASE-LX10 PMD	59.3	Device supports long wavelength (1310 nm) over dual multimode and single-mode fibers.	O/1	Yes [ ] No [ ]
*BXD	1000BASE-BX10-D PMD	Table 59–6	Device operates with one single single-mode fiber and transmits at downstream wavelength (1490 nm).	O/1	Yes [ ] No [ ]
*BXU	1000BASE-BX10-U PMD	Table 59–6	Device operates with one single single-mode fiber and transmits upstream wavelength (1310 nm).	O/1	Yes [ ] No [ ]
*INS	Installation / cable	59.9	Items marked with INS include installation practices and cable specifications not applicable to a PHY manufacturer.	O	Yes [ ] No [ ]
*OFP	Single-mode offset-launch mode-conditioning patch cord	59.9.5	Items marked with OFP include installation practices and cable specifications not applicable to a PHY manufacturer.	O	Yes [ ] No [ ]

59.10.3.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FN1	Transmit function	59.2.2	Convey bits requested by PMD_UNITDATA.request() to the MDI.	M	Yes [ ]
FN2	Transmitter optical signal	59.2.2	Higher optical power is a logical 1.	M	Yes [ ]
FN3	Receive function	59.2.3	Convey bits received from the MDI to PMD_UNITDATA.indication().	M	Yes [ ]
FN4	Receiver optical signal	59.2.3	Higher optical power is a logical 1.	M	Yes [ ]
FN5	Signal detect function	59.2.4	Mapping to PMD interface.	M	Yes [ ]
FN6	Signal detect behavior	59.2.4	Generated according to Table 59–2.	M	Yes [ ]

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59.10.3.2 PMD to MDI optical specifications for 1000BASE-LX10

Item	Feature	Subclause	Value/Comment	Status	Support
LX1	1000BASE-LX10 transmitter	59.3.1	Transmitter meets specifications in Table 59–3.	LX:M	Yes [ ] N/A [ ]
LX2	Offset-launch mode-conditioning patch cord	59.3.1	Required for LX10 multimode operation.	OFP:M	Yes [ ] N/A [ ]
LX3	1000BASE-LX10 receiver	59.3.2	Receiver meets mandatory specifications in Table 59–5.	LX:M	Yes [ ] N/A [ ]
LX4	1000BASE-LX10 stressed receiver sensitivity	59.3.2	Receiver meets mandatory specifications in Table 59–5.	LX:M	Yes [ ] N/A [ ]

59.10.3.3 PMD to MDI optical specifications for 1000BASE-BX10-D

Item	Feature	Subclause	Value/Comment	Status	Support
BXD1	1000BASE-BX10-D transmitter	59.4.1	Transmitter meets specifications in Table 59–6.	BXD:M	Yes [ ] N/A [ ]
BXD2	1000BASE-BX10-D receiver	59.4.2	Receiver meets mandatory specifications in Table 59–7.	BXD:M	Yes [ ] N/A [ ]
BXD3	1000BASE-BX10-D stressed receiver sensitivity	59.4.2	Receiver meets specifications in Table 59–7.	BXD:O	Yes [ ] No [ ] N/A [ ]

59.10.3.4 PMD to MDI optical specifications for 1000BASE-BX10-U

Item	Feature	Subclause	Value/Comment	Status	Support
BXU1	1000BASE-BX10-U transmitter	59.4.1	Transmitter meets specifications in Table 59–6.	BXU:M	Yes [ ] N/A [ ]
BXU2	1000BASE-BX10-U receiver	59.4.2	Receiver meets mandatory specifications in Table 59–7.	BXU:M	Yes [ ] N/A [ ]
BXU3	1000BASE-BX10-U stressed receiver sensitivity	59.4.2	Receiver meets specifications in Table 59–7.	BXU:O	Yes [ ] No [ ] N/A [ ]

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59.10.3.5 Optical Measurement requirements

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	Measurement cable		2 m to 5 m in length.	M	Yes [ ]
OM2	Test patterns	59.7.1	See Table 59–11.	M	Yes [ ]
OM3	Wavelength and spectral width	59.7.2	Per TIA-455-127-A under modulated conditions.	M	Yes [ ]
OM4	Average optical power	59.7.3	Per TIA/EIA-455-95.	M	Yes [ ]
OM5	Extinction ratio	59.7.4	Per IEC 61280-2-2 with minimal back reflections and fourth-order Bessel-Thomson receiver.	M	Yes [ ]
OM6	$RIN_{12}OMA$	58.7.7	As described in 58.7.7.	M	Yes [ ]
OM7	Transmit optical waveform (transmit eye)	59.7.8	Per ANSI/TIA/EIA-526-4A with test pattern and fourth-order Bessel-Thomson receiver.	M	Yes [ ]
OM8	Transmit rise/fall characteristics	59.7.9	Waveforms conform to mask in Figure 59–4, measure from 20% to 80%, using patch cable per 59.7.	LX:M	Yes [ ]
OM9	Transmitter and dispersion penalty	59.7.10	As described in 58.7.9.	M	Yes [ ]
OM10	Receive sensitivity	59.7.11	With specified pattern.	M	Yes [ ]
*OM11	Stressed receiver conformance	59.7.14	As described in 59.7.14.	O	Yes [ ] N/A[ ]
OM12	Receiver 3dB electrical upper cutoff frequency	59.7.15	As described in 59.7.15.	M	Yes [ ]

59.10.3.6 Environmental, safety, and labeling specifications

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	General safety	59.8.1	Conforms to IEC 60950-1.	M	Yes [ ]
ES2	Laser safety—IEC Hazard Level 1	59.8.2	Conform to Hazard Level 1 laser requirements defined in IEC 60825-1 and IEC 60825-2.	M	Yes [ ]
ES3	Documentation	59.8.2	Explicitly define requirements and usage restrictions to meet safety certifications.	M	Yes [ ]
ES4	Operating temperature range labeling	59.8.5	If required, label range over which compliance is ensured.	M	Yes [ ] N/A[ ]

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59.10.3.7 Characteristics of the fiber optic cabling

Item	Feature	Subclause	Value/Comment	Status	Support
FO1	Fiber optic cabling	59.9	Meets specifications in Table 59–16.	INS:M	Yes [ ] N/A [ ]
FO2	End-to-end channel loss	59.9.1	Meet the requirements specified in Table 59–1.	INS:M	Yes [ ] N/A [ ]
FO3	Maximum discrete reflectance for multimode connections	59.9.3	Less than –20 dB.	INS:M	Yes [ ] N/A [ ]
FO4	Maximum discrete reflectance for single-mode connections	59.9.3	Less than –26 dB.	INS:M	Yes [ ] N/A [ ]
FO5	MDI requirements	59.9.4	Meet the interface performance specifications of IEC 61753-1, if remateable.	INS:O	Yes [ ] No[ ] N/A [ ]

59.10.3.8 Offset-launch mode-conditioning patch cord

Item	Feature	Subclause	Value/Comment	Status	Support
LPC1	Offset-launch mode-conditioning patch cord	59.9.5	Meet conditions of 59.9.5.	OFP:M	Yes [ ] N/A [ ]
LPC2	Single-mode mechanics in offset-launch mode-conditioning patch cords	59.9.5	IEC 61754-1:1997 [B39] grade 1 ferrule.	OFP:M	Yes [ ] N/A [ ]
LPC3	Single-mode fiber in offset-launch mode-conditioning patch cords	59.9.5	Per 59.9.5.	OFP:M	Yes [ ] N/A [ ]
LPC4	Multimode fiber in offset-launch mode-conditioning patch cords	59.9.5	Same type as used in cable plant.	OFP:M	Yes [ ] N/A [ ]

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60. Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-PX (long wavelength passive optical networks)

60.1 Overview

The 1000BASE-PX10, 1000BASE-PX20, 1000BASE-PX30, and 1000BASE-PX40 PMD sublayers provide point-to-multipoint (P2MP) 1000BASE-X connections over passive optical networks (PONs). The 1000BASE-PX10 PMD sublayers support a reach of at least 10 km whereas the 1000BASE-PX20, 1000BASE-PX30, and 1000BASE-PX40 PMD sublayers support a reach of at least 20 km. The 1000BASE-PX10 and 1000BASE-PX20 PMD sublayers support a typical split ratio of 1:16. The 1000BASE-PX30 PMD sublayers support a typical split ratio of 1:32. The 1000BASE-PX40 PMD sublayers support a typical split ratio of 1:64. In an Ethernet PON, a single downstream (D) PMD broadcasts to multiple upstream (U) PMDs and receives bursts from each "U" PMD over a single branched topology, single-mode fiber network. The same fibers are used simultaneously in both directions. This clause specifies a single-mode fiber medium and the following PMDs (including MDI): 1000BASE-PX10-D, 1000BASE-PX10-U, 1000BASE-PX20-D, 1000BASE-PX20-U, 1000BASE-PX30-D, 1000BASE-PX30-U, 1000BASE-PX40-D, and 1000BASE-PX40-U. A 1000BASE-PX-U PMD or a 1000BASE-PX-D PMD is connected to the appropriate 1000BASE-X PMA of Clause 65, and to the medium through the MDI. A PMD is optionally combined with the management functions that may be accessible through the management interface defined in Clause 22 or by other means.

A 1000BASE-PX10 link uses a 1000BASE-PX10-U PMD at one end and a 1000BASE-PX10-D PMD at the other. A 1000BASE-PX20 link uses a 1000BASE-PX20-U PMD at one end and a 1000BASE-PX20-D PMD at the other. A 1000BASE-PX30 link uses a 1000BASE-PX30-U PMD at one end and a 1000BASE-PX30-D PMD at the other. A 1000BASE-PX40 link uses a 1000BASE-PX40-U PMD at one end and a 1000BASE-PX40-D PMD at the other. A 1000BASE-PX20-D PMD is interoperable with a 1000BASE-PX10-U PMD. This allows certain upgrade possibilities from 10 km to 20 km PONs.

Two optional temperature ranges are defined; see 60.10.4 for further details. Implementations may be declared as compliant over one or both complete ranges, or not so declared (compliant over parts of these ranges or another temperature range).

Table 60–1 shows the primary attributes of each PMD type.

60.1.1 Goals and objectives

All 1000BASE-PX PMDs share the objectives of:

a) Point-to-multipoint on optical fiber.
b) BER better than or equal to 10^{-12} at the PHY service interface.
c) 1000 Mb/s on one single-mode fiber.

1000BASE-PX10 has an objective of operating at the distance of at least of 10 km and at a split ratio of at least of 1:16. 1000BASE-PX20 has an objective of operating at the distance of at least of 20 km and at a split ratio of at least of 1:16. 1000BASE-PX30 has an objective of operating at the distance of at least of 20 km and at a split ratio of at least of 1:32. 1000BASE-PX40 has an objective of operating at the distance of at least of 20 km and at a split ratio of at least of 1:64.

60.1.2 Positioning of this PMD set within the IEEE 802.3 architecture

Figure 60–1 depicts the relationships of the PMD (shown shaded) with other sublayers and the ISO/IEC Open System Interconnection (OSI) reference model.

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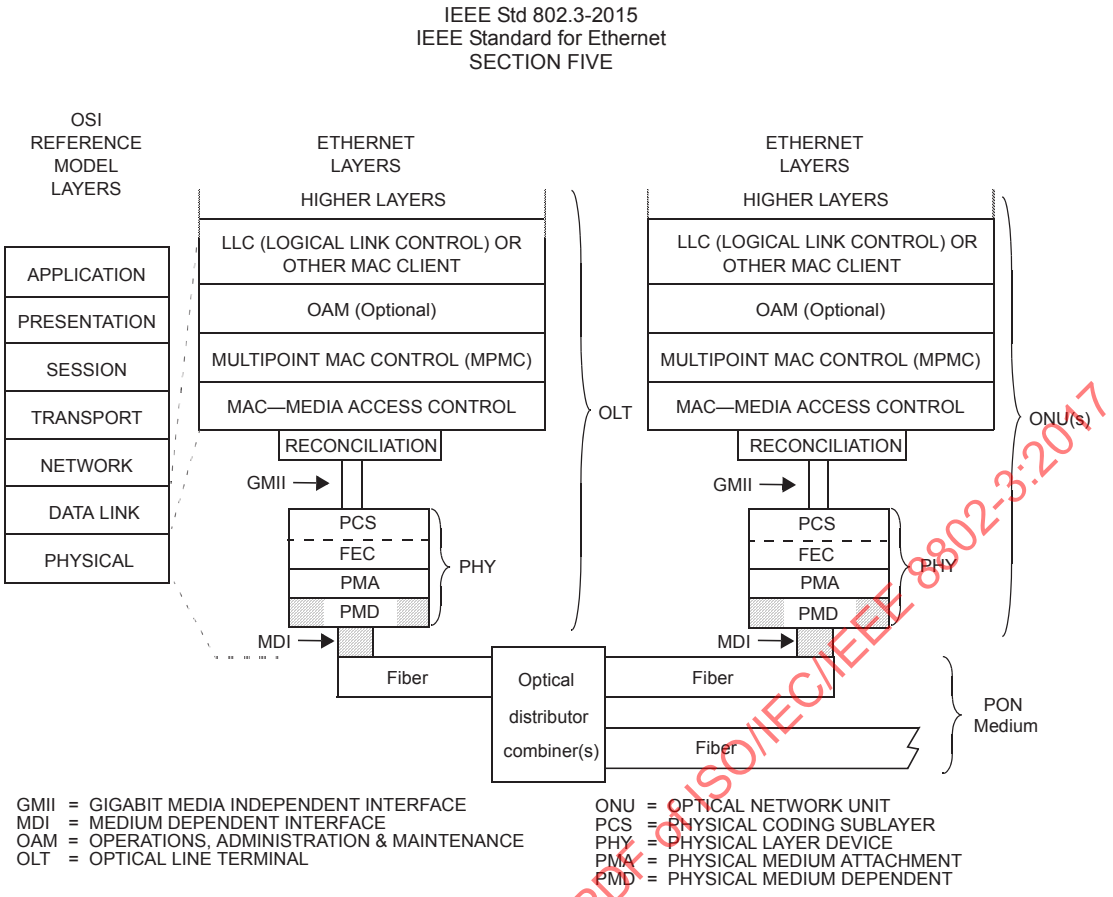

Figure 60–1—P2MP PMDs relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

60.1.3 Terminology and conventions

The following list contains references to terminology and conventions used in this clause:

Basic terminology and conventions, see 1.1 and 1.2.

Normative references, see 1.3.

Definitions, see 1.4.

Abbreviations, see 1.5.

Informative references, see Annex A.

Introduction to 1000 Mb/s baseband networks, see Clause 34.

Introduction to Ethernet for subscriber access networks, see Clause 56.

60.1.4 Physical Medium Dependent (PMD) sublayer service interface

The following specifies the services provided by the 1000BASE-PX10, 1000BASE-PX20, 1000BASE-PX30, and 1000BASE-PX40 PMDs.

These PMD sublayer service interfaces are described in an abstract manner and do not imply any particular implementation. The PMD Service Interface supports the exchange of 8B/10B code-groups between the PMA and PMD entities. The PMD translates the serialized data of the PMA to and from signals suitable for the specified medium. The following primitives are defined:

PMD_UNITDATA.request

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PMD_UNITDATA.indication

PMD_SIGNAL.request

PMD_SIGNAL.indication

Table 60–1—PMD types specified in this clause

Description	1000BASE-PX10-U	1000BASE-PX10-D	1000BASE-PX20-U	1000BASE-PX20-D	1000BASE-PX30-U	1000BASE-PX30-D	1000BASE-PX40-U	1000BASE-PX40-D	Unit
Fiber type	IEC 60793–2 B1.1, B1.3 SMF				IEC 60793–2 B1.1, B1.3 SMF ITU–T G.652, G.657 SMF				
Number of fibers	1				1				
Nominal transmit wavelength	1310	1490	1310	1490	1310	1490	1310	1490	nm
Transmit direction[a]	US	DS	US	DS	US	DS	US	DS	
Minimum range[b]	0.5 m to 10 km		0.5 m to 20 km						
Maximum channel insertion loss[c]	20	19.5	24	23.5	29		33		dB
Minimum channel insertion loss[d]	5		10		15		18		dB

[a]US stands for Upstream, DS stands for Downstream.
[b]In an FEC enabled link, the minimum range may be increased, or, links with a higher channel insertion loss may be used.
[c]At nominal transmit wavelength.
[d]The differential insertion loss for a link is the difference between the maximum and minimum channel insertion loss, and not applicable to 1000BASE-PX30 and 1000BASE-PX40.

60.1.5 Delay constraints

Delay requirements from the MDI to the GMII which include the PMD layer are specified in Clause 36. Of the budget, up to 20 ns is reserved for each of the transmit and receive functions of the PMD to account for those cases where the PMD includes a pigtail.

60.1.5.1 PMD_UNITDATA.request

This primitive defines the transfer of a serial data stream from the PMA to the PMD.

The semantics of the service primitive are PMD_UNITDATA.request(tx_bit). The data conveyed by PMD_UNITDATA.request is a continuous stream of bits. The tx_bit parameter can take one of two values: ONE or ZERO. The PMA continuously sends the appropriate stream of bits to the PMD for transmission on the medium, at a nominal 1.25 GBd signaling speed. Upon receipt of this primitive, the PMD converts the specified stream of bits into the appropriate signals at the MDI.

60.1.5.2 PMD_UNITDATA.indication

This primitive defines the transfer of data from the PMD to the PMA.

The semantics of the service primitive are PMD_UNITDATA.indication(rx_bit). The data conveyed by PMD_UNITDATA.indication is a continuous stream of bits. The rx_bit parameter can take one of two values: ONE or ZERO. The PMD continuously sends a stream of bits to the PMA corresponding to the signals received from the MDI.

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60.1.5.3 PMD_SIGNAL.request

In the upstream direction, this primitive is generated by the PCS to turn on and off the transmitter according to the granted time. A signal for laser control is generated in 65.3.1.1.

The semantics of the service primitive are PMD_SIGNAL.request(tx_enable). The tx_enable parameter can take on one of two values: ENABLE or DISABLE, determining whether the PMD transmitter is on (enabled) or off (disabled). The PCS generates this primitive to indicate a change in the value of tx_enable. Upon receipt of this primitive, the PMD turns the transmitter on or off as appropriate.

60.1.5.4 PMD_SIGNAL.indication

This primitive is generated by the PMD to indicate the status of the signal being received from the MDI.

The semantics of the service primitive are PMD_SIGNAL.indication(SIGNAL_DETECT). The SIGNAL_DETECT parameter can take on one of two values: OK or FAIL, indicating whether the PMD is detecting light at the receiver (OK) or not (FAIL). When SIGNAL_DETECT = FAIL, PMD_UNITDATA.indication(rx_bit) is undefined. The PMD generates this primitive to indicate a change in the value of SIGNAL_DETECT. If the MDIO interface is implemented, then PMD_global_signal_detect shall be continuously set to the value of SIGNAL_DETECT.

NOTE—SIGNAL_DETECT = OK does not guarantee that PMD_UNITDATA.indication(rx_bit) is known good. It is possible for a poor quality link to provide sufficient light for a SIGNAL_DETECT = OK indication and still not meet the specified bit error ratio. PMD_SIGNAL.indication(SIGNAL_DETECT) has different characteristics for upstream and downstream links, see 60.2.4.

60.2 PMD functional specifications

The 1000BASE-PX PMDs perform the transmit and receive functions that convey data between the PMD service interface and the MDI.

60.2.1 PMD block diagram

The PMD sublayer is defined at the four reference points shown in Figure 60–2 where the first digit represents the downstream direction and the second the upstream. Two points, TP2 and TP3, are compliance points. TP1 and TP4 are reference points for use by implementers. The optical transmit signal is defined at the output end of a patch cord (TP2), between 2 m and 5 m in length, of a fiber type consistent with the link type connected to the transmitter. Unless specified otherwise, all transmitter measurements and tests defined in 60.9 are made at TP2. The optical receive signal is defined at the output of the fiber optic cabling (TP3) connected to the receiver. Unless specified otherwise, all receiver measurements and tests defined in 60.9 are made at TP3.

The electrical specifications of the PMD service interface (TP1 and TP4) are not system compliance points (these are not readily testable in a system implementation). It is expected that in many implementations, TP1 and TP4 will be common between 1000BASE-PX PMDs.

60.2.2 PMD transmit function

The PMD Transmit function shall convey the bits requested by the PMD service interface message PMD_UNITDATA.request(tx_bit) to the MDI according to the optical specifications in this clause. The higher optical power level shall correspond to tx_bit = ONE.

In the upstream direction, the flow of bits is interrupted according to PMD_SIGNAL.request(tx_enable). This implies three optical levels, 1, 0, and dark, the latter corresponding to the transmitter being in the OFF state.

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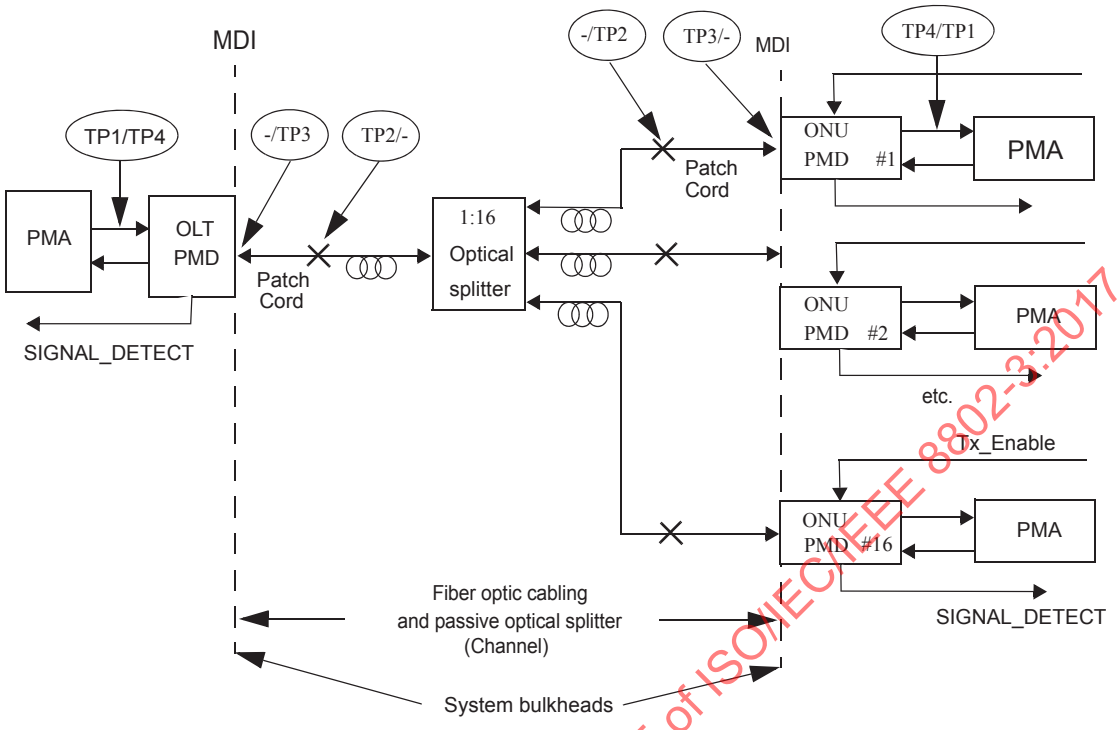

Figure 60–2—1000BASE-PX block diagram

60.2.3 PMD receive function

The PMD Receive function shall convey the bits received from the MDI according to the optical specifications in this clause to the PMD service interface using the message PMD_UNITDATA.indication(rx_bit). The higher optical power level shall correspond to rx_bit = ONE.

60.2.4 PMD signal detect function

60.2.4.1 ONU PMD signal detect (downstream)

The PMD Signal Detect function for the continuous mode downstream signal shall report to the PMD service interface, using the message PMD_SIGNAL.indication(SIGNAL_DETECT), which is signaled continuously. PMD_SIGNAL.indication is intended to be an indicator of optical signal presence.

The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 60–2 for 1000BASE-PX. The PMD receiver is not required to verify whether a compliant 1000BASE-PX signal is being received.

60.2.4.2 OLT PMD signal detect (upstream)

The response time for the PMD Signal Detect function for the burst mode upstream signal may be longer or shorter than a burst length, thus, it may not fulfill the traditional requirements placed on Signal Detect. PMD_SIGNAL.indication is intended to be an indicator of optical signal presence. The signal detect function in the OLT may be realized in the PMD or PMA layer.

The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 60–2 for 1000BASE-PX. The PMD receiver is not required to verify whether a compliant 1000BASE-PX signal is being received.

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60.2.4.3 1000BASE-PX Signal detect functions

The Signal Detect value definitions for the 1000BASE-PX PMDs are shown in Table 60–2.

Table 60–2—1000BASE-PX SIGNAL_DETECT value definition

PMD type	Receive conditions	SIGNAL_DETECT value
1000BASE-PX10	Average input optical power ≤ Signal Detect Threshold (min) in Table 60–5 at the specified receiver wavelength	FAIL
	Average input optical power ≥ Receive sensitivity (max) in Table 60–5 with a compliant 1000BASE-X signal input at the specified receiver wavelength	OK
	All other conditions	Unspecified
1000BASE-PX20	Average input optical power ≤ Signal Detect Threshold (min) in Table 60–8 at the specified receiver wavelength	FAIL
	Average input optical power ≥ Receive sensitivity (max) in Table 60–8 with a compliant 1000BASE-X signal input at the specified receiver wavelength	OK
	All other conditions	Unspecified
1000BASE-PX30	Average input optical power ≤ Signal Detect Threshold (min) in Table 60–9 at the specified receiver wavelength	FAIL
	Average input optical power ≥ Receive sensitivity (max) in Table 60–9 with a compliant 1000BASE-X signal input at the specified receiver wavelength	OK
	All other conditions	Unspecified
1000BASE-PX40	Average input optical power ≤ Signal Detect Threshold (min) in Table 60–12 at the specified receiver wavelength	FAIL
	Average input optical power ≥ Receive sensitivity (max) in Table 60–12 with a compliant 1000BASE-X signal input at the specified receiver wavelength	OK
	All other conditions	Unspecified

60.2.5 PMD transmit enable function for ONU

PMD_SIGNAL.request(tx_enable) is defined for the two ONU PMDs. PMD_SIGNAL.request(tx_enable) is asserted prior to data transmission by the ONU PMDs.

60.3 PMD to MDI optical specifications for 1000BASE-PX10-D and 1000BASE-PX10-U

The operating range for 1000BASE-PX10 is defined in Table 60–1. A 1000BASE-PX10 compliant transceiver supports all media types listed in Table 60–19 according to the specifications described in 60.11. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant (e.g., a single-mode solution operating at 10.5 km meets the minimum range requirement of 0.5 m to 10 km for 1000BASE-PX10).

NOTE—The specifications for OMA have been derived from extinction ratio and average launch power (minimum) or receiver sensitivity (maximum). The calculation is defined in 58.7.6.

60.3.1 Transmitter optical specifications

The 1000BASE-PX10-D and 1000BASE-PX10-U transmitter's specifications described in Table 60–3 are normative requirements, per measurement techniques described in 60.9, with the exception of $RIN_{15}OMA$ which is an optional requirement per measurement techniques described in 60.9.7.

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Table 60–3—1000BASE-PX10-D and 1000BASE-PX10-U transmit characteristics

Description	1000BASE-PX10-D	1000BASE-PX10-U	Unit
Nominal transmitter type[a]	Longwave Laser	Longwave Laser	
Signaling speed (range)	1.25 ± 100 ppm	1.25 ± 100 ppm	GBd
Wavelength[b] (range)	1480 to 1500	1260 to 1360	nm
RMS spectral width (max)	see Table 60–4		nm
Average launch power (max)	+2	+4	dBm
Average launch power (min)	–3	–1	dBm
Average launch power of OFF transmitter (max)	–39	–45	dBm
Extinction ratio (min)	6	6	dB
$RIN_{15}OMA$ (max)	–118	–113	dB/Hz
Launch OMA (min)	–2.2 (0.6)	–0.22 (0.95)	dBm (mW)
Transmitter eye mask definition {X1, X2, Y1, Y2, Y3}	{0.22, 0.375, 0.2, 0.2, 0.3}	{0.22, 0.375, 0.2, 0.2, 0.3}	UI
T_{on} (max)	N/A	512	ns
T_{off} (max)	N/A	512	ns
Optical return loss tolerance (max)	15	15	dB
Optical return loss of ODN (min)	20	20	dB
Transmitter reflectance (max)	–10	–6	dB
Transmitter and dispersion penalty (max)	1.3	2.8	dB
Decision timing offset for transmitter and dispersion penalty (min)	± 0.1	± 0.125	UI

[a]The nominal transmitter type is not intended to be a requirement on the source type, and any device meeting the transmitter characteristics specified may be substituted for the nominal transmitter type.
[b]This represents the range of centre wavelength ±1σ of the rms spectral width.

The maximum RMS spectral width vs. wavelength for 1000BASE-PX10 is shown in Table 60–4 and for 1000BASE-PX10-U in Figure 60–3. The equation used to generate these values is included in 60.9.2. The central column values are normative, the right hand column is informative.

Table 60–4—1000BASE-PX10-D and 1000BASE-PX10-U transmitter spectral limits

Center Wavelength	RMS spectral width (max)[a]	RMS spectral width to achieve epsilon ε ≤ 0.115 (informative)
nm	nm	nm
1260	**2.09**	1.43
1270	**2.52**	1.72
1280	**3.13**	2.14

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Table 60–4—1000BASE-PX10-D and 1000BASE-PX10-U transmitter spectral limits *(continued)*

Center Wavelength	RMS spectral width (max)[a]	RMS spectral width to achieve epsilon $\varepsilon \leq 0.115$ (informative)
nm	nm	nm
1286	**3.50**	2.49
1290		2.80
1297		3.50
1329		
1340		2.59
1343		2.41
1350	**3.06**	2.09
1360	**2.58**	1.76
1480 to 1500	**0.88**	0.60

[a]These limits for the 1000BASE-PX10-U transmitter are illustrated in Figure 60–3. The equation used to calculate these values is detailed in 60.9.2. Limits at intermediate wavelengths may be found by interpolation.

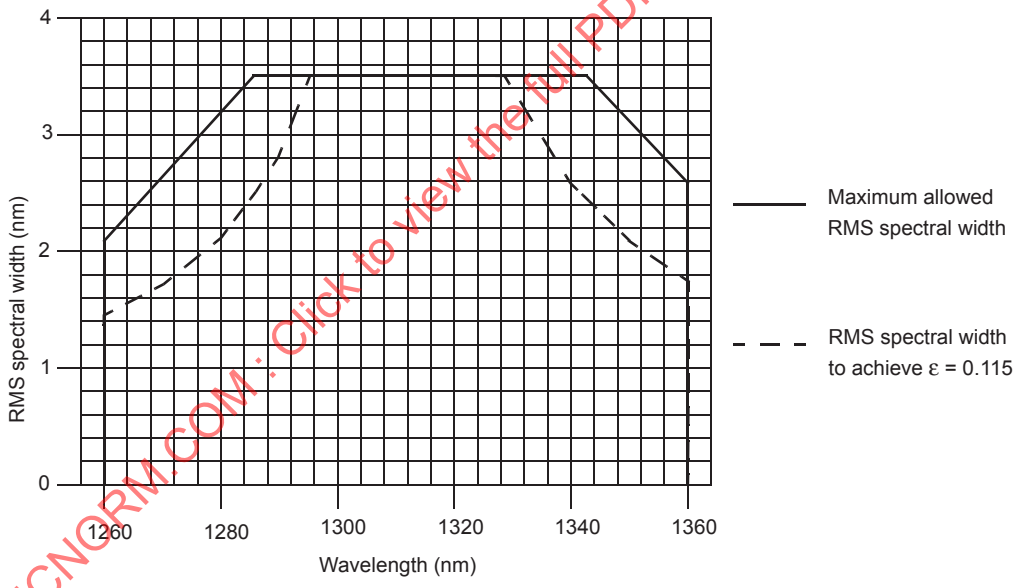

Figure 60–3—1000BASE-PX10-U transmitter spectral limits

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60.3.2 Receiver optical specifications

The 1000BASE-PX10-D and 1000BASE-PX10-U receiver shall meet the specifications defined in Table 60–5 per measurement techniques defined in 60.9.10 with the following exceptions. The stressed receive sensitivity (OMA) should meet the values listed in Table 60–5 per measurement techniques described in 60.9.11. Either the damage threshold included in Table 60–5 shall be met, or, the receiver shall be labeled to

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indicate the maximum optical input power level to which it can be continuously exposed without damage. The vertical eye-closure penalty, the stressed eye jitter, the jitter corner frequency, and the sinusoidal jitter limits are test conditions for measuring stressed receiver sensitivity and are not required characteristics of the receiver.

Table 60–5—1000BASE-PX10-D and 1000BASE-PX10-U receive characteristics

Description	1000BASE-PX10-D	1000BASE-PX10-U	Unit
Signaling speed (range)	1.25 ± 100 ppm	1.25 ± 100 ppm	GBd
Wavelength (range)	1260 to 1360	1480 to 1500	nm
Bit error ratio (max)	10^{-12}		
Average receive power (max)	–1	–3	dBm
Damage threshold (max)	+4	+2	dBm
Receiver sensitivity (max)	–24	–24	dBm
Receiver sensitivity OMA (max)	–23.2 (5)	–23.2 (5)	dBm (μW)
Signal detect threshold (min)	–45	–44	dBm
Receiver reflectance (max)	–12	–12	dB
Stressed receive sensitivity (max)	–22.3	–21.4	dBm
Stressed receive sensitivity OMA (max)	–21.5 (7)	–20.7 (8.6)	dBm (μW)
Vertical eye-closure penalty (min)	1.2	2.2	dB
$T_{receiver_settling}$ (max)	400	N/A	ns
Stressed eye jitter (min)	0.25	0.25	UI pk-pk
Jitter corner frequency	637	637	kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	(0.05, 0.15)	(0.05, 0.15)	UI

60.4 PMD to MDI optical specifications for 1000BASE-PX20-D and 1000BASE-PX20-U

The operating range for 1000BASE-PX20 is defined in Table 60–1. A 1000BASE-PX20 compliant transceiver supports all media types listed in Table 60–19 according to the specifications described in 60.11.2. A transceiver that exceeds the operational range requirement while meeting all other optical specifications is considered compliant (e.g., a single-mode solution operating at 20.5 km meets the minimum range requirement of 0.5 m to 20 km for 1000BASE-PX20).

NOTE—The specifications for OMA have been derived from extinction ratio and average launch power (minimum) or receiver sensitivity (maximum). The calculation is explained in 58.7.6.

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60.4.1 Transmitter optical specifications

The 1000BASE-PX20-D and 1000BASE-PX20-U transmitter's specifications described in Table 60–6 are normative requirements, per measurement techniques described in 60.9, with the exception of $RIN_{15}OMA$ which is an optional requirement per measurement techniques described in 60.9.7.

Table 60–6—1000BASE-PX20-D and 1000BASE-PX20-U transmit characteristics

Description	1000BASE-PX20-D	1000BASE-PX20-U	Unit
Nominal transmitter type[a]	Longwave Laser	Longwave Laser	
Signaling speed (range)	1.25 ± 100 ppm	1.25 ± 100 ppm	GBd
Wavelength[b] (range)	1480 to 1500	1260 to 1360	nm
RMS spectral width (max)	see Table 60–7		nm
Average launch power (max)	+7	+4	dBm
Average launch power (min)	+2	–1	dBm
Average launch power of OFF transmitter (max)	–39	–45	dBm
Extinction ratio (min)	6	6	dB
$RIN_{15}OMA$ (max)	–115	–115	dB/Hz
Launch OMA (min)	2.8 (1.9)	–0.22 (0.95)	dBm (mW)
Transmitter eye mask definition {X1, X2, Y1, Y2, Y3}	{0.22, 0.375, 0.2, 0.2, 0.3}	{0.22, 0.375, 0.2, 0.2, 0.3}	UI
T_{on} (max)	N/A	512	ns
T_{off} (max)	N/A	512	ns
Optical return loss tolerance (max)	15	15	dB
Optical return loss of ODN (min)	20	20	dB
Transmitter reflectance (max)	–10	–10	dB
Transmitter and dispersion penalty (max)	2.3	1.8	dB
Decision timing offset for transmitter and dispersion penalty (min)	± 0.1	± 0.125	UI

[a]The nominal transmitter type is not intended to be a requirement on the source type, and any device meeting the transmitter characteristics specified may be substituted for the nominal transmitter type.
[b]This represents the range of centre wavelength ±1σ of the rms spectral width.

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The maximum RMS spectral width vs. wavelength for 1000BASE-PX20 is shown in Table 60–7 and for 1000BASE-PX20-U in Figure 60–4. The equation used to generate these values is included in 60.9.2. The central column values are normative, the right hand column is informative.

60.4.2 Receiver optical specifications

The 1000BASE-PX20-D and 1000BASE-PX20-U receiver shall meet the specifications defined in Table 60–8 per measurement techniques defined in 60.9.10 with the following exceptions. The stressed receive sensitivity (OMA) should meet the values listed in Table 60–8 per measurement techniques described in

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Table 60–7—1000BASE-PX20-D and 1000BASE-PX20-U transmitter spectral limits

Center Wavelength	RMS spectral width (max) [a]	RMS spectral width to achieve epsilon ε ≤ 0.10 (informative)
nm	nm	nm
1260	**0.72**	0.62
1270	**0.86**	0.75
1280	**1.07**	0.93
1290	**1.40**	1.22
1300	**2.00**	1.74
1304	**2.5**	2.42
1305	**2.55**	2.5
1308	**3.00**	
1317		
1320	**2.53**	2.2
1321	**2.41**	
1330	**1.71**	1.48
1340	**1.29**	1.12
1350	**1.05**	0.91
1360	**0.88**	0.77
1480 to 1500	**0.44**	0.30

[a]These limits for the 1000BASE-PX20-U are illustrated in Figure 60–4. The equation used to calculate these values is detailed in 60.9.2. Limits at intermediate wavelengths may be found by interpolation.

60.9.11. Either the damage threshold included in Table 60–8 shall be met, or, the receiver shall be labeled to indicate the maximum optical input power level to which it can be continuously exposed without damage. The vertical eye-closure penalty, the stressed eye jitter, the jitter corner frequency, and the sinusoidal jitter limits are test conditions for measuring stressed receiver sensitivity and are not required characteristics of the receiver.

Table 60–8—1000BASE-PX20-D and 1000BASE-PX20-U receive characteristics

Description	1000BASE-PX20-D	1000BASE-PX20-U	Unit
Signaling speed (range)	1.25 ± 100 ppm	1.25 ± 100 ppm	GBd
Wavelength (range)	1260 to 1360	1480 to 1500	nm
Bit error ratio (max)	10^{-12}		
Average receive power (max)	–6	–3	dBm
Damage threshold (max)	+4	+7	dBm
Receive sensitivity (max)	–27	–24	dBm
Receiver sensitivity OMA (max)	–26.2 (2.4)	–23.2 (5)	dBm (μW)

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Table 60–8—1000BASE-PX20-D and 1000BASE-PX20-U receive characteristics *(continued)*

Description	1000BASE-PX20-D	1000BASE-PX20-U	Unit
Signal detect threshold (min)	–45	–44	dBm
Receiver reflectance (max)	–12	–12	dB
Stressed receive sensitivity (max)	–24.4	–22.1	dBm
Stressed receive sensitivity OMA (max)	–23.6 (4.3)	–21.3 (7.4)	dBm (μW)
Vertical eye-closure penalty (min)	2.2	1.5	dB
$T_{receiver_settling}$ (max)	400	N/A	ns
Stressed eye jitter (min)	0.28	0.25	UI pk-pk
Jitter corner frequency	637	637	kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	(0.05, 0.15)	(0.05, 0.15)	UI

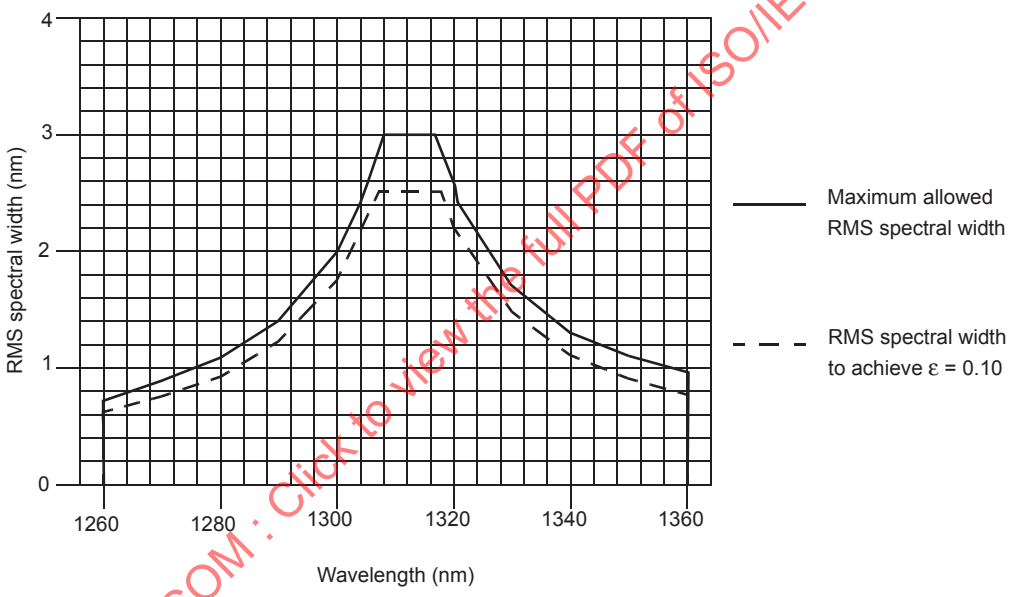

Figure 60–4—1000BASE-PX20-U transmitter spectral limits

60.5 PMD to MDI optical specifications for 1000BASE-PX30-D and 1000BASE-PX30-U

The operating range for 1000BASE-PX30 is defined in Table 60–1. A 1000BASE-PX30 compliant transceiver supports all media types listed in Table 75–14 according to the specifications described in 75.9. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant (e.g., a single-mode solution operating at 20.5 km meets the minimum range requirement of 0.5 m to 20 km for 1000BASE-PX30).

NOTE—The specifications for OMA have been derived from extinction ratio and average launch power (minimum) or receiver sensitivity (maximum). The calculation is defined in 58.7.6.

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60.5.1 Transmitter optical specifications

The 1000BASE-PX30-D and 1000BASE-PX30-U transmitter's specifications described in Table 60–9 are normative requirements, per measurement techniques described in 60.8, with the exception of $RIN_{15}OMA$ which is an optional requirement, per measurement techniques described in 60.9.7.

The maximum RMS spectral width vs. wavelength for 1000BASE-PX30 is shown in Table 60–10 and for 1000BASE-PX30-U in Figure 60–5. 1000BASE-PX30-D transmitter uses a DFB laser, and 1000BASE-PX30-U transmitter can use either a DFB or Fabry-Perot laser. If 1000BASE-PX30-U PMD employs a DFB laser, Side Mode Suppression Ratio requirement shown in Table 60–9 is mandatory. If 1000BASE-PX30-U PMD employs a Fabry-Perot laser, RMS spectral width requirement shown in Table 60–10 and Figure 60–5 is mandatory. The equation used to generate these values is included in 60.9.2. The central column values are normative, the right hand column is informative.

Table 60–9—1000BASE-PX30-D and 1000BASE-PX30-U transmit characteristics

Description	1000BASE-PX30-D	1000BASE-PX30-U	Unit
Nominal transmitter type[a]	Longwave Laser	Longwave Laser	
Signaling speed (range)	1.25 ± 100 ppm	1.25 ± 100 ppm	GBd
Wavelength[b] (range)	1480 to 1500	1260 to 1360	nm
Side Mode Suppression Ratio	30	30[c]	dB
RMS spectral width (max)	N/A	see Table 60–10[c]	nm
Average launch power (max)	7	5.62	dBm
Average launch power (min)	3	0.62	dBm
Average launch power of OFF transmitter (max)	–39	–45	dBm
Extinction ratio (min)	6	6	dB
$RIN_{15}OMA$ (max)	–115	–115	dB/Hz
Launch OMA (min)	3.78 (2.39)	1.4 (1.38)	dBm (mW)
Transmitter eye mask definition {X1, X2, Y1, Y2, Y3}	{0.22, 0.375, 0.2, 0.2, 0.3}	{0.22, 0.375, 0.2, 0.2, 0.3}	UI
T_{on} (max)	N/A	512	ns
T_{off} (max)	N/A	512	ns
Optical return loss tolerance (max)	15	15	dB
Optical return loss of ODN (min)	20	20	dB
Transmitter reflectance (max)	–10	–10	dB
Transmitter and dispersion penalty (max)	1	1.4	dB
Decision timing offset for transmitter and dispersion penalty (min)	±0.1	±0.125	UI

[a]The nominal transmitter type is not intended to be a requirement on the source type, and any device meeting the transmitter characteristics specified may be substituted for the nominal transmitter type.
[b]This represents the range of centre wavelength ±1σ of the rms spectral width.
[c]If 1000BASE-PX30-U PMD employs a DFB laser, Side Mode Suppression Ratio is mandatory. If it employs a Fabry-Perot laser, RMS spectral width requirement is mandatory.

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Table 60–10—1000BASE-PX30-U transmitter spectral limits

Center wavelength	RMS spectral width (max)[a]	RMS spectral width to achieve epsilon ε ≤ 0.08 (informative)
nm	nm	nm
1260	0.59	0.5
1270	0.7	0.59
1280	0.87	0.74
1290	1.14	0.97
1300	1.64	1.39
1304	1.98	1.67
1305	2.09	1.77
1308	2.4	2
1317	2.4	2
1320	2.07	1.75
1321	1.98	1.67
1330	1.4	1.18
1340	1.06	0.89
1350	0.86	0.72
1360	0.72	0.61
1480 to 1500	0.25	0.21

[a]These limits for the 1000BASE–PX30–U transmitter are illustrated in Figure 60–5. The equation used to calculate these values is detailed in 60.9.2. Limits at intermediate wavelengths may be found by interpolation.

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60.5.2 Receiver optical specifications

The 1000BASE-PX30-D and 1000BASE-PX30-U receiver shall meet the specifications defined in Table 60–11 per measurement techniques defined in 60.9.10 with the following exceptions. The stressed receive sensitivity OMA (max) should meet the value listed in Table 60–11 per measurement techniques described in 60.9.11. Either the damage threshold included in Table 60–11 shall be met, or, the receiver shall be labeled to indicate the maximum optical input power level to which it can be continuously exposed without damage. The vertical eye-closure penalty, the stressed eye jitter, the jitter corner frequency, and the sinusoidal jitter limits are test conditions for measuring stressed receiver sensitivity and are not required characteristics of the receiver.

60.6 PMD to MDI optical specifications for 1000BASE-PX40-D and 1000BASE-PX40-U

The operating range for 1000BASE-PX40 is defined in Table 60–1. A 1000BASE-PX40 compliant transceiver supports all media types listed in Table 75–14 according to the specifications described in 75.9. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant (e.g., a single-mode solution operating at 20.5 km meets the minimum range requirement of 0.5 m to 20 km for 1000BASE-PX40).

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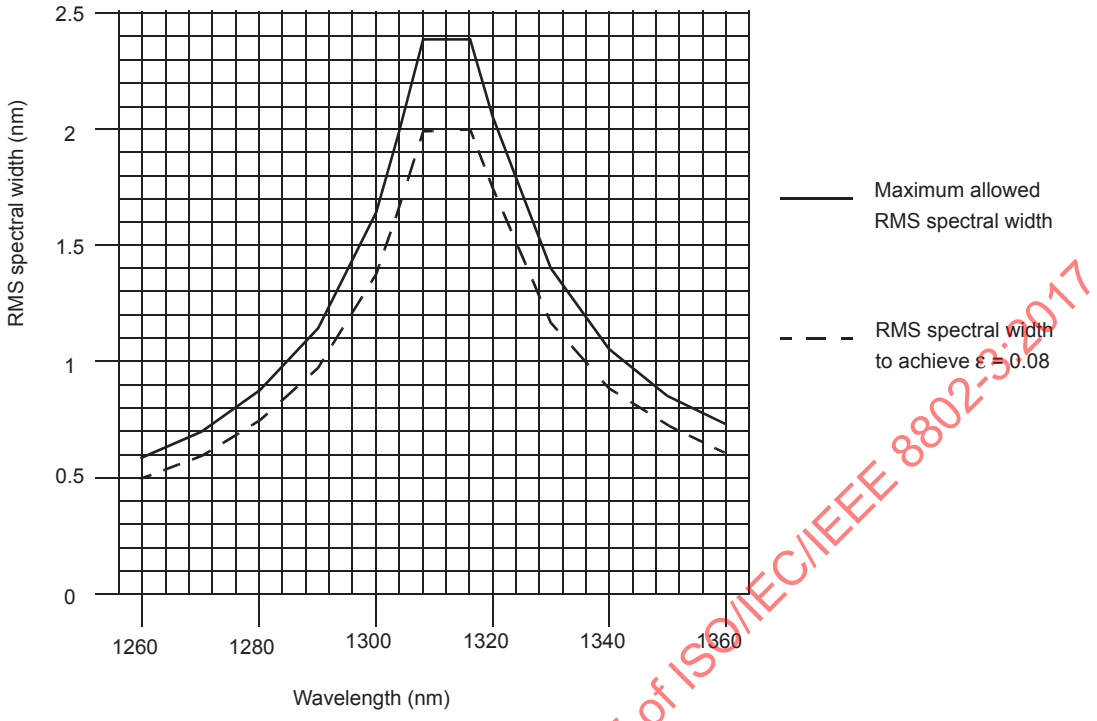

Figure 60–5—1000BASE-PX30-U transmitter spectral limits

Table 60–11—1000BASE-PX30-D and 1000BASE-PX30-U receive characteristics

Description	1000BASE-PX30-D	1000BASE-PX30-U	Unit
Signaling speed (range)	1.25 ± 100 ppm	1.25 ± 100 ppm	GBd
Wavelength (range)	1260 to 1360	1480 to 1500	nm
Bit error ratio (max)	10^{-12}		
Average receive power (max)	–9.38	–8	dBm
Damage threshold (max)[a]	–5	+4	dBm
Receiver sensitivity (max)	–29.78	–27	dBm
Receiver sensitivity OMA (max)	–29 (1.26)	–26.22 (2.39)	dBm (μW)
Signal detect threshold (min)	–45	–44	dBm
Receiver reflectance (max)	–12	–12	dB
Stressed receive sensitivity (max)	–28.38	–26	dBm
Stressed receive sensitivity OMA (max)	–27.6 (1.74)	–25.22 (3.01)	dBm (μW)
Vertical eye-closure penalty (min)	1.4	1.5	dB

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Table 60–11—1000BASE-PX30-D and 1000BASE-PX30-U receive characteristics *(continued)*

Description	1000BASE-PX30-D	1000BASE-PX30-U	Unit
$T_{receiver_settling}$ (max)[b]	400	N/A	ns
Stressed eye jitter (min)	0.28	0.25	UI pk-pk
Jitter corner frequency	637	637	kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	(0.05, 0.15)	(0.05, 0.15)	UI

[a]Direct ONU–OLT connection may result in damage of the receiver.
[b]$T_{receiver_settling}$ represents an upper bound. Optics with better performance may be used in compliant implementations, since the OLT notifies the ONUs of its requirements in terms of the $T_{receiver_settling}$ time via the sync time parameter.

NOTE—The specifications for OMA have been derived from extinction ratio and average launch power (minimum) or receiver sensitivity (maximum). The calculation is defined in 58.7.6.

60.6.1 Transmitter optical specifications

The 1000BASE-PX40-D and 1000BASE-PX40-U transmitter's specifications described in Table 60–12 are normative requirements, per measurement techniques described in 60.9, with the exception of $RIN_{15}OMA$ which is an optional requirement, per measurement techniques described in 60.9.7.

Table 60–12—1000BASE-PX40-D and 1000BASE-PX40-U transmit characteristics

Description	1000BASE-PX40-D	1000BASE-PX40-U	Unit
Nominal transmitter type[a]	Longwave Laser	Longwave Laser	
Signaling speed (range)	1.25 ± 100 ppm	1.25 ± 100 ppm	GBd
Wavelength (range)	1480 to 1500	1290 to 1330	nm
Side Mode Suppression Ratio (min)[b]	30		dB
Average launch power (max)	10	6	dBm
Average launch power (min)	4	2	dBm
Average launch power of OFF transmitter (max)	–39	–45	dBm
Extinction ratio (min)	6	6	dB
$RIN_{15}OMA$ (max)	–115	–115	dB/Hz
Launch OMA (min)	4.78 (3.01)	2.78 (1.9)	dBm (mW)
Transmitter eye mask definition {X1, X2, Y1, Y2, Y3}	{0.22, 0.375, 0.2, 0.2, 0.3}	{0.22, 0.375, 0.2, 0.2, 0.3}	UI
T_{on} (max)	N/A	512	ns
T_{off} (max)	N/A	512	ns
Optical return loss tolerance (max)	15	15	dB
Optical return loss of ODN (min)	20	20	dB
Transmitter reflectance (max)	–10	–10	dB
Transmitter and dispersion penalty (max)	1	1	dB
Decision timing offset for transmitter and dispersion penalty (min)	±0.1	±0.125	UI

[a]The nominal device type is not intended to be a requirement on the source type, and any device meeting the transmitter characteristics specified may be substituted for the nominal device type.

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[b]Transmitter is a single longitudinal mode device. Chirp is allowed such that the total penalty does not exceed that found in Table 60–14.

60.6.2 Receiver optical specifications

The 1000BASE-PX40-D and 1000BASE-PX40-U receiver shall meet the specifications defined in Table 60–13 per measurement techniques defined in 60.9.10 with the following exceptions. The stressed receive sensitivity OMA (max) should meet the value listed in Table 60–13 per measurement techniques described in 60.9.11. Either the damage threshold included in Table 60–13 shall be met, or, the receiver shall be labeled to indicate the maximum optical input power level to which it can be continuously exposed without damage. The vertical eye-closure penalty, the stressed eye jitter, the jitter corner frequency, and the sinusoidal jitter limits are test conditions for measuring stressed receiver sensitivity and are not required characteristics of the receiver.

Table 60–13—1000BASE-PX40-D and 1000BASE-PX40-U receive characteristics

Description	1000BASE-PX40-D	1000BASE-PX40-U	Unit
Signaling speed (range)	1.25 ± 100 ppm	1.25 ± 100 ppm	GBd
Wavelength (range)	1260 to 1360	1480 to 1500	nm
Bit error ratio (max)	10^{-12}		
Average receive power (max)	–12	–8	dBm
Damage threshold (max)[a]	–6	–3	dBm
Receiver sensitivity (max)	–32	–30	dBm
Receiver sensitivity OMA (max)	–31.22 (0.76)	–29.22 (1.2)	dBm (μW)
Signal detect threshold (min)	–45	–44	dBm
Receiver reflectance (max)	–12	–12	dB
Stressed receive sensitivity (max)	–31	–29	dBm
Stressed receive sensitivity OMA (max)	–30.22 (0.95)	–28.22 (1.51)	dBm (μW)
Vertical eye-closure penalty (min)	2.2	1.5	dB
$T_{receiver_settling}$ (max)[b]	400	N/A	ns
Stressed eye jitter (min)	0.28	0.25	UI pk-pk
Jitter corner frequency	637	637	kHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	(0.05, 0.15)	(0.05, 0.15)	UI

[a]Direct ONU–OLT connection may result in damage of the receiver.
[b]$T_{receiver_settling}$ represents an upper bound. Optics with better performance may be used in compliant implementations, since the OLT notifies the ONUs of its requirements in terms of the $T_{receiver_settling}$ time via the syncTime parameter.

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60.7 Illustrative 1000BASE-PX channels and penalties (informative)

Illustrative power budget for 1000BASE-PX10, 1000BASE-PX20, 1000BASE-PX30, and 1000BASE-PX40 channels are shown in Table 60–14.

Table 60–14—Illustrative 1000BASE-PX channel insertion loss and penalties

Description[a]	1000BASE-PX10		1000BASE-PX20		1000BASE-PX30		1000BASE-PX40		Unit
	US	DS	US	DS	US	DS	US	DS	
Fiber type	IEC 60793–2 B1.1, B1.3 SMF				IEC 60793–2 B1.1, B1.3 SMF ITU-T G.652, G.657 SMF				
Measurement wavelength for fiber	1310	1550[b]	1310	1550[b]	1310	1550[b]	1310	1550[b]	nm
Nominal distance	10		20						km
Available power budget[c]	23	21	26	26	30.4	30	34	34	dB
Channel insertion loss (max)[d]	20	19.5	24	23.5	29		33		dB
Channel insertion loss (min)[e]	5		10		15		18		dB
Allocation for penalties[f]	3	1.5	2	2.5	1.4	1	1	1	dB
Optical return loss of ODN (min)	20								dB

[a]US stands for Upstream, DS stands for Downstream.
[b]The nominal transmit wavelength is 1490 nm.
[c]In an FEC enabled link, when not operating at the dispersion limit, the available power budget is increased by 2.5 dB.
[d]The channel insertion loss is based on the cable attenuation at the target distance and nominal measurement wavelength. The channel insertion loss also includes the loss for connectors, splices and other passive components such as splitters.
[e]The power budgets for PX10, PX20, PX30, and PX40 links are such that a minimum insertion loss is assumed between transmitter and receiver. This minimum attenuation is required for PMD testing.
[f]The allocation for penalties is the difference between the available power budget and the channel insertion loss; insertion loss difference between nominal and worst case operating wavelength is considered a penalty. This allocation may be used to compensate for transmission related penalties. Further details are given in 60.9.2.

NOTE—The budgets include an allowance for –12 dB reflection at the receiver.

60.8 Jitter at TP1 to TP4 for 1000BASE-PX (informative)

The entries in Table 60–15 and Table 60–16 represent high-frequency jitter (above 637 kHz) and do not include low frequency jitter or wander. They are two sided (peak-to-peak) measures. Table 60–15 applies to the downstream direction (D to U) while Table 60–16 applies to the upstream direction (U to D). All values are informative.

For the 1000BASE-PX upstream jitter budget, the jitter transfer function is defined by Equation (60-2) where the value is given in Figure 60–6 when input sinusoidal jitter according to the mask defined in 58.7.11.4 and values in Table 60–5, Table 60–8, Table 60–11, and Table 60–13 are applied to the receiver input of the ONU. Two sets of upstream jitter values are defined in Table 60–16, one set corresponds to testing the upstream link with no jitter on the downstream (jitter generation) and the other set with maximum jitter on the downstream (generated and transferred jitter).

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Table 60–15—1000BASE-PX downstream jitter budget (informative)

	Total jitter		Deterministic jitter	
Reference point	**UI**	**ps**	**UI**	**ps**
TP1	0.24	192	0.10	80
TP1 to TP2	0.191	153	0.15	120
TP2	0.431	345	0.25	200
TP2 to TP3	0.009	7	0	0
TP3	0.44	352	0.25	200
TP3 to TP4	0.309	247	0.212	170
TP4	0.749	599	0.462	370

Table 60–16—1000BASE-PX upstream jitter budget (informative)

	No Jitter input to ONU				Jitter input to ONU			
	Total jitter		*W*		Total jitter		*W*	
Reference point	**UI**	**ps**	**UI**	**ps**	**UI**	**ps**	**UI**	**ps**
TP1	0.19	152	0.06	48	0.24	192	0.11	88
TP1 to TP2	0.16	128	0.14	112	0.16	128	0.14	112
TP2	0.35	280	0.2	160	0.4	320	0.25	200
TP2 to TP3	0.09	72	0.05	40	0.09	72	0.05	40
TP3	0.44	352	0.25	200	0.49	392	0.30	24
TP3 to TP4	0.18	144	0.15	120	0.18	144	0.15	120
TP4	0.62	496	0.4	320	0.67	536	0.45	360

NOTE—Informative jitter values are chosen to be compatible with the limits for eye mask and TDP (see 58.7.9).

Total jitter in this table is defined at 10^{-12} BER. In a commonly used model,

$$TJ = 14.1\sigma + DJ \text{ at } 10^{12} \quad (60–1)$$

W is similar but not necessarily identical to deterministic jitter (DJ). A jitter measurement procedure is described in 58.7.12. Other jitter measurements are described in 59.7.12 and 59.7.13. Jitter at TP2 or TP3 is defined with a receiver of the same bandwidth as specified for the transmitted eye.

$$\text{Jitter Transfer} = 20\log_{10}\left[\frac{\text{Jitter on upstream signal (UI)}}{\text{Jitter on downstream signal (UI)}}\right] \quad (60\text{-}2)$$

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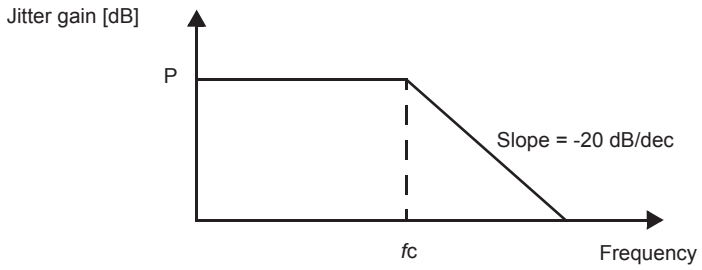

Figure 60–6—Jitter gain curve values for 1000BASE-PX10-U and 1000BASE-PX20-U

Table 60–17—Jitter gain curve values for 1000BASE-PX10-U and 1000BASE-PX20-U

	Value	Unit
P	0.3	dB
fc	1274	kHz

60.9 Optical measurement requirements

The following sections describe definitive patterns and test procedures for certain PMDs of this standard. implementers using alternative verification methods must ensure adequate correlation and allow adequate margin such that specifications are met by reference to the definitive methods. All optical measurements, except TDP and $RIN_{15}OMA$, shall be made through a short patch cable between 2 m and 5 m in length.

60.9.1 Frame-based test patterns

Subclause 59.7.1 provides suitable patterns for frame-based testing.

NOTE—Users are advised to take care that the system under test is not connected to a network in service.

60.9.2 Wavelength and spectral width measurements

The wavelength and spectral width (RMS) shall meet specifications according to TIA-455-127-A, under modulated conditions using a valid 1000BASE-X signal.

NOTE 1—The allowable range of central wavelengths is narrower than the operating wavelength range by the actual RMS spectral width at each extreme.

NOTE 2—The 20 dB width for SLM lasers is taken as 6.07 times the RMS width.

The interaction between the transmitter and the chromatic dispersion of the fiber is accounted for by a parameter ε (epsilon), which is defined as the product of 10^{-3} times the signaling speed (in GBd) times the path dispersion (in ps/nm) times the RMS spectral width (in nm).

$$\varepsilon = \text{dispersion} \times \text{length} \times \text{RMS spectral width} \times 10^{-3} \quad (60\text{–}3)$$

For the 1000BASE-PX10-D and 1000BASE-PX10-U links, a maximum ε close to 0.168 is imposed by the middle column of Table 60–4. If the spectral width is kept below the limits of the right hand column, ε will not exceed 0.115, and the chromatic dispersion penalty is expected to be below 2 dB when all link

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parameters are simultaneously at worst case values. For the 1000BASE-PX20-D and 1000BASE-PX20-U links, a maximum ε close to 0.115 is imposed by the middle column of Table 60–7. If the spectral width is kept below the limits of the right hand column, ε will not exceed 0.10, and the chromatic dispersion penalty is expected to be below 1.5 dB when all link parameters are simultaneously at worst case values.

For the 1000BASE-PX30-D and 1000BASE-PX30-U links, a maximum ε close to 0.095 is imposed by the middle column of Table 60–10. If the spectral width is kept below the limits of the right hand column, ε will not exceed 0.08, and the chromatic dispersion penalty is expected to be below 0.9 dB when all link parameters are simultaneously at worst case values.

The chromatic dispersion penalty is a component of transmitter and dispersion penalty (TDP), which is specified in Table 60–3, Table 60–6, Table 60–9, and Table 60–12, and described in 58.7.9.

60.9.3 Optical power measurements

Optical power shall meet specifications according to the methods specified in ANSI/EIA-455-95. A measurement may be made with the port transmitting any valid encoded 8B/10B data stream.

60.9.4 Extinction ratio measurements

Extinction ratio shall meet specifications according to IEC 61280-2-2 with the port transmitting a repeating idle pattern /I2/ ordered set (see 36.2.4.12) that may be interspersed with OAM packets per 57A.2, and with minimal back reflections into the transmitter, lower than –20 dB. The /I2/ ordered set is defined in Clause 36, and is coded as /K28.5/D16.2/, which is binary 0011 1010 100100 0101 within idles. The extinction ratio is expected to be similar for other valid 8B/10B bit streams. The test receiver has the frequency response as specified for the transmitter optical waveform measurement.

60.9.5 OMA measurements (informative)

Subclause 58.7.5 provides a reference technique for performing OMA measurements.

60.9.6 OMA relationship to extinction ratio and power measurements (informative)

The normative way of measuring transmitter characteristics is extinction ratio and mean power. Clause 58 provides information on how OMA, extinction ratio and mean power are related to each other (see 58.7.6).

60.9.7 Relative intensity noise optical modulation amplitude ($RIN_{15}OMA$)

$RIN_{15}OMA$ is the ratio of noise to modulated optical signal in the presence of a back reflection. The measurement procedure is described in 58.7.7.

60.9.8 Transmitter optical waveform (transmit eye)

The required transmitter pulse shape characteristics are specified in the form of a mask of the transmitter eye diagram as shown in Figure 60–7.

The measurement procedure is described in 58.7.8 and references therein.

The eye shall comply to the mask of the eye using a fourth-order Bessel-Thomson receiver response with f_r = 0.9375 GHz, and where the relative response vs. relative frequency is defined in ITU-T G.957, Table B.2 (STM-16 values), along with the allowed tolerances for its physical implementation.

NOTE 1—This Bessel-Thomson filter is not intended to represent the noise filter used within an optical receiver, but is intended to provide uniform measurement conditions on the transmitter.

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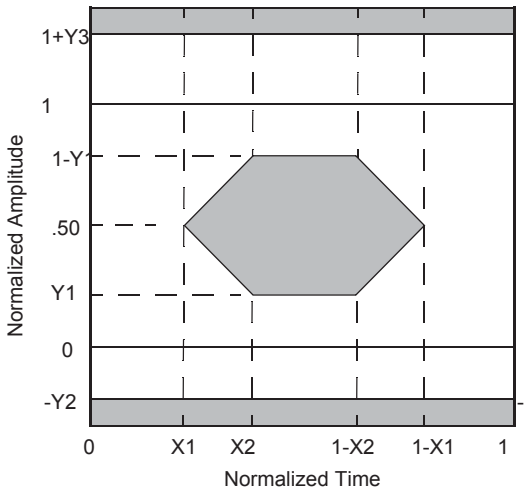

Figure 60–7—Transmitter eye mask definition

NOTE 2—The fourth order Bessel-Thomson filter is reactive. In order to suppress reflections, a 6 dB attenuator may be required at the filter input and/or output.

60.9.9 Transmitter and dispersion penalty (TDP)

TDP measurement tests for transmitter impairments with chromatic effects for a transmitter to be used with single-mode fiber. Possible causes of impairment include intersymbol interference, jitter, RIN and mode partition noise. Meeting the separate requirements (e.g., eye mask, spectral characteristics) does not in itself guarantee the transmitter and dispersion penalty (TDP). The TDP limit shall be met. See 58.7.9 for details of the measurement.

60.9.10 Receive sensitivity measurement

Receiver sensitivity is defined for the random pattern test frame and an ideal input signal quality with the specified extinction ratio. The measurement procedure is described in 58.7.10. The sensitivity shall be met for the bit error ratio defined in Table 60–5, Table 60–8, Table 60–11, or Table 60–13 as appropriate.

60.9.11 Stressed receive conformance test

The stressed receiver conformance test is intended to screen against receivers with poor frequency response or timing characteristics which could cause errors when combined with a distorted but compliant signal at TP3. Modal (MMF) or chromatic (SMF) dispersion can cause distortion. The conformance test signal uses the random pattern test frame and is conditioned by applying deterministic jitter and intersymbol interference. If the option for stressed receiver compliance is chosen, the receiver shall meet the specified bit error ratio at the power level and signal quality defined in Table 60–5, Table 60–8, Table 60–11, and Table 60–13 as appropriate, according to the measurement procedures of 58.7.11.

60.9.12 Jitter measurements (informative)

Jitter measurements for 1000 Mb/s are described in 58.7.12.

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60.9.13 Other measurements

60.9.13.1 Laser On/Off timing measurement

T_{on} is defined in 60.9.13.1.1, value is less than 512 ns (defined in Table 60–3, Table 60–6, Table 60–9, and Table 60–12).

$T_{receiver_settling}$ is defined in 60.9.13.2.1 (informative), value is less than 400 ns (defined in Table 60–5, Table 60–8, Table 60–11, and Table 60–13).

T_{CDR} is defined in 65.3.2.1, value is less than 400 ns (defined in 60.2.2).

$T_{code_group_align}$ is defined in 36.3.2.4, value is less than 4 ten-bit code-groups.

T_{off} is defined in 60.9.13.1.1, value is less than 512 ns (defined in Table 60–3, Table 60–6, Table 60–9, and Table 60–12).

60.9.13.1.1 Definitions

T_{on} is denoted as the time beginning from the falling edge of the Tx_Enable line to the ONU PMD and ending at the time that the optical signal at TP2 of the ONU PMD is within 15% of its steady state parameters (average launched power, wavelength, RMS spectral width, transmitter and dispersion penalty, optical return loss tolerance, jitter, $RIN_{15}OMA$, extinction ratio and eye mask opening) as defined in Table 60–3 for 1000BASE-PX10-U, Table 60–6 for 1000BASE-PX20-U, Table 60–9 for 1000BASE-PX30-U, and Table 60–12 for 1000BASE-PX40-U. T_{on} is presented in Figure 60–8. The data transmitted may be any valid 8B/10B symbols.

T_{off} is denoted as the time beginning from the rising edge of the Tx_Enable line to the ONU PMD and ending at the time that the optical signal at TP2 of the ONU PMD reaches the specified average launch power of off transmitter as defined in Table 60–3 for 1000BASE-PX10-U, Table 60–6 for 1000BASE-PX20-U, Table 60–9 for 1000BASE-PX30-U, and Table 60–12 for 1000BASE-PX40-U. T_{off} is presented in Figure 60–8. The data transmitted may be any valid 8B/10B symbols.

60.9.13.1.2 Test specification

The test setup for measuring T_{on} and T_{off} is described in Figure 60–9. An O/E converter is used to convert the optical signal at TP3 to an electrical signal at TP4 where it is assumed that the response time of the converter is considerably shorter that the T_{on} value under measurement. A scope, with a variable delay, can measure the time from the Tx_Enable trigger to the time the optical signal reaches all its specified conditions. The delay to the scope trigger is adjusted until the point that the received signal meets all its specified conditions. This is the T_{on} in question.

A non-rigorous way to describe this test setup would be: for a PMD with a declared T_{on} and T_{off}, measure all PMD optical parameter after T_{on} and T_{off} from the Tx_Enable trigger, reassuring conformance 15% of the steady state values. Notice that only the steady state optical OFF power must be conformed when measuring T_{off} time, since that is the only relevant parameter.

60.9.13.2 Receiver settling timing measurement (informative)

60.9.13.2.1 Definitions

$T_{receiver_settling}$ is denoted as the time beginning from the time that the optical power in the receiver at TP3 reaches the conditions specified in 38.6.11, 58.7.11.2 and ending at the time that the electrical signal after the PMD at TP4, reaches within 15% of its steady state parameter, (average power, jitter), see Table 60–5,

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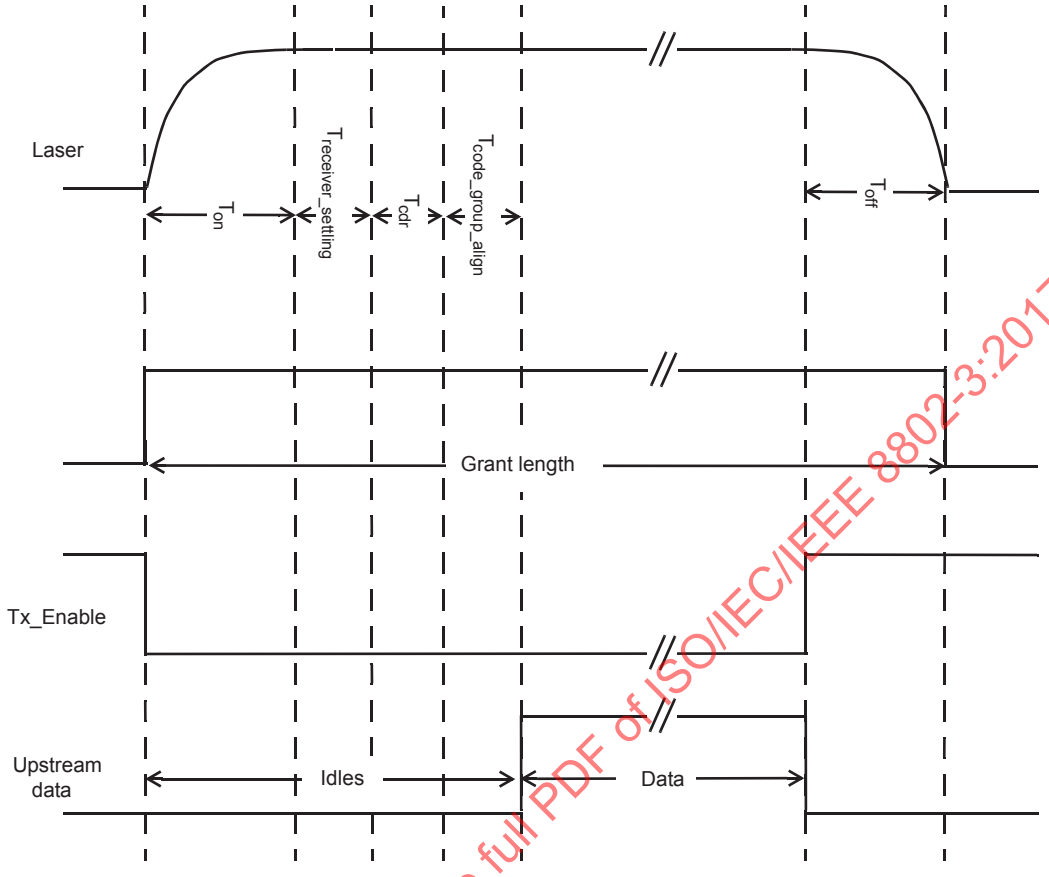

Figure 60–8—P2MP timing parameter definition

Table 60–8, Table 60–11, and Table 60–13: $T_{receiver_settling}$ is presented in Figure 60–8. The data transmitted may be any valid 8B/10B symbols (or a specific power synchronization sequence). The optical signal at TP3, at the beginning of the locking, may have any valid 8B/10B pattern, optical power level, jitter, or frequency shift matching the standard specifications.

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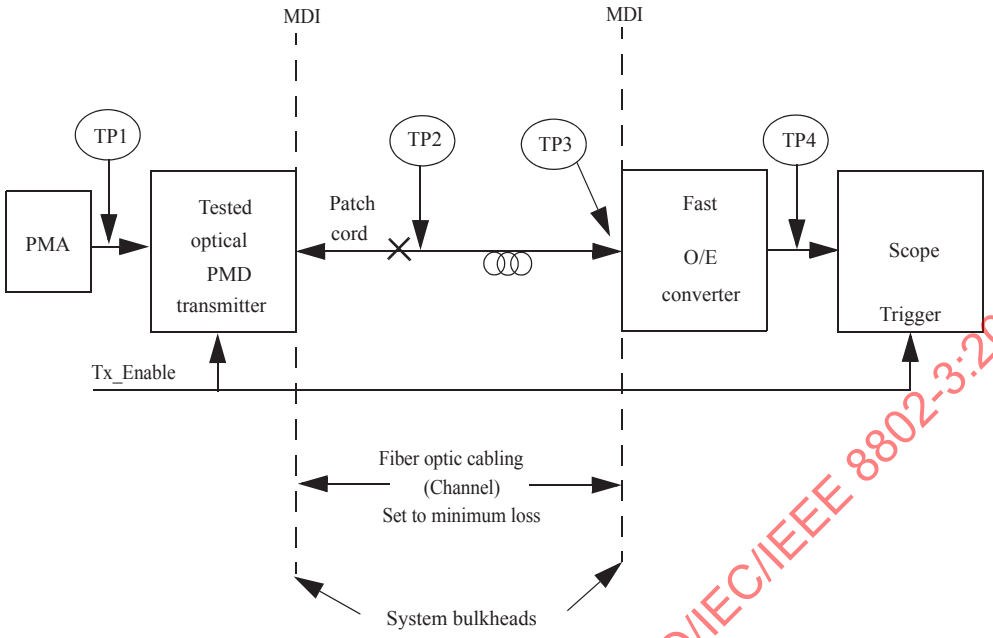

Figure 60–9—ONU PMD Laser on/off time measurement setup

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60.9.13.2.2 Test specification

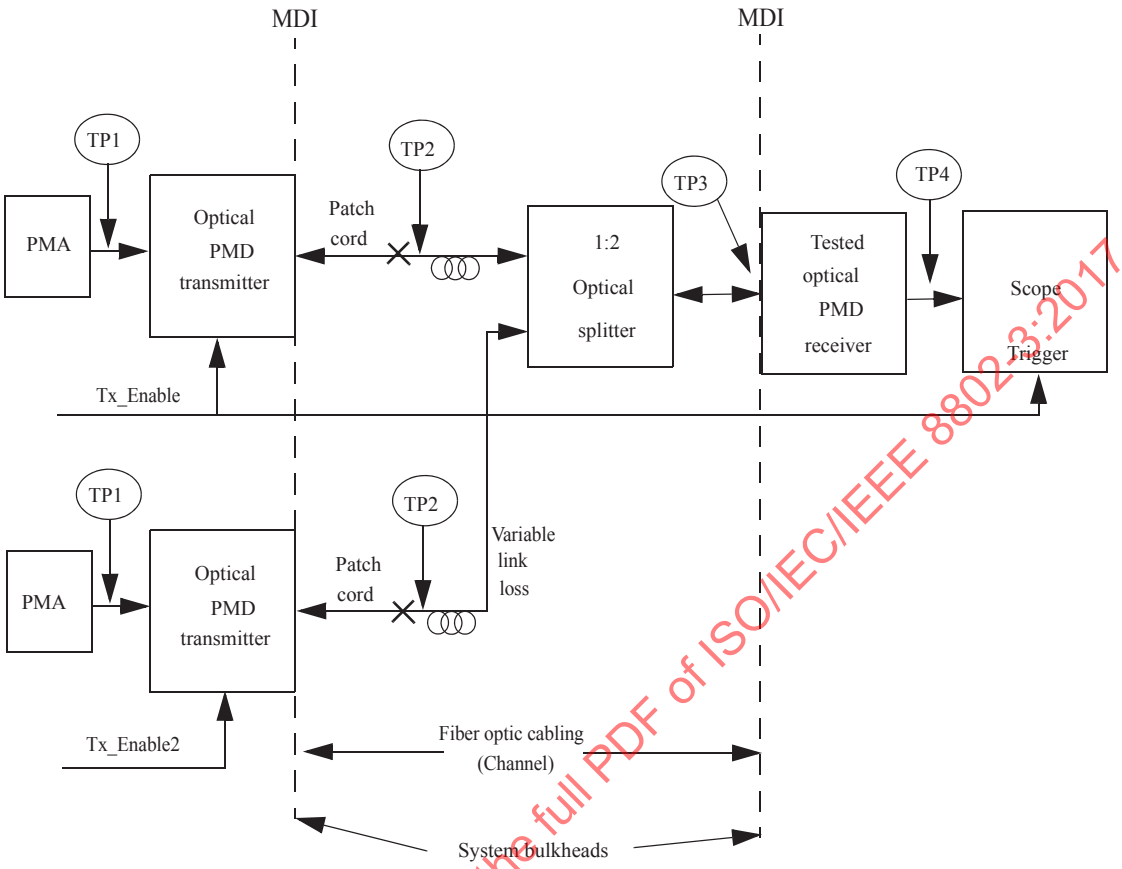

Figure 60–10—Receiver settling time measurement setup

Figure 60–10 illustrates the test setup for the OLT PMD receiver (upstream) $T_{receiver_settling}$ time. The optical PMD transmitter has well-known parameters, with a fixed known T_{on} time. After T_{on} time the parameters of the reference transmitter, at TP2 and therefore at TP3, reach within 15% of its steady state values as specified in Table 60–3 for 1000BASE-PX10-U, Table 60–6 for 1000BASE-PX20-U, Table 60–9 for 1000BASE-PX30-U, and Table 60–12 for 1000BASE-PX40-U.

Define $T_{receiver_settling}$ time as the time from the Tx_Enable assertion, minus the known T_{on} time, to the time the electrical signal at TP4 reaches within 15% of its steady state conditions.

Conformance should be assured for an optical signal at TP3 with any level of its specified parameters before the Tx_Enable assertion. Especially the $T_{receiver_settling}$ time must be met in the following scenarios:

- Switching from a ‘weak’ (minimal received power at TP3) ONU to a ‘strong’ (maximal received power at TP3) ONU, with minimal guard band between.
- Switching from a ‘strong’ ONU to a ‘weak’ ONU, with minimal guard band between.
- Switching from noise level, with maximal duration interval, to ‘strong’ ONU power level.

A non-rigorous way to describe this test setup would be (using a transmitter with a known T_{on}).

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For a tested PMD receiver with a declared $T_{receiver_settling}$ time, measure all PMD receiver electrical parameters at TP4 after $T_{receiver_settling}$ from the TX_ENABLE trigger minus the reference transmitter T_{on}, reassuring conformance to within 15% of its specified steady state values.

60.10 Environmental, safety, and labeling

60.10.1 General safety

All equipment meeting this standard shall conform to IEC 60950-1.

60.10.2 Laser safety

1000BASE-PX10, 1000BASE-PX20, 1000BASE-PX30, and 1000BASE-PX40 optical transceivers shall conform to Hazard Level 1 laser requirements as defined in IEC 60825-1 and IEC 60825-2, under any condition of operation. This includes single fault conditions whether coupled into a fiber or out of an open bore. Conformance to additional laser safety standards may be required for operation within specific geographic regions.

Laser safety standards and regulations require that the manufacturer of a laser product provide information about the product's laser, safety features, labeling, use, maintenance, and service. This documentation shall explicitly define requirements and usage restrictions on the host system necessary to meet these safety certifications.

60.10.3 Installation

It is recommended that proper installation practices, as defined by applicable local codes and regulation, be followed in every instance in which such practices are applicable.

60.10.4 Environment

Reference Annex 67A for additional environmental information.

Two optional temperature ranges are defined in Table 60–18. Implementations shall be declared as compliant over one or both complete ranges, or not so declared (compliant over parts of these ranges or another temperature range).

Table 60–18—Component case temperature classes

Class	Low temperature (°C)	High temperature (°C)
Warm extended	–5	+85
Cool extended	–40	+60
Universal extended	–40	+85

60.10.5 PMD labeling requirements

It is recommended that each PHY (and supporting documentation) be labeled in a manner visible to the user, with at least the applicable safety warnings and the applicable port type designation (e.g., 1000BASE-PX10-U).

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Labeling requirements for Hazard Level 1 lasers are given in the laser safety standards referenced in 60.10.2.

Each systems and field pluggable component shall be clearly labeled with its operating temperature range over which their compliance is ensured.

60.11 Characteristics of the fiber optic cabling

The 1000BASE-PX fiber optic cabling shall meet the dispersion specifications defined in IEC 60793-2 and ITU-T G.652, or the requirements of Table 60–19 where they differ. The fiber optic cabling consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together. It also includes a connector plug at each end to connect to the MDI. The fiber optic cabling spans from one MDI to another MDI, as shown in Figure 60–11.

60.11.1 Fiber optic cabling model

The fiber optic cabling model is shown in Figure 60–11.

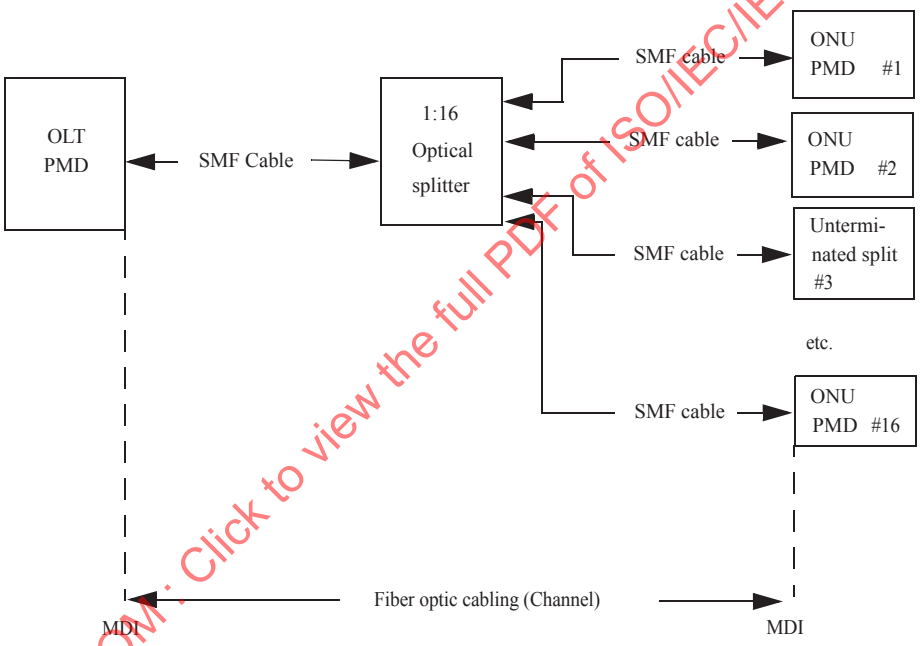

Figure 60–11—Fiber optic cable model

NOTE—The 1:16 optical splitter may be replaced by a number of smaller 1:n splitters such that a different topology may be implemented while preserving the link characteristics and power budget as defined in Table 60–14.

The maximum channel insertion losses shall meet the requirements specified in Table 60–1. Insertion loss measurements of installed fiber cables are made in accordance with ANSI/TIA/EIA-526-7 [B16], method A-1. The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment. The term channel is used here for consistency with generic cabling standards.

60.11.2 Optical fiber and cable

The fiber optic cable requirements for 1000BASE-PX10 and 1000BASE-PX20 are satisfied by the fibers specified in IEC 60793-2 Type B1.1 (dispersion un-shifted single-mode fiber) and Type B1.3 (low water peak single-mode fiber) and ITU-T G.652, or by the requirements of Table 60–19 where they differ.

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The fiber optic cable requirements for 1000BASE-PX30 and 1000BASE-PX40 are satisfied by the fibers specified in IEC 60793–2 Type B1.1 (dispersion un–shifted single-mode fiber), Type B1.3 (low water peak single-mode fiber), ITU-T G.652, and ITU-T G.657 (bend–insensitive single-mode fiber), or by the requirements of Table 75–14 where they differ.

60.11.3 Optical fiber connection

Table 60–19—Optical fiber and cable characteristics

Description[a]	Type B1.1, B1.3 SMF		Unit
Nominal wavelength[b]	1310	1550	nm
Cabled optical fiber attenuation (max)[c]	0.4	0.35	dB/km
Zero dispersion wavelength[d]	$1300 \le \lambda_0 \le 1324$		nm
Dispersion slope (max)	0.093		ps / nm^2 · km

[a]The fiber dispersion values are normative, all other values in the table are informative.
[b]Wavelength specified is the nominal wavelength and typical measurement wavelength. Power penalties at other wavelengths are accounted for.
[c]Attenuation for single-mode optical fiber cables is defined in ITU-T G.652.
[d]See IEC 60793 or ITU-T G.652.

An optical fiber connection as shown in Figure 60–11 consists of a mated pair of optical connectors. The 1000BASE-PX is coupled to the fiber optic cabling through an optical connection and any optical splitters into the MDI optical receiver, as shown in Figure 60–11. The channel insertion loss includes the loss for connectors, splices and other passive components such as splitters, see Table 60–14.

The link attenuations have been calculated on the assumption of 14.5 dB for a 16:1 splitter; 3.5 dB, 4 dB, 7.5 dB, or 8 dB (at the appropriate measurement wavelength where these attenuations are a combination of the minimum range given in Table 60–1 and the values in Table 60–19) for cabled optical fiber attenuation and 1.5 dB for connectors and splices. For example, this allocation supports three connections with an average insertion loss equal to 0.5 dB (or less) per connection, or two connections with a maximum insertion loss of 0.75 dB. Other arrangements, such as a shorter link length and a higher split ratio in the case of 1000BASE-PX20, may be used provided the requirements of Table 60–1 are met.

The maximum discrete reflectance for single-mode connections shall be less than –26 dB.

60.11.4 Medium Dependent Interface (MDI)

The 1000BASE-PX10, 1000BASE-PX20, 1000BASE-PX30, or 1000BASE-PX40 PMD is coupled to the fiber cabling at the MDI. The MDI is the interface between the PMD and the “fiber optic cabling” as shown in Figure 60–11. Examples of an MDI include the following:

a) Connectorized fiber pigtail
b) PMD receptacle

When the MDI is a remateable connection, it shall meet the interface performance specifications of IEC 61753-1. The MDI carries the signal in both directions for 1000BASE-PX10, 1000BASE-PX20, 1000BASE-PX30, and 1000BASE-PX40 and couples to a single fiber.

NOTE—Compliance testing is performed at TP2 and TP3 as defined in 60.2.1, not at the MDI.

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60.12 Protocol implementation conformance statement (PICS) proforma for Clause 60, Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-PX (long wavelength passive optical networks)[8]

60.12.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 60, Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-PX (long wavelength passive optical networks), shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

60.12.2 Identification

60.12.2.1 Implementation identification

Supplier[1]	
Contact point for inquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1,3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations. NOTE2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

60.12.2.2 Protocol Summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 60, Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-PX
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	

Date of Statement	

[8]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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60.12.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
HT	High temperature operation	60.10.4	–5 °C to 85 °C	O	Yes [ ] No [ ]
LT	Low temperature operation	60.10.4	–40 °C to 60 °C	O	Yes [ ] No [ ]
*PX10U	1000BASE-PX10-U-PHY or 1000BASE-PX10-U PMD	60.3	Device supports 10 km	O/1	Yes [ ] No [ ]
*PX10D	1000BASE-PX10-D-PHY or 1000BASE-PX10-D PMD	60.3	Device supports 10 km	O/1	Yes [ ] No [ ]
*PX20U	1000BASE-PX20-U-PHY or 1000BASE-PX20-U PMD	60.4	Device supports 20 km	O/1	Yes [ ] No [ ]
*PX20D	1000BASE-PX20-D-PHY or 1000BASE-PX20-D PMD	60.4	Device supports 20 km	O/1	Yes [ ] No [ ]
*PX30U	1000BASE-PX30-U-PHY or 1000BASE-PX30-U PMD	60.5	Device supports 20 km	O/1	Yes [] No []
*PX30D	1000BASE-PX30-D-PHY or 1000BASE-PX30-D PMD	60.5	Device supports 20 km	O/1	Yes [] No []
*PX40U	1000BASE-PX40-U-PHY or 1000BASE-PX40-U PMD	60.6	Device supports 20 km	O/1	Yes [] No []
*PX40D	1000BASE-PX40-D-PHY or 1000BASE-PX40-D PMD	60.6	Device supports 20 km	O/1	Yes [] No []
*INS	Installation / Cable	60.3.1	Items marked with INS include installation practices and cable specifications not applicable to a PHY manufacturer.	O	Yes [ ] No [ ]

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60.12.4 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and medium, type 1000BASE-PX (long wavelength passive optical networks)

60.12.4.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FN1	Transmit function	60.2.2	Conveys bits from PMD service interface to MDI	M	Yes [ ]
FN2	Transmitter optical signal	60.2.2	Higher optical power transmitted is a logic 1	M	Yes [ ]
FN3	Receive function	60.2.3	Conveys bits from MDI to PMD service interface	M	Yes [ ]
FN4	Receiver optical signal	60.2.3	Higher optical power received is a logic 1	M	Yes [ ]
FN5	Signal detect function (downstream)	60.2.4.1	Mapping to PMD service interface	M	Yes [ ]
FN6	Signal detect parameter (downstream)	60.2.4.1	Generated according to Table 60–2	M	Yes [ ]
FN7	Signal detect function (upstream)	60.2.4.2	Mapping to PMD service interface	O/2	Yes [ ]
FN7	Signal detect function (upstream)	60.2.4.2	Provided by higher layer	O/2	Yes [ ]
FN8	Signal detect parameter (upstream)	60.2.4.1	Generated according to Table 60–2	O	Yes [ ]

60.12.4.2 PMD to MDI optical specifications for 1000BASE-PX10-D

Item	Feature	Subclause	Value/Comment	Status	Support
PX10D1	1000BASE-PX10-D transmitter	60.3.1	Meets specifications in Table 60–3	PX10D:M	Yes [ ] N/A [ ]
PX10D2	1000BASE-PX10-D transmitter $RIN_{15}OMA$	60.3.1	Meets the $RIN_{15}OMA$ specification in Table 60–3	PX10D:O	Yes [ ] N/A [ ]
PX10D3	1000BASE-PX10-D receiver	60.3.2	Meets specifications in Table 60–5	PX10D:M	Yes [ ] N/A [ ]
PX10D4	1000BASE-PX10-D stressed receiver sensitivity	60.3.2	Meets specifications in Table 60–5	PX10D:O	Yes [ ] No [ ] N/A[ ]
PX10D5	1000BASE-PX10-D receiver damage threshold	60.3.2	If the receiver does not meet the damage requirements in Table 60–5 then label accordingly	PX10D:M	Yes [ ] N/A [ ]

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60.12.4.3 PMD to MDI optical specifications for 1000BASE-PX10-U

Item	Feature	Subclause	Value/Comment	Status	Support
PX10U1	1000BASE-PX10-U transmitter	60.3.1	Meets specifications in Table 60–3	PX10U:M	Yes [ ] N/A [ ]
PX10U2	1000BASE-PX10-U transmitter $RIN_{15}OMA$	60.3.1	Meets the $RIN_{15}OMA$ specification in Table 60–3	PX10U:O	Yes [ ] N/A [ ]
PX10U3	1000BASE-PX10-U receiver	60.3.2	Meets specifications in Table 60–5	PX10U:M	Yes [ ] N/A [ ]
PX10U4	1000BASE-PX10-U stressed receiver sensitivity	60.3.2	Meets specifications in Table 60–5	PX10U:O	Yes [ ] No [ ] N/A[ ]
PX10U5	1000BASE-PX10-U receiver damage threshold	60.3.2	If the receiver does not meet the damage requirements in Table 60–5 then label accordingly	PX10U:M	Yes [ ] N/A [ ]

60.12.4.4 PMD to MDI optical specifications for 1000BASE-PX20-D

Item	Feature	Subclause	Value/Comment	Status	Support
PX20D1	1000BASE-PX20-D transmitter	60.4.1	Meets specifications in Table 60–6	PX20D:M	Yes [ ] N/A [ ]
PX20D2	1000BASE-PX20-D transmitter $RIN_{15}OMA$	60.4.1	Meets the $RIN_{15}OMA$ specification in Table 60–6	PX20D:O	Yes [ ] N/A [ ]
PX20D3	1000BASE-PX20-D receiver	60.4.2	Meets specifications in Table 60–8	PX20D:M	Yes [ ] N/A [ ]
PX20D4	1000BASE-PX20-D stressed receiver sensitivity	60.4.2	Meets specifications in Table 60–8	PX20D:O	Yes [ ] No [ ] N/A[ ]
PX20D5	1000BASE-PX20-D receiver damage threshold	60.4.2	If the receiver does not meet the damage requirements in Table 60–8 then label accordingly	PX20D:M	Yes [ ] N/A [ ]

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60.12.4.5 PMD to MDI optical specifications for 1000BASE-PX20-U

Item	Feature	Subclause	Value/Comment	Status	Support
PX20U1	1000BASE-PX20-U transmitter	60.4.1	Meets specifications in Table 60–6	PX20U:M	Yes [ ] N/A [ ]
PX20U2	1000BASE-PX20-U transmitter $RIN_{15}OMA$	60.4.1	Meets the $RIN_{15}OMA$ specification in Table 60–6	PX20U:O	Yes [ ] N/A [ ]
PX20U3	1000BASE-PX20-U receiver	60.4.2	Meets specifications in Table 60–8	PX20U:M	Yes [ ] N/A [ ]
PX20U4	1000BASE-PX20-U stressed receiver sensitivity	60.4.2	Meets specifications in Table 60–8	PX20U:O	Yes[ ] No [ ] N/A[ ]
PX20U5	1000BASE-PX20-U receiver damage threshold	60.4.2	If the receiver does not meet the damage requirements in Table 60–8 then label accordingly	PX20U:M	Yes [ ] N/A [ ]

60.12.4.6 PMD to MDI optical specifications for 1000BASE-PX30-D

Item	Feature	Subclause	Value/Comment	Status	Support
PX30D1	1000BASE-PX30-D transmitter	60.5.1	Meets normative specifications in Table 60–9	PX30D:M	Yes [ ] N/A [ ]
PX30D2	1000BASE-PX30-D transmitter $RIN_{15}OMA$	60.5.1	Meets the $RIN_{15}OMA$ specification in Table 60–9	PX30D:O	Yes [ ] N/A [ ]
PX30D3	1000BASE-PX30-D receiver	60.5.2	Meets specifications in Table 60–11	PX30D:M	Yes [ ] N/A [ ]
PX30D4	1000BASE-PX30-D stressed receiver sensitivity	60.5.2	Meets specifications in Table 60–11	PX30D:O	Yes [ ] No [ ] N/A[ ]
PX30D5	1000BASE-PX30-D receiver damage threshold	60.5.2	If the receiver does not meet the damage requirements in Table 60–11 then label accordingly	PX30D:M	Yes [ ] N/A [ ]

60.12.4.7 PMD to MDI optical specifications for 1000BASE-PX30-U

Item	Feature	Subclause	Value/Comment	Status	Support
PX30U1	1000BASE-PX30-U transmitter	60.5.1	Meets specifications in Table 60–9	PX30U:M	Yes [ ] N/A [ ]
PX30U2	1000BASE-PX30-U transmitter $RIN_{15}OMA$	60.5.1	Meets the $RIN_{15}OMA$ specification in Table 60–9	PX30U:O	Yes [ ] N/A [ ]
PX30U3	1000BASE-PX30-U receiver	60.5.2	Meets specifications in Table 60–11	PX30U:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
PX30U4	1000BASE-PX30-U stressed receiver sensitivity	60.5.2	Meets specifications in Table 60–11	PX30U:O	Yes [ ] No [ ] N/A[ ]
PX30U5	1000BASE-PX30-U receiver damage threshold	60.5.2	If the receiver does not meet the damage requirements in Table 60–11 then label accordingly	PX30U:M	Yes [ ] N/A [ ]

60.12.4.8 PMD to MDI optical specifications for 1000BASE-PX40-D

Item	Feature	Subclause	Value/Comment	Status	Support
PX40D1	1000BASE-PX40-D transmitter	60.6.1	Meets specifications in Table 60–12	PX40D:M	Yes [ ] N/A [ ]
PX40D2	1000BASE-PX40-D transmitter $RIN_{15}OMA$	60.6.1	Meets the $RIN_{15}OMA$ specification in Table 60–12	PX40D:O	Yes [ ] N/A [ ]
PX40D3	1000BASE-PX40-D receiver	60.6.2	Meets specifications in Table 60–13	PX40D:M	Yes [ ] N/A [ ]
PX40D4	1000BASE-PX40-D stressed receiver sensitivity	60.6.2	Meets specifications in Table 60–13	PX40D:O	Yes[ ] No [ ] N/A[ ]
PX40D5	1000BASE-PX40-D receiver damage threshold	60.6.2	If the receiver does not meet the damage requirements in Table 60–13 then label accordingly	PX40D:M	Yes [ ] N/A [ ]

60.12.4.9 PMD to MDI optical specifications for 1000BASE-PX40-U

Item	Feature	Subclause	Value/Comment	Status	Support
PX40U1	1000BASE-PX40-U transmitter	60.6.1	Meets specifications in Table 60–12	PX40U:M	Yes [ ] N/A [ ]
PX40U2	1000BASE-PX40-U transmitter $RIN_{15}OMA$	60.6.1	Meets the $RIN_{15}OMA$ specification in Table 60–12	PX40U:O	Yes [ ] N/A [ ]
PX40U2	1000BASE-PX40-U receiver	60.6.2	Meets specifications in Table 60–13	PX40U:M	Yes [ ] N/A [ ]
PX40U3	1000BASE-PX40-U stressed receiver sensitivity	60.6.2	Meets specifications in Table 60–13	PX40U:O	Yes[ ] No [ ] N/A[ ]
PX40U4	1000BASE-PX40-U receiver damage threshold	60.6.2	If the receiver does not meet the damage requirements in Table 60–13 then label accordingly	PX40U:M	Yes [ ] N/A [ ]

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60.12.4.10 Optical measurement requirements

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	Measurement cable	60.9	2 m to 5 m in length	M	Yes [ ]
OM2	Wavelength and spectral width measurement	60.9.2	Per TIA-455-127-A under modulated conditions	M	Yes [ ]
OM3	Average optical power	60.9.3	Per TIA/EIA-455-95	M	Yes [ ]
OM4	Extinction ratio	60.9.4	Per IEC 61280-2-2 with minimal back reflections and fourth-order Bessel-Thomson receiver	M	Yes [ ]
OM5	$RIN_{15}OMA$	60.9.7	As described in 58.7.7	M	Yes [ ]
OM6	Transmit optical waveform (transmit eye)	60.9.8	Per 58.7.8 and references therein	M	Yes [ ]
OM7	Transmitter and dispersion penalty measurements	60.9.9	As described in 58.7.9	M	Yes [ ]
OM8	Receive sensitivity	60.9.10	With specified pattern	M	Yes [ ]
*OM9	Stressed receiver conformance test	60.9.11	As described in 60.9.11	O	Yes[ ] N/A[ ]

60.12.4.11 Characteristics of the fiber optic cabling and MDI

Item	Feature	Subclause	Value/Comment	Status	Support
FO1	Fiber optic cabling	60.11	Specified in Table 60–19	INS:M	Yes [ ] N/A[ ]
F02	End-to-end channel loss	60.11	Meeting the requirements of Table 60–1	INS:M	Yes [ ] N/A[ ]
FO3	Maximum discrete reflectance - single-mode fiber	60.11.2	Less than –26 dB	INS:M	Yes [ ] N/A [ ]
FO4	MDI requirements	60.11.4	Meet the interface performance specifications of IEC 61753-1, if rematerable	INS:O	Yes [ ] No [ ] N/A [ ]

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60.12.4.12 Environmental specifications

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	General safety	60.10.1	Conforms to IEC 60950-1	M	Yes [ ]
ES2	Laser safety —IEC Hazard Level 1	60.10.2	Conform to Hazard Level 1 laser requirements defined in IEC 60825-1 and IEC 60825-2.	M	Yes [ ]
ES3	Documentation	60.10.2	Explicitly defines requirements and usage restrictions to meet safety certifications	M	Yes [ ]
ES4	Operating temperature range labeling	60.10.5	If required	M	Yes [ ] N/A[ ]

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61. Physical Coding Sublayer (PCS), Transmission Convergence (TC) sublayer, and common specifications, type 10PASS-TS and type 2BASE-TL

61.1 Overview

This clause specifies the Physical Coding Sublayer (PCS), Transmission Convergence sublayer (TC), and handshaking mechanisms that are common to a family of Physical Layer implementations for Ethernet over voice-grade copper known as 10PASS-TS and 2BASE-TL. These PHYs deliver a minimum of 10 Mb/s over distances of up to 750 m, and a minimum of 2 Mb/s over distances of up to 2700 m, using a single copper pair. Optionally, transmission over multiple copper pairs is supported.

The copper category of EFM PHYs is based on Digital Subscriber Line (DSL) PMDs defined for use in the access network according to ATIS T1, ETSI, and ITU-T standards. These systems are intended to be used in public as well as private networks; therefore they shall be capable of compliance with appropriate regulatory, governmental and regional requirements.

Unlike the specified copper categories for 10BASE-T, 100BASE-T, and 1000BASE-T, existing common carrier voice-grade copper has channel characteristics that are very diverse. Therefore it is conventional to discuss the channel behavior only in terms of averages, standard deviations and percentage worst case.

The 10PASS-TS and 2BASE-TL EFM Copper PHYs, in conjunction with the MAC specified in Clause 4 and Annex 4A, are used for point-to-point communications on a subscriber access network, typically between centralized distribution equipment, such as a Central Office (CO), and equipment located at the subscriber premises [Customer Premises Equipment, (CPE)].

For the 10PASS-TS and 2BASE-TL EFM Copper PHYs, two subtypes are defined: 10PASS-TS-O and 10PASS-TS-R are the subtypes of 10PASS-TS; 2BASE-TL-O and 2BASE-TL-R are the subtypes of 2BASE-TL. A connection can only be established between a 10PASS-TS-O PHY on one end of the voice-grade copper line, and a 10PASS-TS-R PHY on the other end, or between a 2BASE-TL-O PHY on one end and a 2BASE-TL-R PHY on the other end. In public networks, a 10PASS-TS-O or 2BASE-TL-O PHY is used at a CO, a cabinet or other centralized distribution point; a 10PASS-TS-R or 2BASE-TL-R PHY is used as CPE. In private networks, the network administrator will designate one end of each link as the network end. In this clause, 10PASS-TS-O and 2BASE-TL-O are collectively referred to as “CO-subtypes”; 10PASS-TS-R and 2BASE-TL-R are collectively referred to as “CPE-subtypes”. The CO and CPE subtypes of a 10PASS-TS or 2BASE-TL PHY may be implemented in a single physical device.

10PASS-TS and 2BASE-TL PHYs do not provide support for unidirectional links as described in 57.2.12. If a particular anomaly or failure occurs in either downstream or upstream, sublayer-specific signaling will alert the remote end of this condition. In the case of a sustained anomaly or failure, the link will reinitialize.

61.1.1 Scope

This clause defines the Physical Coding Sublayer (PCS) and Transmission Convergence (TC) sublayer for 2BASE-TL and 10PASS-TS. The PCS has similarities to other IEEE 802.3 PCS types, but also differs since new sublayers are added within the PCS sublayer to accommodate the operation of Ethernet over access network copper channels. The TC contains additional functions specific to the EFM Copper PHYs. This clause also defines the common startup and handshaking mechanism used by both PHYs. Parts of register 3.0, parts of register 3.4, and registers 3.60 through 3.73 specified in Clause 45 may be used to control the PCS specified in this clause. The remaining PCS registers defined in Clause 45 do not have any effect on the PCS specified in this clause. Parts of register 6.0 and registers 6.16 through 6.23 specified in Clause 45 may be used to control the TC sublayer specified in this clause.

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61.1.2 Objectives

The following are the objectives for 2BASE-TL and 10PASS-TS:

a) To provide 100 Mb/s burst data rate at the MII using Rate Matching.
b) To provide support for simultaneous transmission and reception without interference.
c) To provide for operating over unshielded voice grade twisted pair cable.
d) To provide a communication channel with a mean BER at the PMA service interface of less than 10^{-7} with a noise margin of 6 dB (10PASS-TS) or 5 dB (2BASE-TL).
e) To provide optional support for operation on multiple pairs.
f) To provide functional layering in the PCS which ensures compatibility with the layering and frame interfaces for xDSL systems, including a γ-interface based on that used for the PTM-TC sublayer as defined in ITU-T Recommendation G.993.1.

61.1.3 Relation of 2BASE-TL and 10PASS-TS to other standards

The relation of 2BASE-TL and 10PASS-TS to other standards is shown schematically in Figure 61–1.

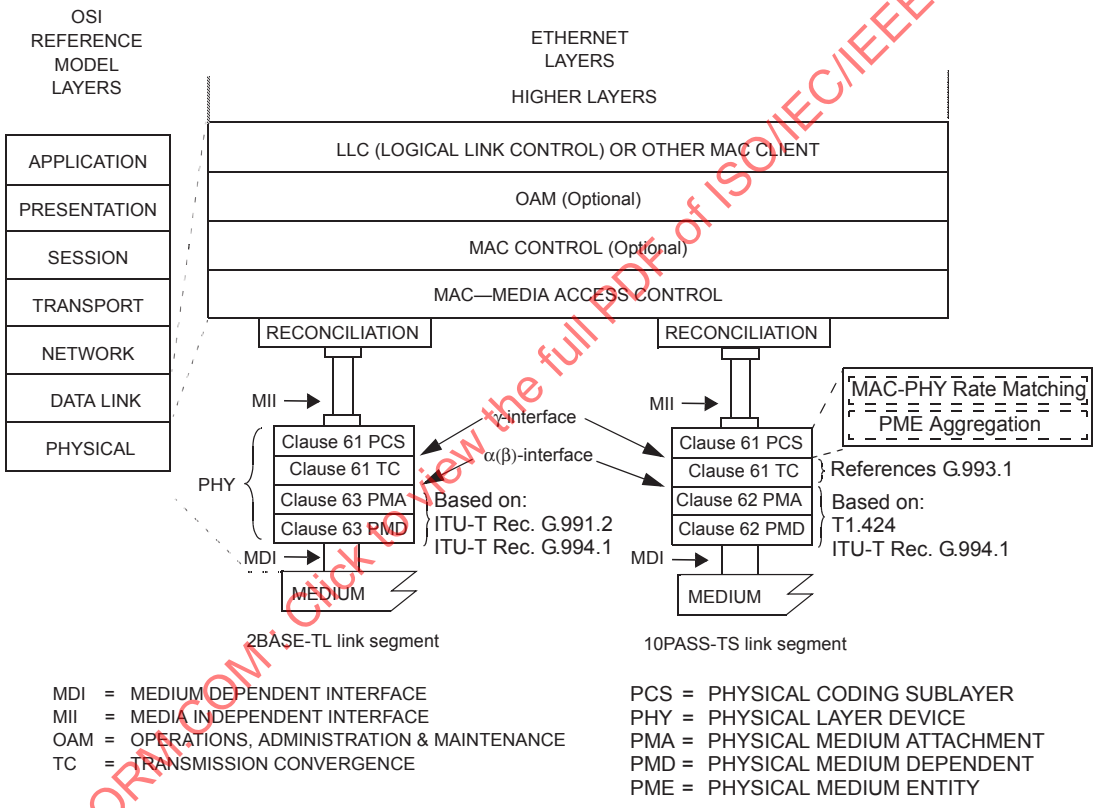

Figure 61–1—Relation of this clause to other standards

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NOTE—The PCS shown in the 2BASE-TL PHY and the PCS shown in the 10PASS-TS PHY are two instances of one unique PCS, specified in this clause. The TC shown in the 2BASE-TL PHY and the TC shown in the 10PASS-TS PHY are two instances of one unique TC, specified in this clause.

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61.1.4 Summary

61.1.4.1 Summary of Physical Coding Sublayer (PCS) specification

The Physical Coding Sublayer (PCS) for 2BASE-TL and 10PASS-TS contains two functions: MAC-PHY rate matching and PME aggregation. The functional position of the PCS is shown in Figure 61–2.

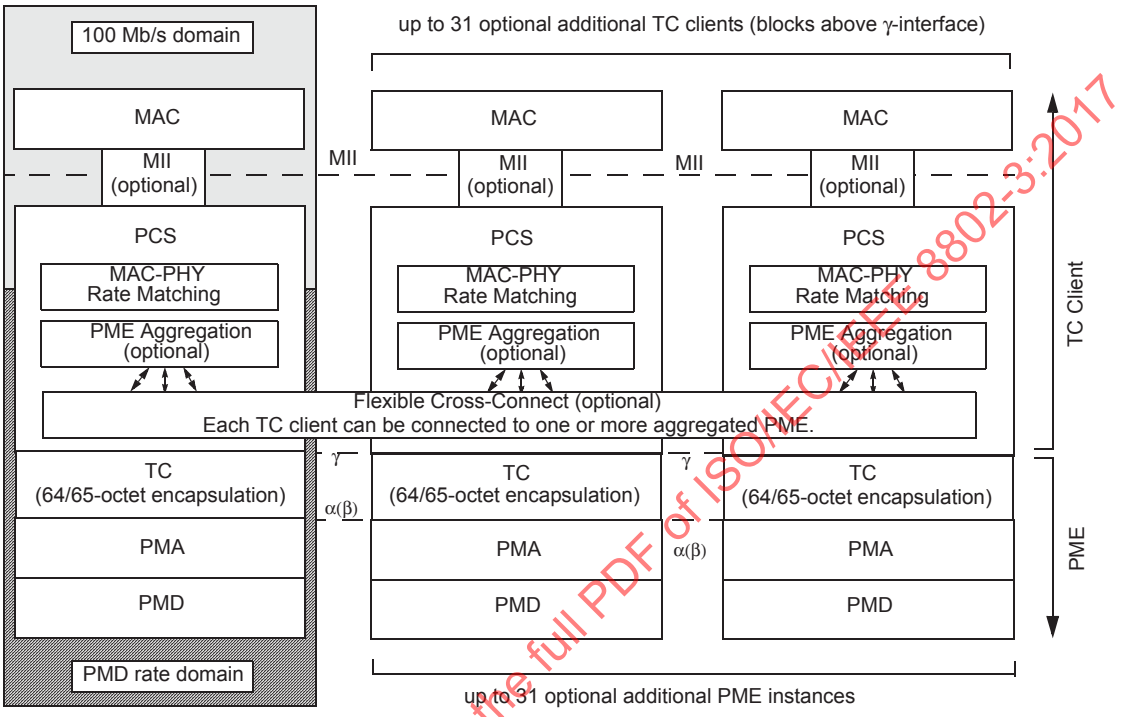

Figure 61–2—Overview of PCS functions

The γ-interface and α(β)-interface are specified in 61.3.1 and 61.3.2, respectively. They are generic interfaces used in various xDSL specifications, such as the ones referenced in Clause 62 and Clause 63. The α(β)-interface is a simple octet-synchronous data interface; the γ-interface adds protocol-awareness (in the case of the TC sublayer defined in this Clause, the γ-interface can signal packet boundaries).

The bit rates in the shaded area labeled "PMD rate domain" are derived from the DSL bit rates. Data is transferred across the γ-interface at the rate imposed by the lower layers. The bit rates in the shaded area labeled "100 Mb/s domain" are synchronous to the MII rate. Data is transferred across the MII at the rate of one nibble per MII clock cycle. The MAC-PHY rate matching function adjusts the inter packet gap so that the net data rate across these interface matches the sum of rates across the γ-interfaces.[9]

In the transmit direction, frames are transferred from the MAC to the PCS across the MII when the MAC-PHY rate matching function allows this. In the PCS, preamble and SFD octets are removed. If the optional PME aggregation function (PAF) is present, the MAC frame is fragmented by the PAF, and fragments are forwarded, optionally through a flexible cross-connect, towards each of the aggregated Physical Medium Entity (PME) instances via their γ-interfaces. If the PAF is not present, the data frame is forwarded to the TC sublayer via the γ-interface. The TC sublayer accepts data from the MAC-PHY rate matching function or the PAF, at the rate at which it can be processed by the TC sublayer, by asserting Tx_Enbl on the γ-interface.

[9]Bit rate domains and physical clock domains do not necessarily coincide. The TC sublayer receives a clock signal from the PMA via the α(β)-interface, and a clock signal from the optional PAF or the MAC-PHY Rate Matching function via the γ-interface. The TC provides matching between these two clock domains.

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In the receive direction the TC sublayer pushes data to the PAF (if present) or the MAC-PHY rate matching function by asserting Rx_Enbl on the γ-interface. If multiple links are aggregated, the PAF reassembles the received fragments into data frames. Preamble and SFD octets are generated and prepended to the data frame prior to passing it up to the MAC across the MII. The MAC-PHY Rate Matching function may delay the transfer of the frame to avoid simultaneous transfer of Transmit and Receive frames if required.

NOTE—The MAC_PHY rate matching function and PME Aggregation function both require some form of frame buffer for many implementations. It is recommended that these frame buffers should be sized to accommodate maximum length envelope frames (see 3.2.7).

61.1.4.1.1 Implementation of Media Independent Interface

10PASS-TS and 2BASE-TL specify the optional use of the MII electrical interface as defined in Clause 22 (see also 61.1.5.2). 10PASS-TS and 2BASE-TL do not utilize the MII management interface as described in 22.2.4. The use of the MDIO interface specified in Clause 45 or an equivalent management interface is recommended.

Notwithstanding the specifications in 22.2.2.9, CRS may be asserted by a full-duplex EFM Copper PHY to reduce the effective MAC rate to that of the PHY.

61.1.4.1.2 Summary of MAC-PHY Rate Matching specification

The 10PASS-TS and 2BASE-TL PCS is specified to work with a MAC operating at 100 Mb/s using the MII as defined in Clause 22. The PCS matches the MAC's rate of data transmission to the transmission data rate of the medium, if slower. This is achieved using deference as defined in Annex 4A.

The MAC transmits data at a rate of 100 Mb/s, which is buffered by the PCS before being transmitted onto the medium. Prior to transmission, the MAC checks the carrierSense variable (mapped from the MII signal CRS), and will not transmit another frame as long as carrierSense is asserted. In order to prevent the PCS's transmit buffer from overflowing, the PCS keeps CRS asserted until it has space to receive a maximum length frame. The PCS forces COL to logic zero to prevent the MAC from dropping the frame and performing a re-transmission.

The transmitter MAC-PHY Rate Matching function strips the Preamble and SFD fields from the MAC frame, and forwards the resulting data frame to the PME Aggregation Function or to the TC sublayer.

For reception the PHY buffers a complete frame, prepends the Preamble and SFD fields, and sends it to the MAC at 100 Mb/s.

It is recognized that some MAC implementations have to be configured for half duplex operation to support deference (according to 4.2.3.2.1), and that these may not allow the simultaneous transmission and reception of data while operating in half duplex mode. To permit operation with these MACs the PHY has an operating mode where MAC data transmission is deferred using CRS when received data is sent from the PHY to the MAC. This mode of operation is defined in Figure 61–8, which describes the MAC-PHY rate matching receive state diagram. This state diagram gives receive frames priority over transmitted frames to ensure the receive buffer does not overflow.

The definition of MAC-PHY rate matching is presented in 61.2.1.

61.1.4.1.3 Summary of PME Aggregation specification

An optional PME Aggregation Function (PAF) allows one or more PMEs to be combined together to form a single logical Ethernet link. The PAF is located in the PCS, between the MAC-PHY Rate Matching function and the TC sublayer. It interfaces with the PMEs across the γ-interface, and to the MAC-PHY Rate Matching function using an abstract interface. The definition of the PAF is presented in 61.2.2.

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61.1.4.1.4 Overview of management

Ethernet OAM (Clause 57) runs over a MAC service which uses a PHY consisting of either a single physical link, or more than one physical 2BASE-TL or 10PASS-TS links, aggregated as described in 61.2.2. The Ethernet OAM operates as long as there is at least one PME in the PHY that is operational. The physical xDSL PMEs in Clause 62 and Clause 63 each have their own management channel that operates per loop (eoc, VOC and IB for 10PASS-TS; EOC and IB for 2BASE-TL).

61.1.4.2 Summary of Transmission Convergence (TC) specification

The Transmission Convergence sublayer (TC) resides between the γ-interface of the PCS and α(β)-interface of the PMA. It is intended to convert the data frame to be sent into the format suitable to be mapped into PMA, and to recognize the received frame at the other end of the link. Since PMA and MII clocks may be unequal, the TC also provides clock rate matching. The definition of the TC sublayer is presented in 61.3.

61.1.4.3 Summary of handshaking and PHY control specification

Both 2BASE-TL and 10PASS-TS use handshake procedures defined in ITU-T G.994.1 at startup. Devices implementing both 2BASE-TL and 10PASS-TS port types may use ITU-T G.994.1 to determine a common mode of operation.

61.1.5 Application of 2BASE-TL, 10PASS-TS

61.1.5.1 Compatibility considerations

The PCS, TC, PMA, and the MDI are defined to provide compatibility among devices designed by different manufacturers. Designers are free to implement circuitry within the PCS, TC, and PMA in an application-dependent manner provided the MDI and MII specifications are met.

61.1.5.2 Incorporating the 2BASE-TL, 10PASS-TS PHY into a DTE

When the PHY is incorporated within the physical bounds of a DTE, conformance to the MII is optional, provided that the observable behavior of the resulting system is identical to that of a system with a full MII implementation. For example, an integrated PHY may incorporate an interface between PCS and MAC that is logically equivalent to the MII, but does not have the full output current drive capability called for in the MII specification.

61.1.5.3 Application and examples of PME Aggregation

The PME Aggregation Function defined in 61.2.2 allows multiple PME instances to be aggregated together to form one logical link underneath one MII (or MAC). Additionally, the control mechanism allows multi-MAC devices to be built with flexible connections between the MACs and the PMEs. Clause 45 defines a mechanism for addressing and controlling this flexible connectivity. The relationship between the flexible connectivity and the other functions within the PCS is shown in Figure 61–2.

The connection relationship between the PCS instances (including MIIs) and the PME instances is defined in two registers: PME_Available_register (see 45.2.3.27) and PME_Aggregate_register (see 45.2.3.28). The PME_Available_register controls which PMEs may be aggregated into a particular PCS (and MII). This register value is limited by the physical connectivity in the device, may be further constrained by management, and is additionally constrained as PMEs are aggregated into other PCSs (which causes their bit to be cleared to zero in the PCS instances that they are not aggregated into). The register represents the potential for connectivity into this PCS at the particular point in time. The PME_Aggregate_register indicates the actual connectivity, i.e., which PMEs are being aggregated into the particular PCS.

NOTE—The addressing of PCS instances is independent of the addressing of PME instances in order to support the flexible connectivity. Each PCS consumes one of the 32 available port addresses.

Bits corresponding to the same PME may appear in multiple PME_Available_registers but the PME_Aggregate_register for each MII shall be set such that each PME is only actively connected to at most

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one MII. A particular bit set in one PME_Aggregate_register shall exclude the same corresponding bit in all other PME_Aggregate_registers for the same MDIO connected system.

61.1.5.3.1 Addressing PCS and PME instances

The addressing of the MDIO management interface is defined in 45.1. It is assumed that the reader is familiar with the definition of this interface. The examples here assume that only three MMDs are used: PCS (MMD = 3), TC (MMD = 6), and PMA/PMD (MMD = 1). The combination of TC, PMA and PMD is shown as PME in Figure 61–3. The difference between these examples and the example shown in 45.1 is that the PCS instances are addressed independently of the PME instances. Up to 32 PCS instances and up to 32 PME instances may be addressed by one MDIO bus. These instances may make up one or more aggregateable subdomains. The connection of the MDIO bus to the MMDs is shown in Figure 61–3.

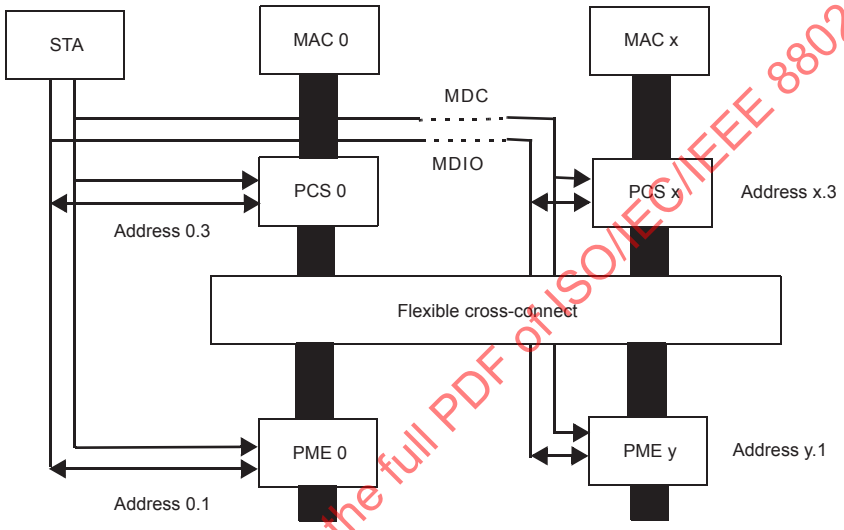

Figure 61–3—Connection of MDIO bus to MMD instances

In the example shown in Figure 61–3 there is no necessary connection between the PCS address and the PME address. The number of PCS instances may be different from the number of PME instances.

61.1.5.3.2 Indicating PME aggregation capability

The PME aggregation capability is indicated by the state of the PME_Available_register (see 45.2.3.27). An instance of this register is readable for each PAF instance *x* at register addresses *x*.3.62 and *x*.3.63. (Device address 3 of every port *x* is assigned to the PCS. The PAF specific registers reside under the *x*.3 register tree, because the PAF is part of the PCS as shown in Figure 61–2.) A bit is set in this register corresponding to the PME address for each PME which can be aggregated through the PAF in that PCS. Some examples are given that show register contents and connectivity for some popular configurations:

a) Simple two PME per MII connections, 32 PMEs are available for aggregation into 16 MIIs (PCS instances). PME_Available_register contents are shown in Table 61–1. A diagram of the connectivity is shown in Figure 61–4.
b) Pairs of 4-to-1 connections, 32 PMEs are available for aggregation into 16 MIIs (PCS instances) in a manner that allows each PME to connect to one of 2 MIIs and each MII to aggregate up to 4 PMEs. PME_Available_register contents are shown in Table 61–2. A diagram of the connectivity is shown in Figure 61–5.
c) 24-to-12 fully flexible connections, 24 PMEs are available for aggregation into 12 MIIs (PCS instances) in a manner that allows any PME to connect to any MII. PME_Available_register

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contents are shown in Table 61–3. No connectivity diagram is shown as any connection is possible between PMEs and MIIs.

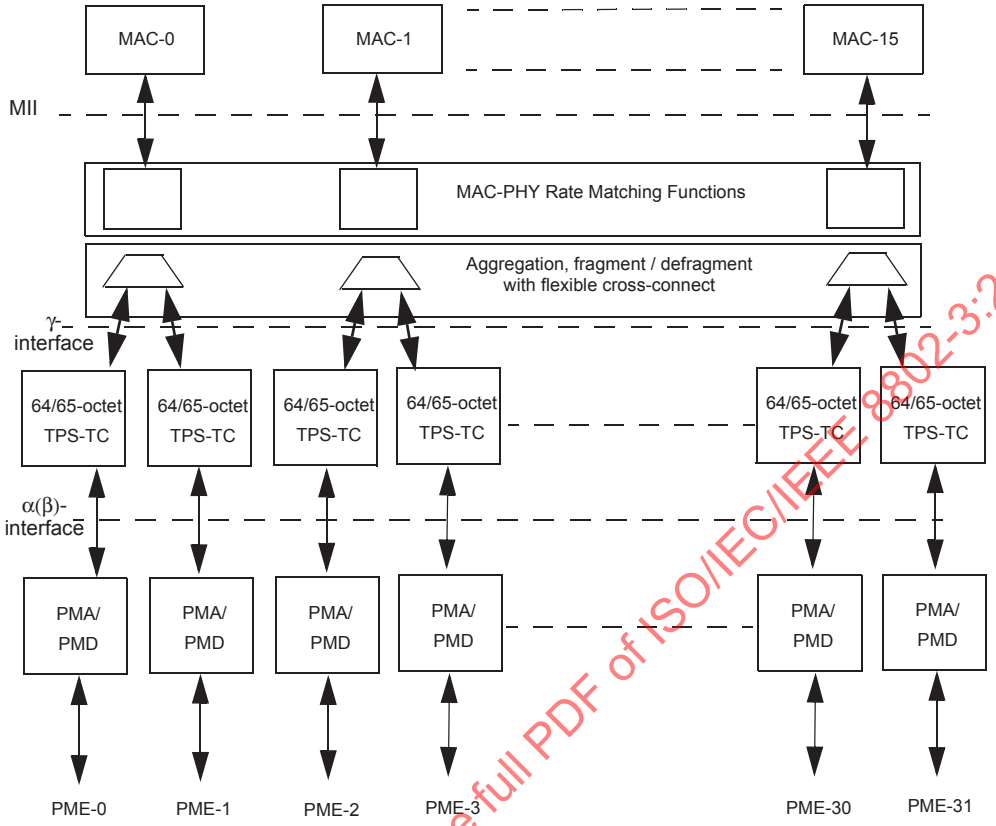

Figure 61–4—2 PME for each MII connectivity

Table 61–1—PME_Available_register contents (example a)

PME_Available_register	Contents
0.3.62 / 63	b11000000_00000000_00000000_00000000
1.3.62 / 63	b00110000_00000000_00000000_00000000
etc.	etc.
15.3.62 / 63	b00000000_00000000_00000000_00000011

Table 61–2—PME_Available_register contents (example b)[a]

PME_Available_register	Contents
0.3.62 / 63	b11110000_00000000_00000000_00000000
1.3.62 / 63	b11110000_00000000_00000000_00000000
etc.	etc.
15.3.62 / 63	b00000000_00000000_00000000_00001111

[a]A mapping in which the same PME is available for connection to several PCS instances (as shown) is only allowed at the CO-side.

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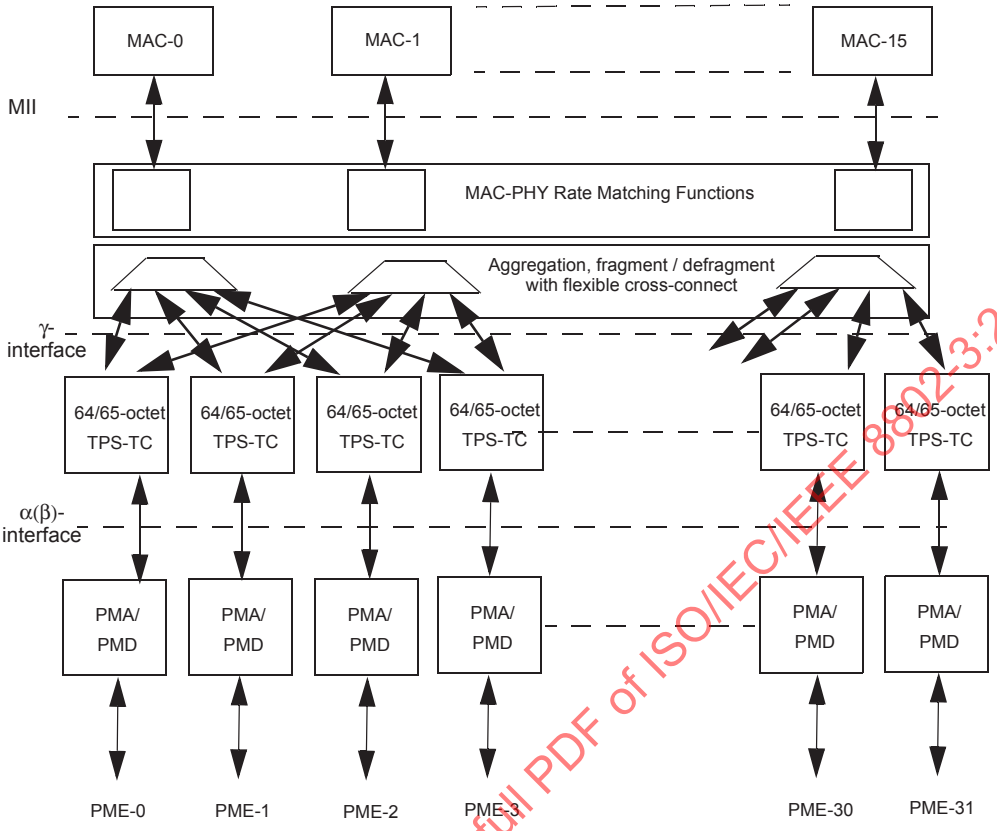

Figure 61–5—4 PME for each 2 MII connectivity

Table 61–3—PME_Available_register contents (example c)[a]

PME_Available_register	Contents
0.3.62 / 63	b11111111_11111111_11111111_00000000
1.3.62 / 63	b11111111_11111111_11111111_00000000
etc.	etc.
11.3.62/ 63	b11111111_11111111_11111111_00000000

[a]A mapping in which the same PME is available for connection to several PCS instances (as shown) is only allowed at the CO-side.

61.1.5.3.3 Setting PME aggregation connection

The PME aggregation connection is set using the PME_Aggregate_register (see 45.2.3.28). This register is writeable for each PCS instance (*x*) at register addresses *x*.3.64 and *x*.3.65. A bit is set in this register corresponding to the PME address for each PME that is to be aggregated through that PCS. Some examples are given that show register contents and connectivity for some popular configurations:

a) Simple two PME per MII connections (as shown in example a above), the first MII aggregates 2 PMEs, the second MII only connects through 1 PME, as does the sixteenth. PME_Aggregate_register contents are shown in Table 61–4.

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b) Pairs of 4-to-1 connections (as shown in example b above), the first MII aggregates 3 PMEs, the second MII only connects through 1 PME, the sixteenth MII aggregates 2 PMEs. PME_Aggregate_register contents are shown in Table 61–5.

c) 24-to-12 fully flexible connections (as shown in example c above), the first MII aggregates 5 PMEs, the second MII only connects through the 24th PME, the eleventh MII is not used, twelfth MII aggregates 2 PMEs. PME_Aggregate_register contents are shown in Table 61–6.

Table 61–4—PME_Aggregate_register contents (example a)

PME_Aggregate_register	Contents
0.3.64 / 65	b11000000_00000000_00000000_00000000
1.3.64 / 65[a]	b00010000_00000000_00000000_00000000
etc.	etc.
15.3.64 / 65	b00000000_00000000_00000000_00000010

[a]The PME Aggregation functions have to be performed when PAF_enable is set, even if only 1 bit is set in the PME_Aggregate_register.

Table 61–5—PME_Aggregate_register contents (example b)

PME_Aggregate_register	Contents
0.3.64 / 65	b11100000_00000000_00000000_00000000
1.3.64 / 65[a]	b00010000_00000000_00000000_00000000
etc.	etc.
15.3.64 / 65	b00000000_00000000_00000000_00000110

[a]The PME Aggregation functions have to be performed when PAF_enable is set, even if only 1 bit is set in the PME_Aggregate_register.

Table 61–6—PME_Aggregate_register contents (example c)

PME_Aggregate_register	Contents
0.3.64 / 65	b11111000_00000000_00000000_00000000
1.3.64 / 65[a]	b00000000_00000000_00000001_00000000
etc.	etc.
10.3.64 / 65	b00000000_00000000_00000000_00000000
11.3.64 / 65	b00000000_00000000_00000110_00000000

[a]The PME Aggregation functions have to be performed when PAF_enable is set, even if only 1 bit is set in the PME_Aggregate_register.

61.1.5.4 Support for handshaking

It is the goal of the ITU-T that all specifications for digital transceivers for use on public telephone network copper subscriber lines use ITU-T G.994.1 for startup. ITU-T G.994.1 procedures allow for a common startup mechanism for identification of available features, exchange of capabilities and configuration information, and selection of operating mode. As the two loop endpoints are usually separated by a large distance (e.g., in separate buildings) and often owned and installed by different entities, ITU-T G.994.1 also aids in diagnosing interoperability problems. ITU-T G.994.1 codespaces have been assigned by ITU-T to ATIS T1, ETSI, and IEEE 802.3 in support of this goal.

The description of how ITU-T G.994.1 procedures are used for Ethernet in the First Mile handshaking and PHY control are contained in 61.4.

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61.2 PCS functional specifications

61.2.1 MAC-PHY Rate Matching functional specifications

61.2.1.1 MAC-PHY Rate Matching functions

The PHY shall use CRS to match the MAC's faster rate of data transmission to the PHY's slower rate.

Upon receipt of a MAC frame on the MII, the PHY shall discard the Preamble and SFD fields, and transmit the resulting data frame across the physical link.

The PHY shall prepend the Preamble and the SFD fields to a received frame before sending it to the MAC.

The PHY shall support a mode of operation where it does not send data to the MAC while the MAC is transmitting (see MII receive during transmit register, defined in 45.2.3.26).

If the PAF is disabled or not present, transmit frames shall not be forwarded to the TC sublayer unless TC_link_state is true for the whole frame. If the PAF is enabled, transmit fragments shall not be forwarded from the PAF to a TC sublayer unless the TC_link_state value of that TC sublayer instance is true for the whole fragment.

NOTE—This implies that in the absence of an active PAF, frames being transmitted over the MII when TC_link_state becomes true are never forwarded to the TC sublayer. A frame being transmitted over the MII when TC_link_state becomes false is aborted.

61.2.1.2 MAC-PHY Rate Matching functional interfaces

61.2.1.2.1 MAC-PHY Rate Matching – MII signals

MII signals are defined in 22.2.2 and listed in Table 23–1 in 23.2.2.1.

COL shall be forced to logic zero by the PCS.

CRS behaves as defined in 61.2.1.3.2.

61.2.1.2.2 MAC-PHY Rate Matching–Management entity signals

See 61.2.3.

61.2.1.3 MAC-PHY Rate Matching state diagrams

61.2.1.3.1 MAC-PHY Rate Matching state diagram constants

No constants are defined for the MAC-PHY rate matching state diagrams.

61.2.1.3.2 MAC-PHY Rate Matching state diagram variables

CRS
: CRS signal of the MII as specified in Clause 22. It is asserted when either of crs_tx or crs_rx are true: CRS ⇐ crs_tx + crs_rx

crs_and_tx_en_infer_col
: True if a reduced-pin MAC-PHY interface is present that infers a collision when TX_EN and CRS are both true simultaneously.

crs_rx
: Asserted by the MAC-PHY rate matching receive state diagram to control CRS

crs_tx
: Asserted by the MAC-PHY rate matching transmit state diagram to control CRS

power_on
: 'power_on' is true while the device is powering up. It becomes false once the device has

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reached full power. Values:
FALSE; The device is completely powered (default).
TRUE; The device has not been completely powered.

Reset
True when the PCS is reset via control register bit 3.0.15.

RX_DV
RX_DV signal of the MII as specified in Clause 22

rx_frame_available
Set when the PHY's receive FIFO contains one or more complete frames

transferFrameCompleted
Variable of type Boolean
TRUE if the transmission of the received frame over the MII has been completed,
FALSE otherwise.
The variable returns to the default state (FALSE) upon entry into any state.

tx_buffer_available
Set when the PHY's transmit FIFO has space to receive a maximum length packet from the MAC

TX_EN
TX_EN signal of the MII as specified in Clause 22

tx_rx_simultaneously
False if the MAC is configured in half duplex mode to support deference and it is not capable of transmitting and receiving simultaneously in this mode.

61.2.1.3.3 MAC-PHY Rate Matching state diagram timers

ipg_timer
Timer used to generate a gap between receive packets across the MII.
Duration: 960 ns, tolerance ±100 ppm.

rate_matching_timer
Timer used in rate matching state diagram
Duration: 1120 ns, tolerance ±100 ppm.

The rate_matching_timer operates in a manner consistent with 14.2.3.2. The timer is restarted on entry to the WAIT_FOR_TIMER_DONE state with the action: 'Start rate_matching_timer'. It is then tested in the exit condition with the expression "rate_matching_timer_done".

The duration is set to 1120 ns to allow 960 ns for the inter frame gap plus 160 ns for the MAC to recognize CRS. 160 ns is equivalent to 16 bit times and is consistent with the assumptions about MAC performance listed in Table 21–2 in 21.7.

61.2.1.3.4 MAC-PHY Rate Matching state diagram functions

transferFrame()
This function transmits a packet to the MAC across the MII, according to the MII protocol as described in 22.2. This function generates RX_DV to delimit the frame in accordance with 22.2.2.6. Upon completion of frame transfer to the MAC, this function sets the variable transferFrameCompleted to TRUE.

61.2.1.3.5 MAC-PHY Rate Matching state diagrams

The state diagrams for the MAC-PHY Rate Matching functions are shown in Figure 61–6, Figure 61–7, and Figure 61–8.

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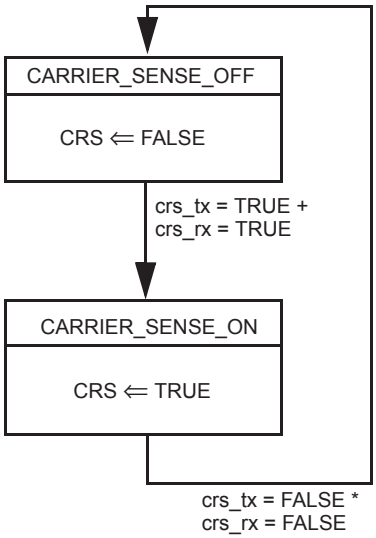

Figure 61–6—Carrier Sense state diagram

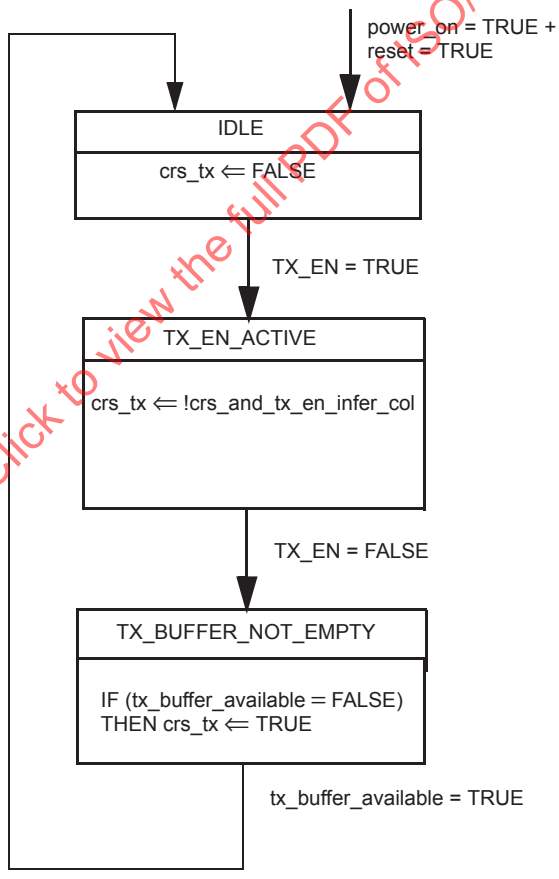

Figure 61–7—MAC-PHY rate matching transmit state diagram

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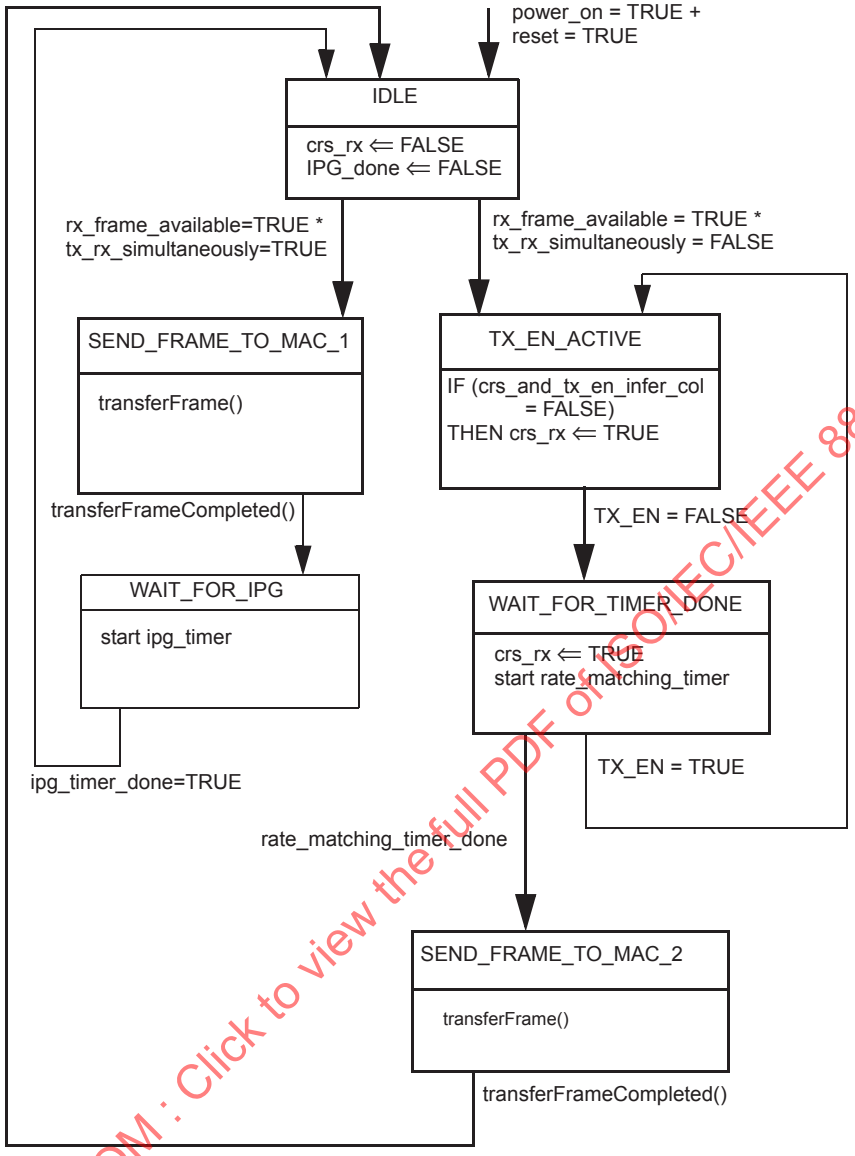

Figure 61–8—MAC-PHY rate matching receive state diagram

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61.2.2 PME Aggregation functional specifications

This subclause defines an optional PME Aggregation Function (PAF) for use with Ethernet MACs in EFM copper PHYs. PME Aggregation allows one or more PMA/PMDs to be combined together to form a single logical Ethernet link.

The PAF is located between the MAC-PHY Rate Matching function and the TC sublayer as shown in Figure 61–2. The PAF interfaces with the TC sublayer instances across the γ-interface. The PAF interfaces to the MAC-PHY Rate Matching function using an abstract interface whose physical realization is left to the implementer, provided the requirements of this standard are met.

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The PME Aggregation function has the following characteristics:

a) Supports aggregation of up to 32 PMA/PMDs
b) Supports individual PMA/PMDs having different data rates
c) Ensures low packet latency and preserves packet sequence
d) Scalable and resilient to PME failure
e) Independent of type of EFM copper PHY
f) Allows vendor discretionary algorithms for fragmentation

61.2.2.1 PAF Enable and Bypass

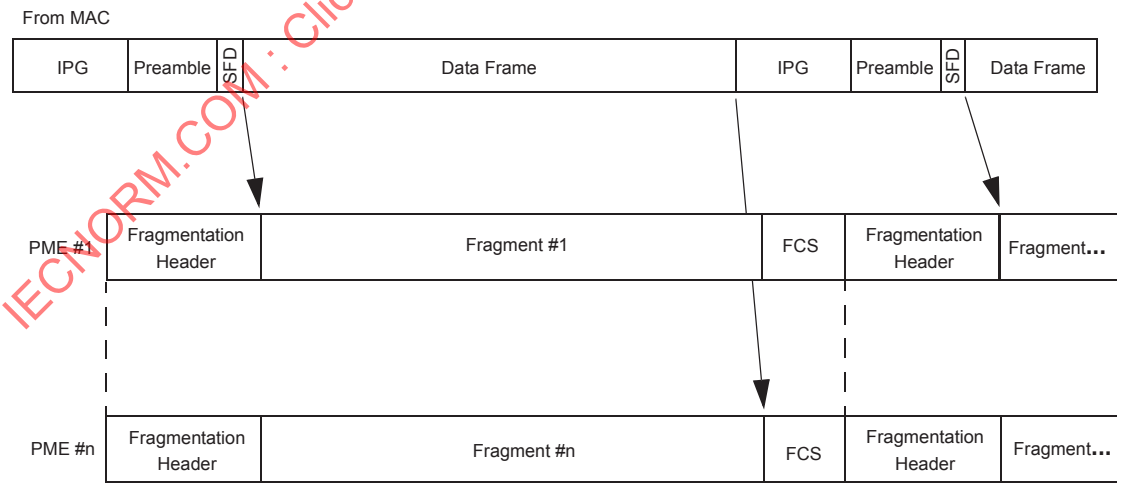
For systems that do not have the ability to aggregate loops PAF_available will not be asserted. Additionally, a system may have PAF_available asserted but PAF_enable will be deasserted to indicate that aggregation is not activated.

In both of these cases, the entire data frame is passed across the γ-interface to the TC sublayer without any fragmentation and without fragmentation header. On the receive end, entire data frames are transferred from the γ-interface to the MAC-PHY rate matching function without any reference to the PAF error detecting rules (see 61.2.2.7). If an error has been detected by the FCS in the TC then the MAC-PHY rate matching function shall assert RX_ER during at least one octet of the frame across the MII.

Systems that have the ability to aggregate but are not enabled for aggregation will have the connectivity between the PCS and one PME set either by default, by local management (for CO-subtype devices) or by remote management (for CPE-subtype devices). This will define which γ-interface is used for the transfer of non-fragmented frames. Refer to 61.2.2.8.3 for the function of PAF_available and PAF_enable and Clause 45 for access to these registers.

61.2.2.2 PME Aggregation functions

The PME Aggregation functions provide a fragmentation procedure at the transmitter and a reassembly procedure at the receiver. The fragmentation and reassembly procedures take a data frame and partition it into one or more fragments as shown in Figure 61–9. Each fragment is given a fragmentation header and transmitted over a specific TC sublayer instance. A Frame Check Sequence, known as the TC-CRC, is added to each fragment by the TC sublayer. The fragmentation header has the format shown in Figure 61–10. Short data frames can be transported over a single fragment, and consequently both StartOfPacket and EndOfPacket can be set to '1' simultaneously.



NOTE—This is one example of how a frame may be fragmented across multiple PMEs.

Figure 61–9—Data frame fragmentation

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SequenceNumber (14 bits)	StartOfPacket (1 bit)	EndOfPacket (1 bit)	Fragment Data

Figure 61–10—Fragment format

61.2.2.3 PME Aggregation Transmit function

The PME Aggregation transmit functions uses the following algorithm:

a) Select an active PME (i.e., one with TC_link_state asserted, see 61.3.1) for the next transmission.
b) Select the number of octets to transmit on that PME (shall not be less than minFragmentSize nor greater than maxFragmentSize, see 61.2.2.6).
c) Increment by one (modulo 2^{14}) and set fragment sequence number in the Fragmentation Header. There is a single sequence number stream for each aggregation, not one per PME. It is this sequence number stream that the receiver uses for fragment reassembly.
d) Set the start-of-packet and end-of-packet bits in the Fragmentation Header as appropriate.
e) Transmit fragment to the TC sublayer.

It is important to note that the selection of the next PME to use in transmission [step a)] and the number of octets to transmit [step b)] is implementation dependent. However, implementations shall follow the restrictions as outlined in 61.2.2.6.

61.2.2.4 PME Aggregation Receive function

The PME aggregation receive function requires per-PME queues as well as a per-MAC fragment buffer for fragment reassembly. The algorithm assumes only "good" fragments are placed on the per-PME receive queues ("bad" fragments are discarded according to the rules in 61.2.2.7).

The sequence number rolls over after it reaches the maximum value, thus all sequence number comparisons shall use "split horizon" calculations. Split horizon calculations are defined for comparisons that are valid for numbers that roll over after reaching the maximum value. Generically, "x is less than y" is defined as $x < y \le x + (\text{maxSequenceNumber}+1)/2$.

61.2.2.4.1 Expected sequence number

During initial start-up and in the event of certain errors, the receive algorithm has to determine which sequence number is expected next (expectedFragmentSequenceNumber). When the link state is changed to UP, the expected sequence number is unknown and no errors in fragment sequencing (see 61.2.2.7.2) shall be recorded.

61.2.2.4.2 PME Aggregation Receive function state diagram variables

The following variables are used in the PME Aggregation Receive function state diagram.

allQueuesNonEmpty
: variable of type Boolean that indicates whether any active queue is currently empty.
TRUE if none of the active queues is currently empty
FALSE if at least one active queue is currently empty

expectedFragmentSequenceNumber
: the sequence number expected in the receive process that would not result in a fragment error, initialized to the smallest sequence number of fragments at the head of per-PME queues when either all active queues are non-empty or at least one queue has been non-empty for maxDifferentialDelay bit times at the bit rate of the PMD associated with that queue

frameLengthOverflow
: variable of type Boolean, indicating that the reassembly buffer is overflowing due to a received frame that is too long, as described in 61.2.2.7.3.

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TRUE if the overflow condition exists
FALSE during normal operation

missingStartOfPacket
: variable of type Boolean, indicating that a fragment was received with the StartOfPacket bit deasserted while the packet assembly function was between frames (i.e., waiting for a Start of Packet).

nextFragmentSequenceNumber
: smallest sequence number of fragments at the head of per-PME queues

noFragmentProcessed_Timer
: variable of type Boolean that indicates whether at least one active queue has been non-empty for maxDifferentialDelay bit times at the bit rate of the PMD associated with that queue. Each fragment processed on any queue restarts all per-queue timers.
TRUE if a timeout of maxDifferentialDelay bit times has expired
FALSE if the timeout of maxDifferentialDelay bit times has not yet expired

oneQueueNonEmpty_Timer
: variable of type Boolean that indicates whether at least one active queue has been non-empty for at least maxDifferentialDelay bit times.
TRUE if at least one active queue has been non-empty for at least maxDifferentialDelay bit times
FALSE otherwise

smallestFragmentSequenceNumber
: smallest sequence number of fragments at the head of per-PME queues

unexpectedEndOfPacket
: variable of type Boolean, indicating that a fragment was received with the EndOfPacket bit asserted and the StartofPacket bit deasserted while the packet assembly function was between frames (i.e., waiting for a Start of Packet)

unexpectedStartOfPacket
: variable of type Boolean, indicating that a fragment is received with the StartOfPacket bit asserted while the packet assembly function was mid-frame (i.e., waiting for an End of Packet)

The following functions are used in the PME Aggregation Receive function state diagram.

errorDetection()
: function comprising the process described in 61.2.2.7.2

fragmentError()
: function comprising the process described in 61.2.2.7.3

61.2.2.4.3 PME Aggregation Receive function state diagram

The receive function executes the algorithm as shown in Figure 61–11. The initial state of the state diagram is INITIALIZING. This state is entered when at least one TC_link_state is asserted for the first time after system power-on, and each time when at least one TC_link_state is asserted after all having been deasserted for any reason.

61.2.2.4.4 PME Aggregation Receive function state diagram description

Aggregation receive algorithm is as follows:

a) Determine the nextFragmentSequenceNumber via the algorithm in 61.2.2.4.1.
b) If the nextFragmentSequenceNumber is equal to the expectedFragmentSequenceNumber, process that fragment and continue to step c). If (nextFragmentSequenceNumber is less than expectedFragmentSequenceNumber) or (all the active PME queues are non-empty and nextFragmentSequenceNumber ≠ expectedFragmentSequenceNumber) or (any PME queue has been non-empty for maxDifferentialDelay bit times without any fragment being processed) follow the fragment sequence error handling rules described in 61.2.2.7.2 before returning to normal fragment processing.

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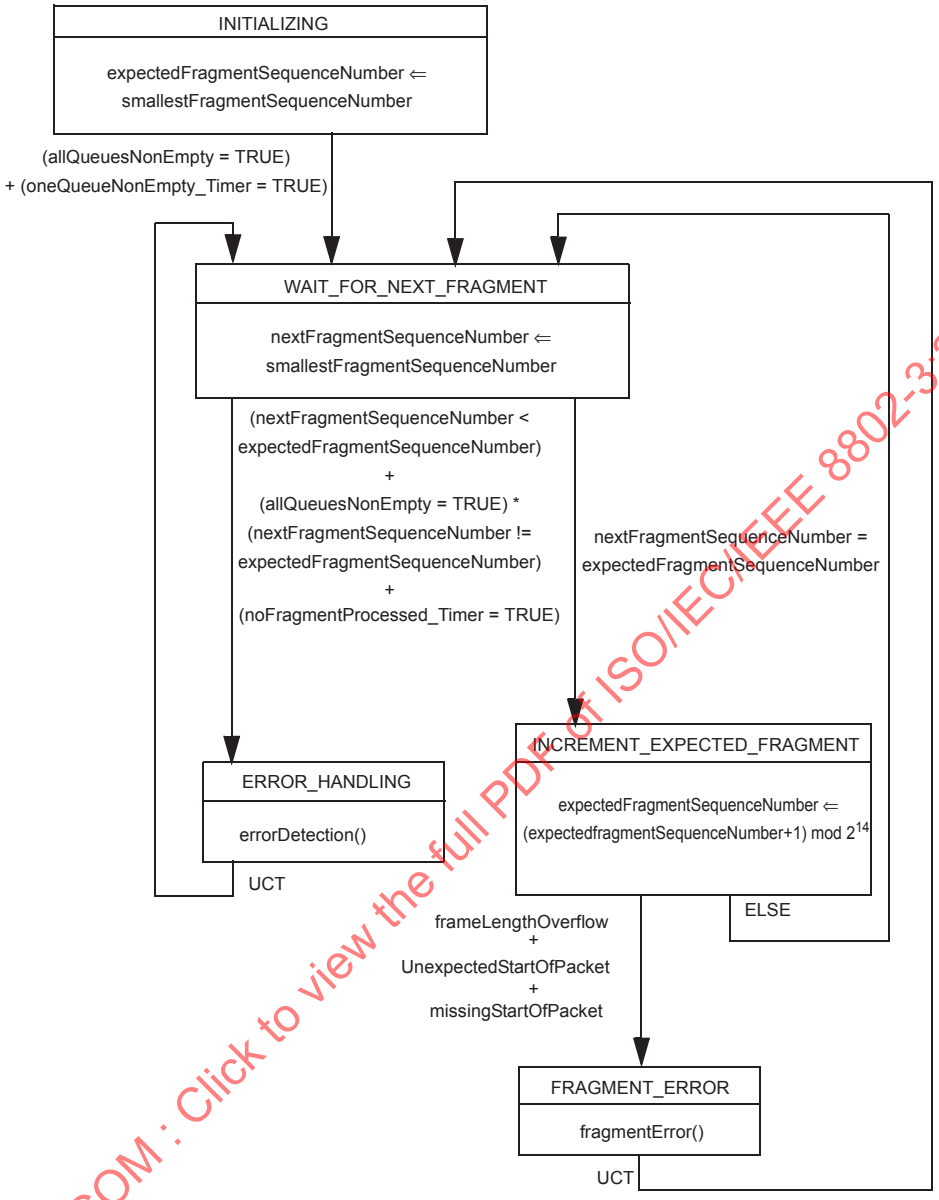

Figure 61–11—Aggregation receive function

c) Accept the fragment into the fragment buffer. If (accepting the fragment into the fragment buffer causes a frame length overflow) or (the fragment is an unexpected start of packet) or (the fragment is an unexpected end of packet) or (the fragment has the StartOfPacket bit deasserted when the start of a new packet is expected) then follow the error handling procedures described in 61.2.2.7.3. Else if that fragment is an end-of-packet, pass the packet to the MAC-PHY Rate Matching layer.
d) Increment (modulo 2^{14}) the expectedFragmentSequenceNumber.
e) Repeat processing.

61.2.2.5 PME Aggregation restrictions

In order to guarantee correct receiver operation, a transmitter must ensure that pairs in an aggregate group obey certain restrictions.

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NOTE 1—These restrictions ensure that buffer sizes for receivers of 2^{14} bits per PME are sufficient.

One factor is the differential latency between multiple PMEs in an aggregated group. Differential latency measures the variation in the time required to transmit across different PMEs. To normalize the latency measurement for high and low speed links it is measured in bit times. A differential latency between two PMEs is defined as the number of bits, N, that can be sent across the fast link, in the time that it takes one maxFragmentSize fragment to be sent across the slow link. Large differential latencies generate greater variance in bit delivery times across aggregated PMEs, which in turn require large sequence number ranges. The PMD control of aggregated links controls the maximum latency difference between any two aggregated links. This is achieved by configuring the bit rate, error correction and interleaving functions in the PMA/PMD of each link. The burst noise protection offered by the error correction and interleaving[10] functions is directly proportional to the latency, therefore it is logical that multiple aggregated links in the same environment should be optimized to have similar latencies. Differences in electrical length will not contribute significantly to the differential latency; no additional per-PME buffer size is required for this variation.

NOTE 2—The value for differential latency for two identical links will be 4096 bit times because the definition includes the length of a maximum size fragment.

The speed ratio of the links also restricts what PMEs can be aggregated together. The speed ratio is defined as the ratio of the bit rate of the faster link divided by the bit rate of the slower link.

The restrictions that govern which PMEs can be aggregated are as follows:

a) The differential latency between any two PMEs in an aggregated group shall be no more than maxDifferentialDelay.
b) The highest ratio of speeds between any two aggregated links shall be maxSpeedRatio. A speed ratio of 4 may only be used if the latency is controlled to meet the restriction.

Table 61–7 specifies the values for constants maxDifferentialDelay and maxSpeedRatio.

Table 61–7—PME Aggregation constants

Constant name	Value
maxDifferentialDelay	15 000 bit times
maxSpeedRatio	4

61.2.2.6 PME Aggregation transmit function restrictions

There are factors that limit the freedom of the transmission algorithm specified in 61.2.2.3.

A first factor is the size of the fragments being transmitted across the PMEs. Very small fragments require larger sequence number ranges as there can be more fragments within the same number of bit times.

Another restriction on the size of the fragments, is that fragments shall be a multiple of 4 octets in size when possible.

The restrictions for the transmission algorithm in 61.2.2.3 are:

a) Fragments shall not be less than minFragmentSize not including PAF header.

[10]Interleaving is the relevant issue here, since it affects latency. While 2BASE-TL does not have block error correction, it does use trellis coding, which is sometimes considered forward error correction.

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b) Fragments shall not be more than maxFragmentSize not including PAF header.
c) The fragment size, not including PAF header, shall be a multiple of 4 octets except for the last fragment of a data frame.

NOTE—A fragment size of maxFragmentSize may only be used if the latency is controlled to meet the restriction a) in 61.2.2.5.

These restrictions allow the use of a 14-bit sequence number space. As a consequence, the maximum sequence number is $2^{14} - 1$ (maxSequenceNumber).

Table 61–8 specifies the values for constants maxFragmentSize and minFragmentSize.

Table 61–8—Fragment size constants

Constant name	Value
maxFragmentSize	512 octets
minFragmentSize	64 octets

61.2.2.7 Error-detecting rules

There are three classes of error detected by the PAF: Errors during fragment reception; Errors in fragment sequencing; and Errors during packet reassembly. In the case of an error detected by the PAF, it sends the frame or part of frame to the MAC with RX_ER asserted. When the PAF is unable to reconstruct or partially reconstruct a frame due to such errors, it sends a garbage frame up to the MAC, in order to allow higher-layer event counters to register the error. The garbage frame shall consist of 64 octets of 00 (including CRC). Preamble and SFD are prepended before the frame is sent to the MII according to 61.2.1.1.

The rules described in this subclause are applied by the functions errorDetection() and fragmentError() referenced in Figure 61–11.

61.2.2.7.1 Errors during fragment reception

The receive TC function passes all decapsulated fragments to the PAF across the γ-interface. If the TC detects an error in the encapsulation, it asserts Rx_Err on the γ-interface. If the TC detects an error in the TC-CRC, it asserts Rx_Err on the γ-interface. Asserting Rx_Err during fragment reception invalidates the entire fragment.

For each PMA α(β)-interface, the per-PMA buffering mechanism shall discard the fragment if any of the following conditions occur:

a) Rx_Err is asserted during the reception of the fragment across the γ-interface.
b) The fragment is too small — less than minFragmentSize as defined in 61.2.2.6.
c) The fragment is too large — more than maxFragmentSize as defined in 61.2.2.6.
d) The fragment would cause the per-PMA received buffer to overflow.

The PAF shall then assert one of the following per-PMA error flags as appropriate:

— TC_PAF_RxErrorReceived
— TC_PAF_FragmentTooSmall
— TC_PAF_FragmentTooLarge
— TC_PAF_Overflow

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61.2.2.7.2 Errors in fragment sequencing

If nextFragmentSequenceNumber is outside the range (expectedFragmentSequenceNumber through expectedFragmentSequenceNumber + (maxSequenceNumber+1)/2) then assert PAF_BadFragmentReceived. Discard the fragment, do not increment ExpectedFragmentSequenceNumber.

If all active PMA buffers are non empty and nextFragmentSequenceNumber is greater than expectedFragmentSequenceNumber then assert PAF_LostFragment, set expectedFragmentSequenceNumber equal to nextFragmentSequenceNumber.

If any PMA buffer is non empty for maxDifferentialDelay bit times (for that PMA/PMD) and no fragment is transferred then assert PAF_LostFragment, set expectedFragmentSequenceNumber equal to nextFragmentSequenceNumber.

Having detected one of the above fragment sequencing errors, the packet assembly function shall act as follows:

— If the packet assembly function was mid-frame (i.e., waiting for an End of Packet), the first part of the frame shall be transferred across the MII, then assert RX_ER signal on the MII, abort frame transfer and flush PMA buffers until the next Start of Packet is received.
— If the packet assembly function was between frames (i.e., waiting for a Start of Packet), assert RX_ER signal on the MII and send a garbage frame as defined in 61.2.2.7 to the MAC.

61.2.2.7.3 Errors in packet reassembly

If a fragment is received with the StartofPacket bit deasserted while the packet assembly function was between frames (i.e., waiting for a Start of Packet), discard the offending fragment, assert RX_ER signal on the MII and send a garbage frame as defined in 61.2.2.7 to the MAC. Assert PAF_LostStart.

If a fragment is received with the StartOfPacket bit asserted while the packet assembly function was mid-frame (i.e., waiting for an End of Packet), the first part of the frame shall be transferred across the MII, then assert RX_ER signal on the MII, abort frame transfer and flush the PMA buffers, starting the next frame with the Start of Packet fragment just received. Assert PAF_LostEnd.

If a fragment is received while the packet assembly function was mid-frame (i.e., waiting for an End of Packet) and would cause the frame size to exceed the maximum supported frame size (see 4.2.4.2.1) then the first part of the frame, excluding the error causing fragment, shall be transferred across the MII, then assert RX_ER signal on the MII, abort frame transfer and flush PMA buffers until the next Start of Packet is received. Assert PAF_LostEnd.

61.2.2.8 PME aggregation functional interfaces

The PAF interfaces with the TC sublayer instances across the γ-interface. The PAF interfaces to the MAC-PHY Rate Matching function using an abstract interface whose physical realization is left to the implementer, provided the requirements of this standard are met.

61.2.2.8.1 PME aggregation–γ-interface signals

The PAF interfaces with the PMA/PMDs across the γ-interface. The γ-interface specification is defined in 61.3.1. This subclause specifies the data, synchronization and control signals that are transmitted between the TC sublayer and the PAF.

61.2.2.8.2 PME aggregation–management entity signals

The management entity signals pertaining to PME aggregation are specified in 61.2.3.

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61.2.2.8.3 PME aggregation register functions

If an MDIO interface is provided (see Clause 22 and Clause 45), PME aggregation registers are accessed via that interface. If not, it is recommended that an equivalent access be provided.

Clause 45 defines one bit each in the EFM 10P/2B capability register and the 10P/2B PCS control register to control the PAF function (see 45.2.3.25 and 45.2.3.26 respectively). PAF_available is used to indicate that the system has the capability to aggregate PMEs, PAF_enable is used to control whether this ability is enabled or not. In all cases, the PAF_available bit is read-only; the PAF_enable bit is read-only when the PAF_available bit is not asserted.

For CO-subtype devices, both the PAF_available and the PAF_enable bits are only accessible locally, the PAF_enable bit is writeable.

For CPE-subtype devices, both the PAF_available and the PAF_enable bits are locally read only and remotely readable. Additionally, the PAF_enable bit is remotely writeable.

Clause 45 defines access to two registers which relate to the PME aggregation function: the PME_Available_register (see 45.2.3.27) and the PME_Aggregate_register (see 45.2.3.28). Additionally the remote_discovery_register and Aggregation_link_state_register shall be implemented.

NOTE—The remote_discovery_register is a variable which is defined for CPE-subtypes only. It is used during the PME aggregation discovery process. The Aggregation_link_state_register is a variable with significance for the PCS only. These variables have no associated management interface registers.

The PME_Available_register is read-only for CO-subtype and may be writeable for CPE-subtype (in order to restrict CPE-subtype connection capability according to 45.2.3.27). It indicates whether an aggregateable link is possible between this PCS and multiple PMDs. For a device that does not support aggregation of multiple PMEs, a single bit of this register shall be set and all other bits clear. The position of bits indicating aggregateable PME links correspond to the PMA/PMD sub-address defined in Clause 45.

For CPE-subtype devices, the PME_Available_register may optionally be writeable by the local management entity. The reset state of the register reflects the capabilities of the device. The management entity (through Clause 45 access) may clear bits which are set, in order to limit the mapping between MII and PME for PME aggregation. For CPE-subtype devices, PMD links shall not be enabled (such that it shall not respond to or initiate any G.994.1 handshaking sessions, on any of its PMEs) until the PME_Available register has been set to limit the connectivity such that each PME maps to at most one MII (see 45.2.3.27). This condition is necessary so that remote commands from the network-end which affect PCS registers have a defined target. PMDs that are not associated to any PCS shall not respond to or initiate any G.994.1 handshaking signals. Multiple PMEs per MII are allowed.

The PME_Aggregate_register is defined in Clause 45. For CO-subtype devices, access to this register is through Clause 45 register read and write mechanisms. For CPE-subtype devices the register may be read locally through Clause 45, and reads and writes shall be allowed from remote devices via the remote access signals passed across the γ-interface from the PMA (see 61.3.1). The operation of the PME_Aggregate_register for CPE-subtype devices is defined as follows:

a) If the remote_discovery_register is clear then the PME_Aggregate_register shall be cleared.
b) If write_remote_Aggregation_reg is asserted, the contents of remote_write_data bit zero is written to PME_Aggregate_register in the bit location corresponding to the PMA/PMD from which the request was received. Acknowledge_read_write is asserted for one octet clock cycle.
c) If read_remote_Aggregation_reg is asserted, the contents of PME_Aggregate_register are placed onto remote_read_data_bus, bits 31 through 0. Unsupported bits are written as zero if the full width of PME_Aggregate_register is not supported. Acknowledge_read_write is asserted for one octet clock cycle.

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61.2.2.8.4 PME aggregation discovery register functions

The remote_discovery_register shall be implemented for CPE-subtype devices. The remote_discovery_register shall support atomic write operations and reads from remote devices via the remote access signals passed across the γ-interface from the PMA (see 61.3.1). The operation of the remote_discovery_register for CPE-subtype devices is defined as follows:

a) If read_remote_discovery_reg is asserted, which corresponds to a "Get" command as described in 61.4.7.1, the contents of remote_discovery_register are placed onto remote_read_data_bus. Acknowledge_read_write is asserted for one octet clock cycle[11].

b) If write_remote_discovery_reg is asserted, which corresponds to a "Set if Clear" command as described in 61.4.7.1, the action depends on the contents of remote_discovery_register. If the remote_discovery_register is currently clear (no bits asserted), the contents of the remote_write_data bus are placed into the remote_discovery_register. The new contents of remote_discovery_register are placed on the remote_read_data_bus. Acknowledge_read_write is asserted for one octet clock cycle. Else if the remote_discovery_register is not currently clear (any bit asserted), no data is written. The old contents of remote_discovery_register are placed on the remote_read_data_bus. NAcknowledge_read_write is asserted for one octet clock cycle. If multiple write_remote_discovery_reg signals are asserted (from multiple γ-interfaces) they shall be acted upon serially.

c) If clear_remote_discovery_reg is asserted, which corresponds to a "Clear if Same" command as described in 61.4.7.1, the action depends on the contents of remote_discovery_register. If the contents of the remote_write_data bus match that of the remote_discovery_register, the remote_discovery_register is cleared, the PME_Aggregate_register is cleared, the new contents of remote_discovery_register are placed on the remote_read_data_bus, and Acknowledge_read_write is asserted for one octet clock cycle. If the contents of the remote_write_data bus do not match that of the remote_discovery_register, the remote_discovery_register is unchanged; its contents are placed on the remote_read_data_bus; and NAcknowledge_read_write is asserted for one octet clock cycle.

d) If the logical AND of the Aggregation_link_state_register and the PME_Aggregate_register is clear then a timeout counter shall be started. If this condition continues for 30 seconds (the timeout period) then the remote_discovery_register shall be cleared.

A single device may be implemented which has multiple MIIs and (therefore) multiple PCS instances. There shall be one remote_discovery_register per PCS instance. The PME_Available_register shall be set prior to the enabling of links so that each PMA/PMD is linked to only one PCS. Access to the remote_discovery_register (read or write) shall be restricted to PMA/PMD instances for which the corresponding PME_Available_register bit is asserted.

The Aggregation_link_state_register is a pseudo-register corresponding to the TC_link_state bits from each γ-interface in the appropriate bit positions according to the PMA/PMD from which the signal is received. Bits corresponding to unsupported aggregation connections are zero.

The remote access mechanisms for the PME aggregation registers are defined in 61.4.7.

61.2.3 PCS sublayer: Management entity signals

The management interface has pervasive connections to all functions. Operation of the management control lines MDC and MDIO is specified in Clause 22 and Clause 45, and requirements for managed objects inside the PCS and PMA are specified in Clause 30.

The following MAC-PHY Rate Matching function signals are mapped to Clause 45 registers:

[11] If the CPE device fails to respond, NAcknowledge_read_write is asserted with remote_read_data_bus set to 000000000000_{16}.

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tx_rx_simultaneously
: this signal is asserted by the management entity to indicate that the MAC which is connected to the PHY is capable of receiving and transmitting simultaneously while in half-duplex mode. The corresponding register ("MII receive during transmit") is defined in 45.2.3.26.

crs_and_tx_en_infer_col
: this signal is asserted by the management entity to indicate that the MAC uses simultaneous detection of TX_EN and CRS to infer a collision. This signal is used in the rate matching state diagrams (Figure 61–7 and Figure 61–8). The corresponding register ("TX_EN and CRS infer a collision") is defined in 45.2.3.26.

The following PAF signals are mapped to Clause 45 registers or cause Clause 45 counters to increment:

PAF_available
: this signal indicates to the management whether the PAF function is available for use. The corresponding register is defined in 45.2.3.25.1.

PAF_enable
: this signal is asserted by the management entity to indicate that the PAF function is enabled. The corresponding register is defined in 45.2.3.26.3.

TC_PAF_RxErrorReceived
: (for each PMA, γ-interface) this signal is asserted to indicate that a fragment has been received across the γ-interface with Rx_Err asserted. The errored fragment has been discarded. The corresponding register is defined in 45.2.3.29.

TC_PAF_FragmentTooSmall
: (for each PMA, γ-interface) this signal is asserted to indicate that a fragment has been received across the γ-interface that was smaller than the minFragmentSize defined. The errored fragment has been discarded. The corresponding register is defined in 45.2.3.30.

TC_PAF_FragmentTooLarge
: (for each PMA, γ-interface) this signal is asserted to indicate that a fragment has been received across the γ-interface that was larger than the maxFragmentSize defined. The errored fragment has been discarded. The corresponding register is defined in 45.2.3.31.

TC_PAF_Overflow
: (for each PMA, γ-interface) this signal is asserted to indicate that a fragment has been received across the γ-interface that would have caused the receive buffer to overflow. The errored fragment has been discarded. The corresponding register is defined in 45.2.3.32.

PAF_BadFragmentReceived
: this signal is asserted to indicate that a fragment has been received that does not fit into the sequence expected by the frame assembly function. The errored fragment has been discarded and the frame buffer flushed to the next valid frame start. The corresponding register is defined in 45.2.3.33.

PAF_LostFragment
: this signal is asserted to indicate that a fragment (or fragments) expected according to sequence has not been received by the frame assembly function. The missing fragment (or fragments) has been skipped and the frame buffer flushed to the next valid frame start. The corresponding register is defined in 45.2.3.34.

PAF_LostStart
: this signal is asserted to indicate that the packet reassembly function did not receive a StartOf Packet indicator in the appropriate sequence. The corresponding register is defined in 45.2.3.35.

PAF_LostEnd
: this signal is asserted to indicate that the packet reassembly function did not receive an EndOfPacket indicator in the appropriate sequence. The corresponding register is defined in 45.2.3.36.

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PCS_link_state
: this signal is asserted to indicate that at least one TC_link_state in the assigned aggregation group is up.

Additionally, the following PAF register is mapped to a Clause 45 register:

remote_discovery_register
: this register is implemented in CPE-subtype devices. It is written or read by the PME via the γ-interface. The PME relays this information to and from the associated CO-subtype device via the handshake messages described in 61.4.7. The CO-subtype device interprets the contents of the remote_discovery_register to determine which remote PMEs connect to the same PCS and may be aggregated. The corresponding Clause 45 register is defined in 45.2.6.6.1.

61.3 TC sublayer functional specifications

The functional model of the TC sublayer is presented in Figure 61–12. The term "TPS-TC" (Transport Protocol Specific - Transmission Convergence) is used in ITU-T Recommendation G.993.1. In this context the term "TC" (Transmission Convergence) is sufficient as no other types of TC are defined in this subclause (e.g., PMS-TC).

Because the PAF function is optional, either entire data frames or data frame fragments may be passed across the γ-interface. In this section, the term "fragment" will be used to describe either fragments or data frames depending on the existence of the PAF.

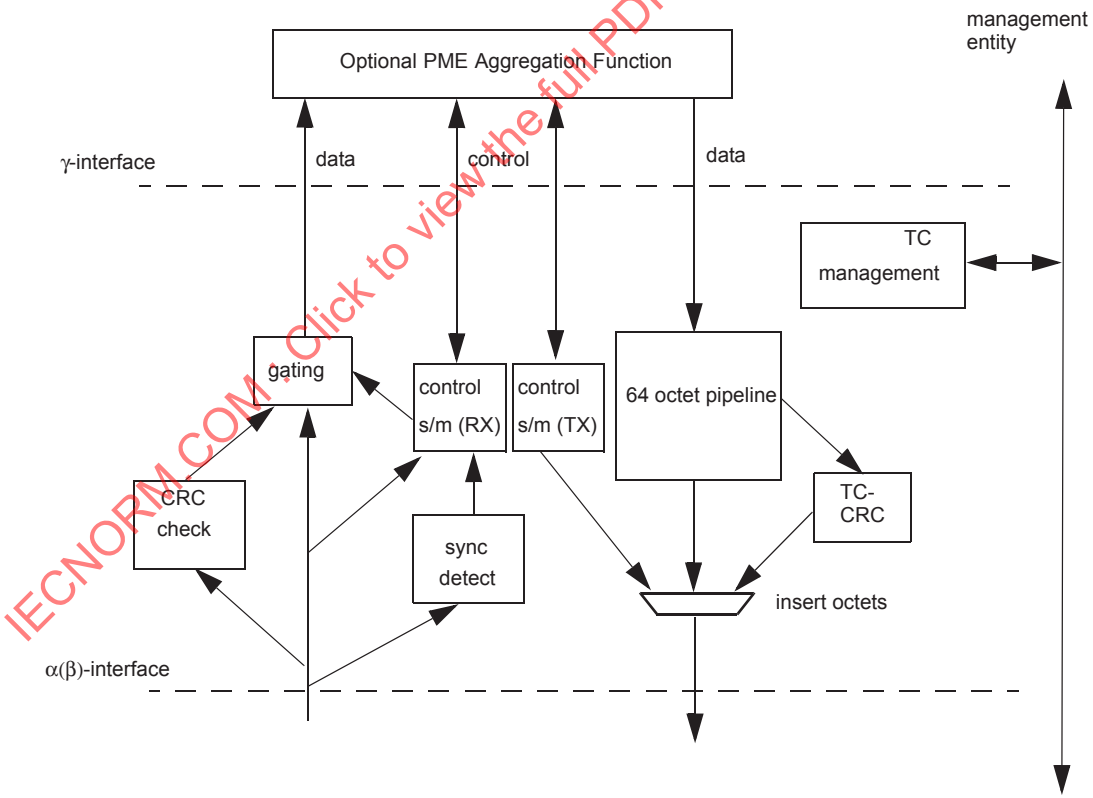

Figure 61–12—Functional diagram of TC sublayer

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61.3.1 The γ-interface

The γ-interface is specified by incorporating section H.3.1 and all subsections of ITU-T Recommendation G.993.1 (Annex H) by reference, with the following exceptions and additions:

The PCS shall assert Tx_Avbl when an entire data fragment is available for transmission, and de-assert Tx_Avbl when there are no data fragments to transmit. Tx_Avbl shall never be de-asserted during the transmission of a data fragment.

OAM Information flow across the γ-interface supports access to registers referenced in Clause 45. Refer to Clause 45 for a complete description of access to TC, PMA and PMD registers from the MDIO interface.

Additional signals, which would be represented in the referenced document section H.3.1.4, are described in Table 61–9. Some of these signals may be unused when Clause 45 is not implemented.

Table 61–9—Additional γ-interface signals for OAM[a]

Signal	Size	Description	Direction
TC_link_state	1 bit	Control signal asserted when link is active and framing has synchronized according to the definition in 61.3.3 (TC_synchronized = TRUE) and remote_TC_out_of_sync (see 61.3.3.7) is not asserted.	TC → PCS
write_remote_aggregation_reg[b]	1 bit	Control signal to write PME_Aggregate_register. Active (min) 1 octet clock cycle	to PCS
write_remote_discovery_reg[b]	1 bit	Control signal to write remote_discovery_register. Active (min) 1 octet clock cycle	to PCS
clear_remote_discovery_reg[b]	1 bit	Control signal to clear remote_discovery_register. Active (min) 1 octet clock cycle	to PCS
read_remote_aggregation_reg[b]	1 bit	Control signal to read PME_Aggregate_register. Active (min) 1 octet clock cycle	to PCS
read_remote_discovery_reg[b]	1 bit	Control signal to read remote_discovery_register. Active (min) 1 octet clock cycle	to PCS
remote_write_data_bus[b]	48 bit	Data bus for writing to PME aggregation registers. Valid during octet clock cycle when write control is asserted	to PCS
remote_read_data_bus[b]	48 bit	Data bus for the results of a read or atomic write function. Valid during octet clock cycle when Acknowledge_read_write or NAcknowledge read_write is asserted	from PCS
Acknowledge_read_write[b]	1 bit	Control signal responding (positively) to read or write. Active 1 octet clock cycle	from PCS
NAcknowledge read_write[b]	1 bit	Control signal responding (negatively) to read or write. Active 1 octet clock cycle	from PCS

[a]The term "OAM" as used here refers to the OAM facilities as defined in the referenced G.993.1 document.
[b]These signals are defined only if PAF is implemented, and then only in CPE subtypes. They are used only during G.994.1 handshake. For CO subtypes, pervasive access by management may be used to obtain the corresponding information. In case of read/write collision the PAF has to process the read/write-requests sequentially.

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61.3.2 The α(β)-interface

The α(β)-interface is specified by incorporating section 7.1 and all subsections of ITU-T Recommendation G.993.1 by reference.

NOTE—An identical α(β)-interface is defined in ITU-T G.991.2.

The α and β reference points define interfaces between the PCS and PMA in the 2BASE-TL-O/10PASS-TS-O and the 2BASE-TL-R/10PASS-TS-R, respectively. Both interfaces are functional, application independent and identical. Both interfaces are defined by the following signal flow:

a) Data flow
b) Synchronization flow
c) OAM flow[12]

61.3.2.1 α(β) data flow: reference G.993.1 section 7.1.1

Referenced as is, with the additions shown in Table 61–10.

Table 61–10— Additional α(β)-Interface signals

Signal(s)	Size	Description	Direction
PMA_receive_synchronized	1 bit	Receive PMA state diagram synchronized	PMA → TC
PMA_PMD_type	8 bit[a]	Signal indicating PMA/PMD mode of operation. Defined values: 00_{16} — 10PASS-TS CO subtype 01_{16} — 2BASE-TL CO subtype 02_{16}–$7B_{16}$ — reserved for allocation by IEEE 802.3 $7C_{16}$–$7F_{16}$ — reserved for allocation by ATIS T1E1.4 80_{16} – 10PASS-TS CPE subtype 81_{16} – 2BASE-TL CPE subtype 82_{16}–FB_{16} — reserved for allocation by IEEE 802.3 FC_{16}–FF_{16} — reserved for allocation by ATIS T1E1.4	PMA → TC

[a]NOTE—The MSB of this octet-wide signal is used to differentiate between CO-subtype and CPE-subtype.

61.3.2.2 α(β) synchronization flow

The synchronization flow comprises the following synchronization signals:

a) Transmission data flow octet synchronization (Osync_t)
b) Reception data flow octet synchronization (Osync_r)
c) Transmit and receive data flow bit-synchronization (Clk_t, Clk_r), optional
d) Transmit and receive data flow frame-synchronization (Fsync_t, Fsync_r), optional
e) Receive PMA state diagram synchronized (PMA_receive_synchronized)

The synchronization signals are asserted by the PMA and directed towards the PCS. The synchronization flow signals are described in Table 61–10.

[12]The term "OAM" as used here refers to the OAM facilities as defined in the referenced G.993.1 document.

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61.3.2.3 α(β) OAM flow[13]

The OAM Flow across the α(β)-interface exchanges OAM information between the PHY-OAM entity, the PMA and the PMD. The OAM flow is bi-directional and transports line related primitives, parameters, configuration setup and maintenance signals or commands.

Refer to Clause 62 and Clause 63 for definitions of the G.994.1 messaging, Operation Channel (OC) and Indicator Bits (IB) mechanisms for accessing remote parameters.

Refer to Annex 61A for an example of aggregation discovery.

61.3.3 TC functions

The TC shall provide full transparent transfer of data fragments between γ_O-interface and γ_R-interface (except non-correctable errors caused by the transmission medium). It shall also provide fragment integrity and fragment error monitoring capability.

In the transmit direction, the TC receives fragments from the PCS via the γ-interface. An additional 16- or 32-bit CRC is calculated on the data and appended. The TC then performs 64/65-octet encapsulation, and sends the resulting codewords to the PMA via the α(β)-interface. In the receive direction, the TC receives codewords from the PMA via α(β)-interface, recovers the transported TC fragment, checks the CRC, and submits the extracted fragment to the PCS via the γ-interface.

An implementation is shown in Figure 61–13 and some example timing diagrams are shown in Figure 61–14.

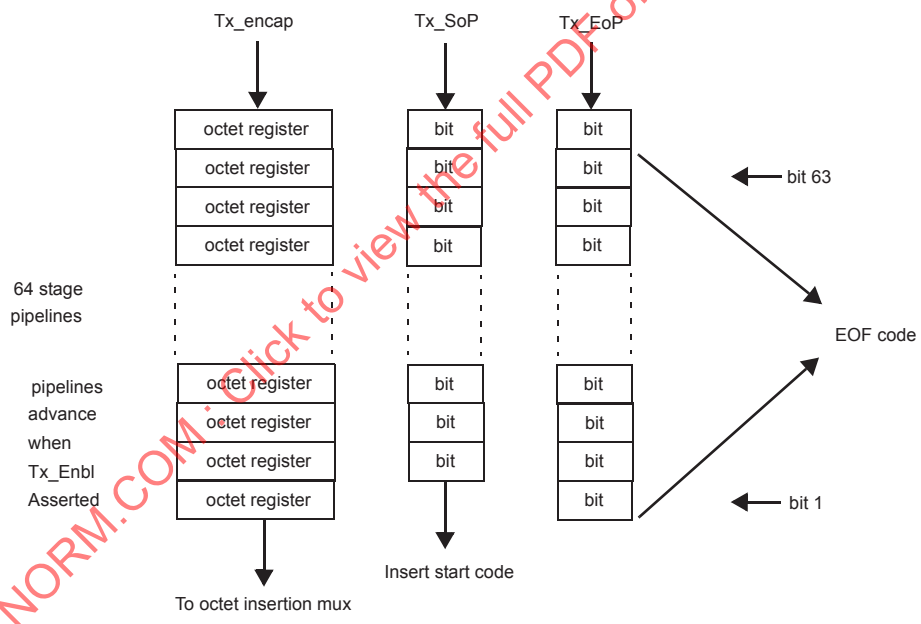

Figure 61–13—Example transmit pipeline

61.3.3.1 TC encapsulation and coding

A TC fragment consists of a fragment, followed by a 16- or 32-bit CRC (referred to as the TC-CRC) as defined in 61.3.3.3.

[13]The term "OAM" as used here refers to the OAM facilities as defined in the referenced G.993.1 document.

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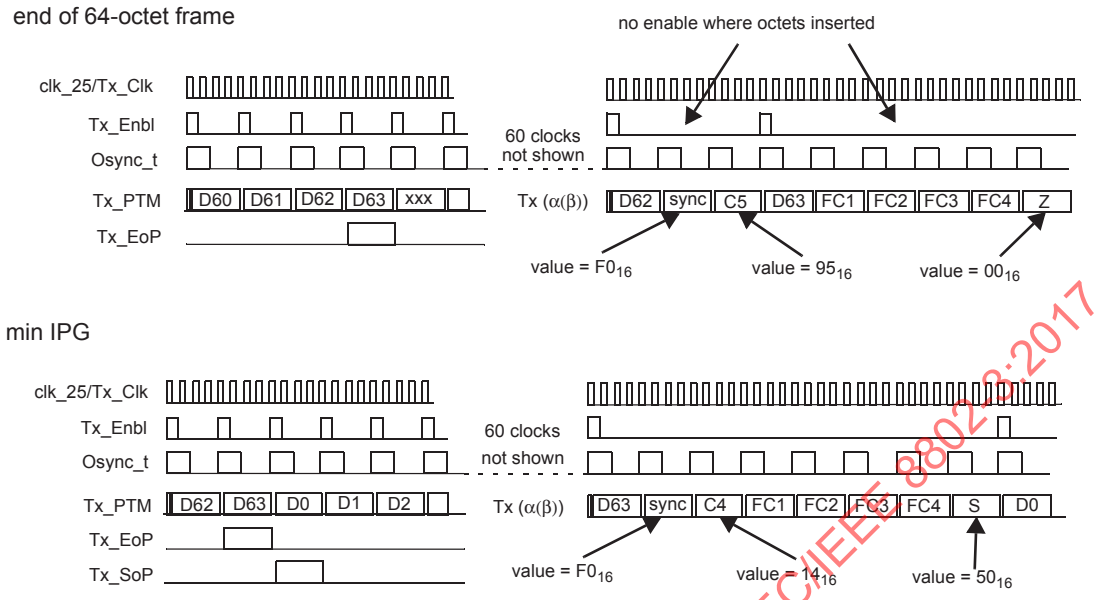

Figure 61–14—Example transmit timing

The TC coding function generates codewords with a fixed length of 65 octets (64/65-octet coding). A codeword consists of a Sync Octet and one of the following combinations:

a) all data: all of the octets in the codeword belong to the same TC fragment.
b) end of frame (go to idle): up to 63 octets in the codeword belong to the same TC fragment, the rest of the codeword consists of Idle octets.
c) end of frame (start new frame): up to 62 octets in the codeword belong to the same TC fragment, a number of Idle octets and a single Start of Frame octet precede the first data octets of the next TC fragment.
d) idle: all of the octets in the codeword are Idle octets.
e) idle (start new frame): a number of Idle octets and a single Start of Frame octet precede up to 63 data octets of the next TC fragment.
f) out-of-sync idle: all of the octets in the codeword are idle octets and the 64/65-octet receive state diagram is out-of-sync (TC_synchronized = FALSE).

Both transmit and receive data may be transferred across both the α(β) and the γ-interfaces at rates that are different from the rate across the MII; the frame buffering is managed in the sublayer above the γ-interface. The TC layer uses the γ-interface flow control signal, Tx_Enbl, to slow transmit data to the rate required for the encapsulated data across the α(β)-interface. The TC layer uses the γ-interface flow control signal, Rx_Enbl, to allow idle cycles in the flow of receive data across the γ-interface.

When a fragment arrives from the γ-interface while an End of Frame codeword is being transmitted, a Start of Frame octet shall be inserted prior to the transmission of data octets belonging to the next fragment. The Start of Frame octet *S* is distinct from the Idle octet *Z*. Valid locations for *S* are any valid location for *Z*, and the presence of an *S* rather than a *Z* octet indicates that what follows is the commencement of data for a new fragment.

No new fragment shall be transmitted when TC_link_state = FALSE (TC_link_state is defined in 61.3.3.7). If a fragment is being transmitted when TC_link_state becomes false, the End of Frame codeword completing the fragment shall not contain an *S* symbol after the end of the fragment. If an Idle codeword is being transmitted when TC_link_state becomes false, it shall be completed with *Z* symbols only. After the completed End of Frame or Idle codeword, only All Idle or All Idle Out-of-Sync codewords shall be

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transmitted until TC_link_state becomes TRUE again. After TC_link_state becomes true again, transmission of data can restart when a new fragment is available for transmission over the gamma-interface.

The data and sync format of the encapsulated data is shown in Table 61–11.

Table 61–11—Codeword formats

Type	Frame Data	Sync Octet	Octet fields 1–64									
all data	*DDDD—DDDD*	$0F_{16}$	D_0	D_1	D_2	D_3	D_4	D_5	...	D_{61}	D_{62}	D_{63}
end of frame	contains k D's, where k = 0 to 63	$F0_{16}$	C_k	D_0	D_1	D_2	D_3	...	D_{k-1}	Z	...	Z
start of frame while transmitting	contains last k D's of 1st frame, where k=0 to 62; & first j D's of 2nd frame, where j=0 to 62-k	$F0_{16}$	C_k	D_0	...	D_{k-1}	Z	...	S	D_0	...	D_{j-1}
all idle	*ZZZZ—ZZZZ*	$F0_{16}$	Z	Z	Z	Z	Z	Z	...	Z	Z	Z
start of frame while idle	contains k D's, where k=0 to 63, and contains j Z's, where j=63-k	$F0_{16}$	Z	Z	S	D_0	D_1	...	...	D_{k-3}	D_{k-2}	D_{k-1}
all idle out-of-sync	*YZZZ—ZZZZ*	$F0_{16}$	Y	Z	Z	Z	Z	Z	...	Z	Z	Z

The end of a TC fragment is always marked with an "end of frame" or "start of frame while transmitting" codeword; e.g., the received sequence [All Data codeword][All Idle codeword] is considered a sequencing error. When any of the following events occur, signal TC_coding_error shall be asserted:

a) An incorrect octet is received when a Sync Octet is expected.
b) Outside a fragment, the received octet following a valid $F0_{16}$ sync is not a Z, Y, S.
c) Inside a fragment, the received octet following a valid $F0_{16}$ sync is not a valid value of C_k.
d) Z or S is expected, and a value different from Z and S is received.

Signal remote_TC_out_of_sync shall be asserted when Y is received after an expected $F0_{16}$ sync symbol, and remain asserted until the beginning of a codeword other than All Idle Out-of-Sync is detected.

NOTE—When the local TC is not synchronized (TC_synchronized = FALSE), it may fail to detect incoming "All Idle Out-of-Sync" codewords. However, this does not affect the behavior of the local TC, which is sending "All Idle Out-of-Sync" codewords itself. Higher sublayers only use the combined signal TC_link_state, defined in 61.3.1.

Figure 61–15 illustrates two interesting examples. In the first example, the last 60 octets of a data frame, plus the 4 encapsulation CRC octets, are transmitted in an All Data codeword. In other words, the end of the (TC-CRC-augmented) frame coincides with the end of the codeword. In this case, the next codeword begins with Sync Octet equal to $F0_{16}$, C_k equal to C_0 (90_{16}). The second codeword indicates an End Of Frame, but with no additional data; in other words, the data in the previous codeword were the last of the frame. In the second example, the first octet of a frame is aligned with the first octet of an All Data codeword.

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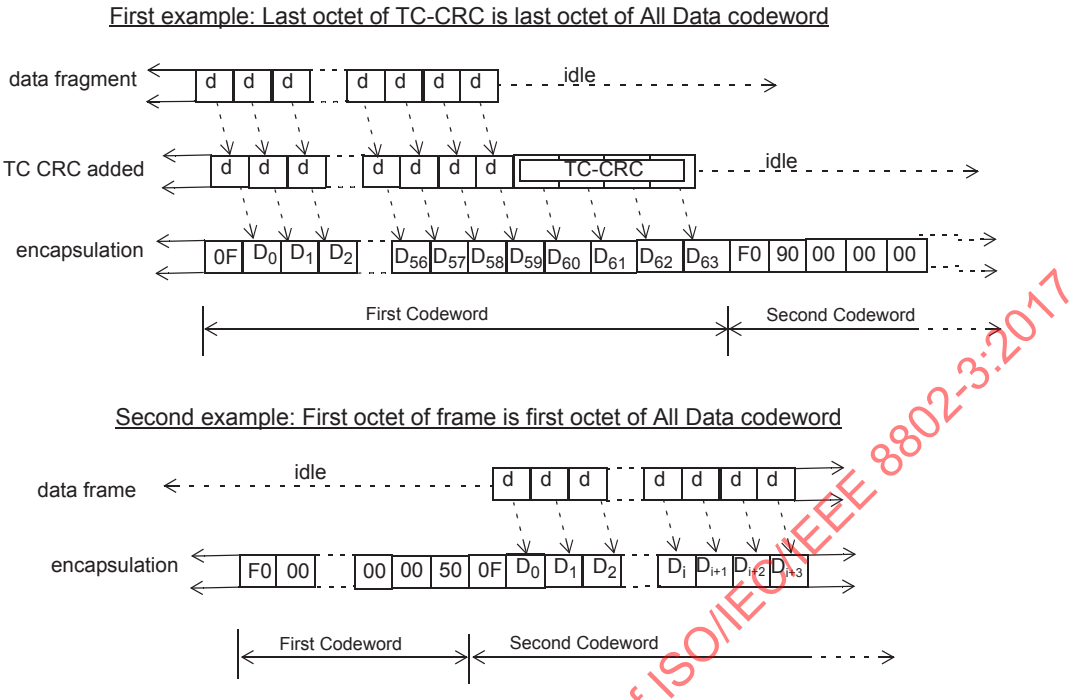

Figure 61–15—TC Encapsulation examples

The values of the TC control characters are shown in Table 61–12.

Table 61–12—TC control character values

Character	Value
Z	00_{16}
C_k, k=0–63	$C_k = k+10_{16}$, with MSB set so that resulting value has even parity; $C_0=90_{16}$, $C_1=11_{16}$, $C_2=12_{16}$, $C_3=93_{16}$, ... $C_{62}=4E_{16}$, $C_{63}=CF_{16}$
Y	$D1_{16}$
S	50_{16}
R	All other values[a]

[a]See the state diagram for the 64/65-octet receive function (Figure 61–19) for required action when receiving reserved codewords.

61.3.3.2 Sync insertion and transmit control

The transmit data path needs a 64 stage pipeline in order to generate the appropriate sync octet along with an end-of-frame indicator when required. The flow control signal, Tx_Enbl, is used to slow the flow of data across the γ-interface to cater for the difference in clock speed between the α(β)-interface and the γ-interface and also to allow for the insertion of sync octets and CRC codes into the data stream.

A simple implementation may use a 64 bit pipeline for the Tx_EOP control signal. In that case, an end of frame sync code ($F0_{16}$, then C_k) would be inserted whenever a bit is set in stages 63 to 1 of the pipeline

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(stage 64 is the first stage). The value of C_k inserted would be such that k is equal to the stage number of the bit that is set.

Some implementations may optimize the insertions of idles between fragments. In particular an implementation may remove idle characters between fragments to increase the effective bandwidth of the channel.

If PMA/PMD link status is not Up (i.e. either Down or Initializing), the TC sublayer shall transmit only Out-of-Sync Idle codewords. The PMA/PMD link status is defined in 45.2.1.16.4.

61.3.3.3 TC-CRC functions

The TC-CRC is generated for the entire payload fragment including any attached header (from PAF), including the Ethernet CRC; i.e., the TC-CRC is computed over octets from the first octet of the PAF header (if present), or the first octet of the DestinationAddress (in the case where the PAF header not present), to the last octet of the Ethernet CRC (for a frame) or the last octet of the fragment (if PAF fragmentation is operating), inclusive. The TC-CRC is added to the data stream after the end of the fragment in the transmit direction. The TC-CRC is checked against the last 2 or 4 octets of the fragment in the receive direction. If the receive TC-CRC is incorrect then Rx_Err is asserted to signal that the fragment is errored.

The encoding for 2BASE-TL is defined by the following generating polynomial in Equation (61–1).

$$x^{32}+x^{28}+x^{27}+x^{26}+x^{25}+x^{23}+x^{22}+x^{20}+x^{19}+ \\ x^{18}+x^{14}+x^{13}+x^{11}+x^{10}+x^{9}+x^{8}+x^{6}+1 = \\ (x+1)(x^{31}+x^{30}+x^{29}+x^{28}+x^{26}+x^{24}+x^{23}+x^{21}+x^{20}+x^{18}+x^{13}+x^{10}+x^{8}+x^{5}+x^{4}+x^{3}+x^{2}+x+1) \quad (61–1)$$

The encoding for 10PASS-TS is defined by the following generating polynomial in Equation (61–2).[14]

$$x^{16}+x^{12}+x^{5}+1 \quad (61–2)$$

Mathematically, the TC-CRC value corresponding to a given payload fragment (including any attached header) is defined by the following procedure:

a) The first 32 bits (in the case of 2BASE-TL) or the first 16 bits (in the case of 10PASS-TS) of the payload are complemented.
b) The n bits of the payload are then considered to be the coefficients of a polynomial $M(x)$ of degree $n–1$. (e.g., the first bit of the fragment corresponds to the x^{n-1} term and the last bit of the fragment corresponds to the x^0 term.)
c) $M(x)$ is multiplied by x^{32} (in the case of 2BASE-TL), or by x^{16} (in the case of 10PASS-TS), and divided by $G(x)$, the TC-CRC polynomial, producing a remainder $R(x)$ of degree 31 (in the case of 2BASE-TL), or degree 15 (in the case of 10PASS-TS).
d) The coefficients of $R(x)$ are considered to be a 32-bit sequence (in the case of 2BASE-TL), or a 16-bit sequence (in the case of 10PASS-TS).
e) The bit sequence is complemented and the result is the TC-CRC.

In the case of 2BASE-TL, the 32 bits of the TC-CRC value are placed so that the x^{31} term is the bit in position b_8 on the α(β)-interface (as shown in Figure 61–16) of the first octet, and the x^0 term is the bit in position b_1 on the α(β)-interface (as shown in Figure 61–16) of the last octet. (The bits of the CRC are thus transmitted in the order x^{31}, x^{30},.., x^1, x^0.) At the receiver, a payload received without error will result in the remainder $1C2D19ED_{16}$ when divided by $G(x)$.

[14]For 10PASS-TS, a 16-bit TC-CRC is sufficient for detecting payload errors, as the error-detecting capabilities of its Reed-Solomon decoder is also employed (see 62.2.2). In 2BASE-TL PHYs, a Reed-Solomon decoder is not present, hence a stronger TC-CRC is required.

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In the case of 10PASS-TS, the 16 bits of the TC-CRC value are placed so that the x^{15} term is the bit in position b_8 on the α(β)-interface (as shown in Figure 61–16) of the first octet, and the x^0 term is the bit in position b_1 on the α(β)-interface (as shown in Figure 61–16) of the last octet. (The bits of the CRC are thus transmitted in the order x^{15}, x^{14},.., x^1, x^0.) At the receiver, a payload received without error will result in the remainder $1D0F_{16}$ when divided by $G(x)$.

If, in the transmitter, the TX_Err signal is asserted during the transmission of the fragment across the γ-interface, the last octet of the TC-CRC shall be ones-complemented (i.e., intentionally corrupted by inverting all the bits of the last octet).

61.3.3.4 Bit ordering

In the transmitter, after encapsulation into 64/65-octet codewords, bits within each octet are labeled from b_1 to b_8, with the MSB labeled as b_1, the LSB labeled as b_8, and intervening bits labeled accordingly. In keeping with the labeling convention for the α(β)-interface in ITU-T Recommendations, bit b_8 is regarded as the MSB at the α(β)-interface, and is transmitted first if the α(β)-interface is serial by implementation.

Observe that the TC functionality defines a correspondence between the LSB at the γ-interface and b_8, between the next-order bit and b_7, etc., in order to conform to the Ethernet bit order convention of transmitting LSB first. See also H.4.1.1 in Annex H of ITU-T Recommendation G.993.1. In transmitting and calculating the TC-CRC, the octets at the γ-interface are processed LSB first.

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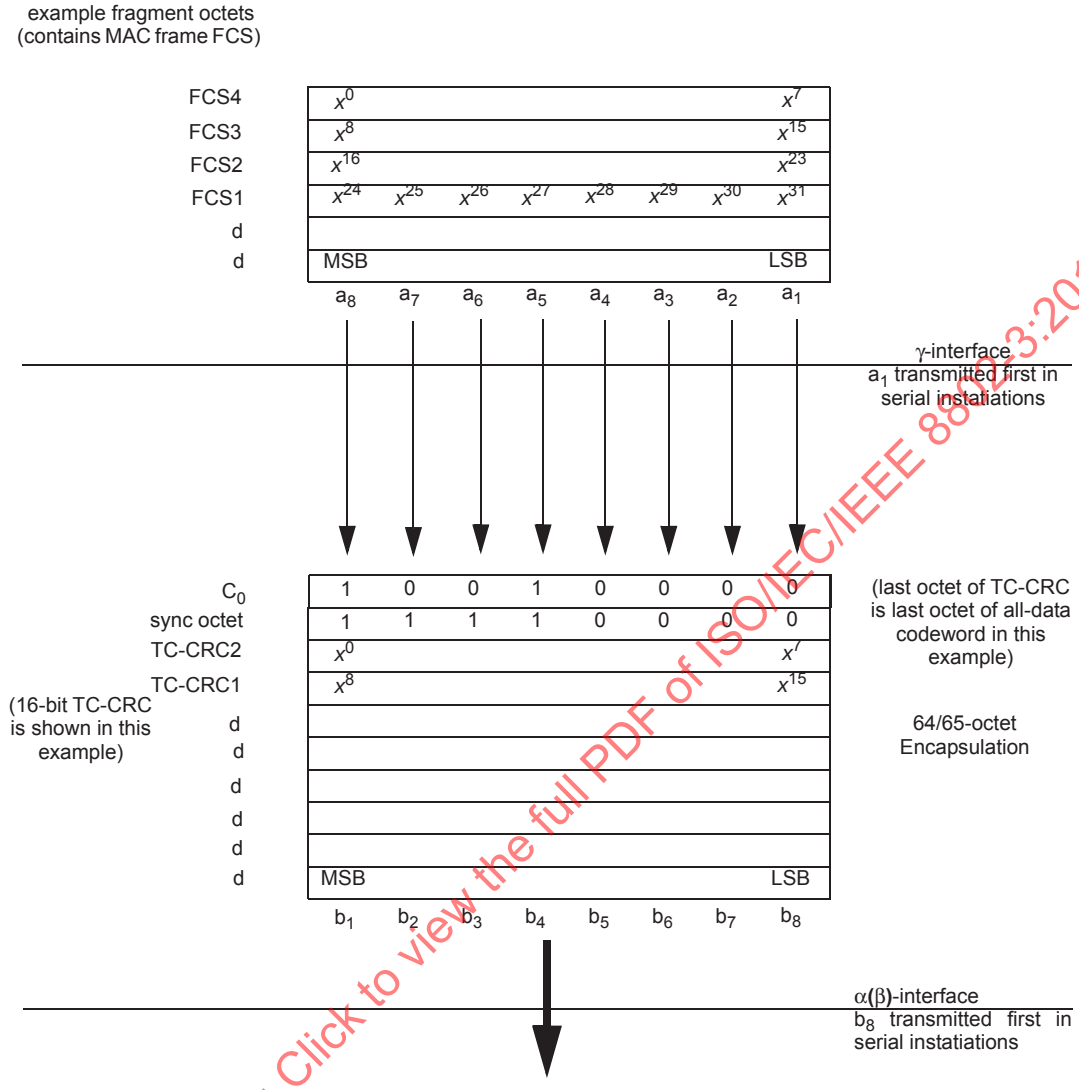

Figure 61–16—γ-interface to α(β)-interface bit ordering

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61.3.3.5 Sync detection

The sync detection function serves two purposes. Firstly, the synchronization is acquired from the incoming data stream, the sync detection function controls the initial acquisition and maintenance of the synchronization. Secondly, the sync detection is needed so that the receive control state diagram can extract framing information from the receive data stream and remove the sync characters and CRC codes. The sync detection state diagram is shown in Figure 61–17.

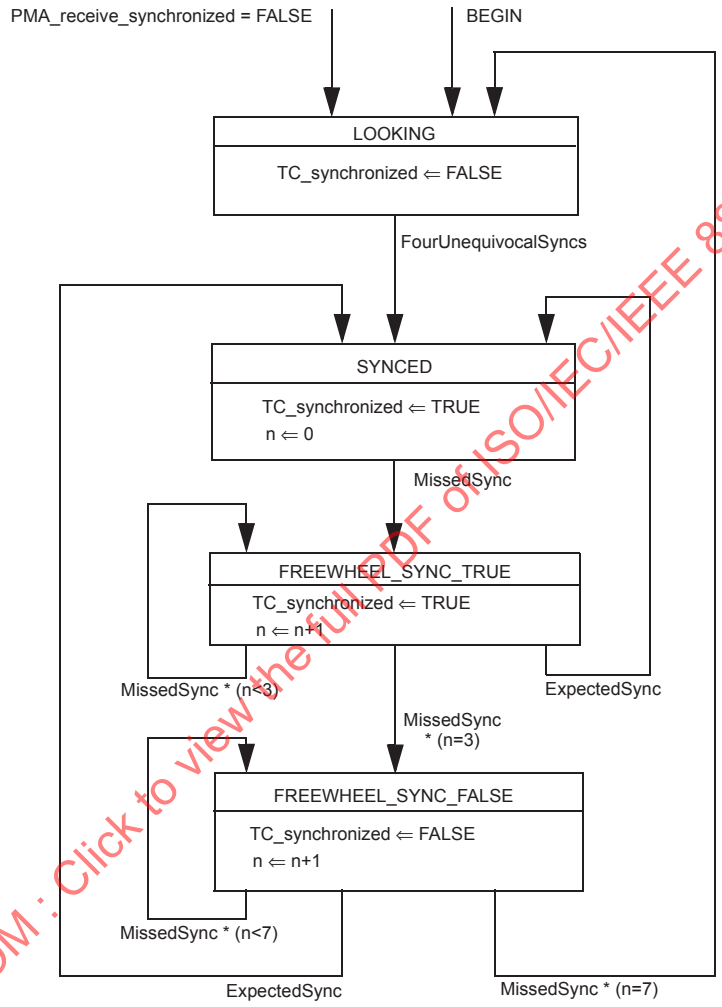

Figure 61–17—Sync detect state diagram

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61.3.3.5.1 State diagram variables

BEGIN
: A variable that resets the functions within the sync detection function (see 45.2.1.1.1.)
TRUE when the TC sublayer is reset.
FALSE when (re-)initialization has completed.

ExpectedSync
: variable of type Boolean, TRUE indicating the occurrence of a sync character in the correct position in the octet stream. The default value of this variable is FALSE; the value of the variable resets to FALSE on every state transition.

FourUnequivocalSyncs
: variable of type Boolean, TRUE indicating the occurrence of a 196-octet sequence with the following two characteristics:

a)the sequence is of the form <sync><data><sync><data><sync><data><sync>, where each <sync> is $0F_{16}$ or $F0_{16}$ and each <data> is 64 octets of any value;
b)the pattern <sync><data><sync><data><sync> occurs nowhere in the sequence, where <sync> and <data> are as defined in (a, unless the <sync> values are coincident with those in (a;

The default value of this variable is FALSE; the value of the variable resets to FALSE on every state transition.

MissedSync
: variable of type Boolean, TRUE indicating the occurrence of a non-sync character in the octet stream position where a sync character is expected. The default value of this variable is FALSE; the value of the variable resets to FALSE on every state transition.

n
: variable of type integer, counting the occurrences of MissedSync = TRUE, used to determine when to leave state FREEWHEEL_SYNC_TRUE or FREEWHEEL_SYNC_FALSE.

PMA_receive_synchronized
: signal of the α(β)-interface, see 61.3.2.

TC_synchronized
: variable of type Boolean, TRUE indicating that the state diagram is in state SYNCED or FREEWHEEL_SYNC_TRUE. This variable is used to calculate the value of signal TC_link_state on the γ-interface (see 61.3.1), and to generate “All Idle Out Of Sync” codewords in the 64/65-octet transmit function (see Figure 61–18).

61.3.3.5.2 State diagram

The receiver shall implement the sync detect state diagram shown in Figure 61–17.

61.3.3.6 Receive control

The receive control function removes the sync characters and encapsulation CRC octets from the data stream and passes it upward across the γ-interface. If TC_synchronized = false then signal RX_Enbl shall be de-asserted. If a CRC error is detected the receive controller shall assert signal TC_CRC_error. The receive controller shall assert signal RX_Err at the γ-interface during at least one octet of a fragment as it is passed up across the γ-interface, if TC_CRC_error is asserted, or if the fragment contains data from a block of data in which the PMA detected errors, but did not correct them (the means by which the PHY passes this information from the PMA to the TC is unspecified).

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61.3.3.7 State diagrams for 64/65-octet encapsulation

This subclause contains the state diagrams for the 64/65-octet encapsulation function. Only the signals that affect the operation of the state diagrams are explicitly mentioned in the state diagrams. Other signals are to be set and read in accordance with the specifications of the γ-interface (see 61.3.1) and the α(β)-interface (see 61.3.2).

61.3.3.7.1 Transmit state diagram

The following variables are used in the state diagram.

BEGIN
: A variable that resets the functions within the sync detection function.
TRUE when the TC-sublayer is reset.
FALSE when (re-)initialization has completed.

k
: variable of type integer, used to keep track of the number of octets used in the current codeword, not including the sync symbols

loop
: variable of type Boolean, keeping track of the fact that an Out-of-Sync Idle codeword is being transmitted, thus preventing a Start-of-Frame to occur within this codeword (initial value is TRUE).

TC_link_state
: variable of type Boolean, indicating the current state of the TC_link_state signal on the γ-interface

TC_link_stateCHANGE
: This function monitors the TC_link_state variable for a state change. The function is set to TRUE on state change detection.
Values:
TRUE; A TC_link_state variable state change has been detected.
FALSE; A TC_link_state variable state change has not been detected (default).

NOTE—TC_link_stateCHANGE is set by this function definition; it is not set explicitly in the state diagrams. TC_link_stateCHANGE evaluates to its default value upon state entry.

TC_synchronized
: variable of type Boolean, indicating whether synchronization has been acquired (as used in Figure 61–17)

Tx_Avbl
: variable of type Boolean, indicating the current state of the Tx_Avbl (transmit data available) signal on γ-interface

Tx_EoP
: variable of type Boolean, indicating the current state of the Tx_EoP (end of packet) signal on γ-interface

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The following functions are used in the state diagram:

flushBuffer()
: function that removes any octets that have been pulled from the PCS by the function pullOctet() from the transmit fifo.

pullOctet()
: function that receives a single octet of data from the γ-interface. This function takes one cycle of the Tx_Enbl (transmit enable) signal (see 61.3.1) to complete. At the end of a fragment, this function returns the octets of the TC-CRC in the order specified in 61.3.3.3.

transmitAllDataSync()
: function that transmits the all-data sync symbol ($0F_{16}$) to the α(β)-interface. This function takes one cycle of the Osync_t signal (see 61.3.3.2) to complete.

transmitC(int k)
: function that transmits the C_k symbol as specified in Table 61–10 to the α(β)-interface. This function takes one cycle of the Osync_t signal (see 61.3.3.2) to complete.

transmitData()
: function that transmits all data currently in the transmit fifo to the α(β)-interface. This function takes one cycle of the Osync_t signal (see 61.3.3.2) per octet of data transmitted to complete.

transmitS()
: function that transmits the *S* symbol as specified in Table 61–12 to the α(β)-interface. This function takes one cycle of the Osync_t signal (see 61.3.3.2) to complete.

transmitSync()
: function that transmits the regular sync symbol ($F0_{16}$) to the α(β)-interface. This function takes one cycle of the Osync_t signal (see 61.3.3.2) to complete.

transmitZ(int k, Boolean loop)
: function that transmits the *Y* symbol ($D1_{16}$) to the α(β)-interface if (k=1) and (loop=TRUE), and transmits the *Z* symbol (00_{16}) to the α(β)-interface otherwise. This function takes one cycle of the Osync_t signal (see 61.3.3.2) to complete.

Figure 61–18 specifies the 64/65-octet encapsulation (transmit) function.

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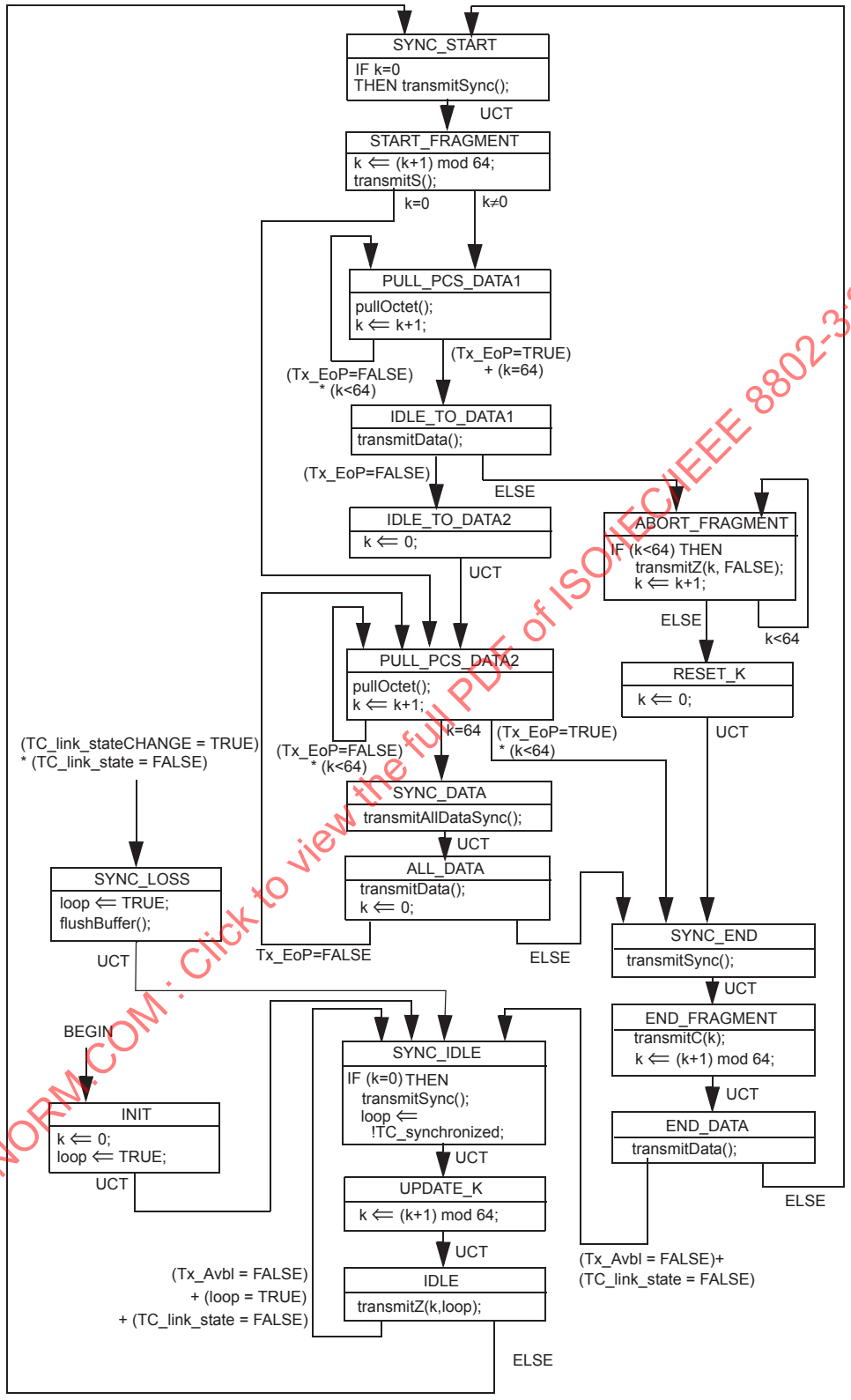

Figure 61–18—State diagram for 64/65-octet transmit function

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61.3.3.7.2 Receive state diagram

The following variables are used in the state diagram.

B
: variable of type octet, used to store a single received octet

C
: variable of type octet, used to store a received C_k symbol

codingViolation
: variable of type Boolean, used to mark detection of a coding violation when a sync octet was expected

expectedSync
: variable of type Boolean, used to mark successful sync octet detections, which are counted towards achieving synchronization as specified in Figure 61–17. The default value of this variable is FALSE; it returns to FALSE on every state transition.

k
: variable of type integer, used to keep track of the number of octets received in the current codeword, not including the sync symbols

kmax
: variable of type integer, used to store the decoded value of a C_k symbol

missedSync
: variable of type Boolean, used to mark unsuccessful sync octet detections, which are counted towards losing synchronization as specified in Figure 61–17. The default value of this variable is FALSE; it returns to FALSE on every state transition.

remote_TC_out_of_sync
: variable of type Boolean, representing the state of the remote TC synchronization state diagram (see 45.2.6.13).
TRUE if the remote TC has lost synchronization according to 61.3.3.5
FALSE if the remote TC has acquired synchronization according to 61.3.3.5

Rx_Err
: variable of type Boolean, representing the corresponding signal (receive error) on the γ-interface

TC_coding_error
: when this signal is asserted, the TPS-TC coding violations counter register is incremented (see 45.2.6.12). The default value of this variable is FALSE; it returns to FALSE on every state transition. If TC_coding_error becomes true during the reception of a fragment, Rx_Err is asserted on the γ-interface to signal this condition to the PCS, thus invalidating the entire fragment.

TC_synchronized
: variable of type Boolean, identical to the variable TC_synchronized defined in 61.3.3.7.1.

TC_synchronizedCHANGE
: This function monitors the TC_synchronized variable for a state change. The function is set to TRUE on state change detection.
Values:
TRUE; A TC_synchronized variable state change has been detected.
FALSE; A TC_synchronized variable state change has not been detected (default).

NOTE—TC_synchronizedCHANGE is set by this function definition; it is not set explicitly in the state diagrams. TC_synchronizedCHANGE evaluates to its default value upon state entry.

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The following functions are used in the state diagram.

decode(octet B)
: function that decodes the C_k symbol as specified in Table 61–12. A return value between 0 and 63 indicates a valid C_k symbol was read.

receiveOctet()
: function that receives a single octet of data over the α(β)-interface. This function takes one cycle of the Osync_r signal (see 61.3.2.2) to complete.

sendOctetToPCS()
: function that sends a single octet of data over an internal γ-interface to an intermediate fifo. The size of the intermediate fifo is more than 2 octets for 10PASS-TS and more than 4 octets for 2BASE-TL. Data is transmitted at the same rate from the intermediate fifo to the PCS (if present) over the γ-interface. This function takes one cycle of the Rx_clk (receive clock) signal (see 61.3.1) to complete. At the end of a fragment, the fifo contains the TC_CRC octets. The TC_CRC octets are never forwarded over the γ-interface. After verification of the TC_CRC octets, the result of the TC_CRC verification is signalled to the PCS (if present) over the γ-interface.

Figure 61–19 specifies the 64/65-octet decapsulation (receive) function.

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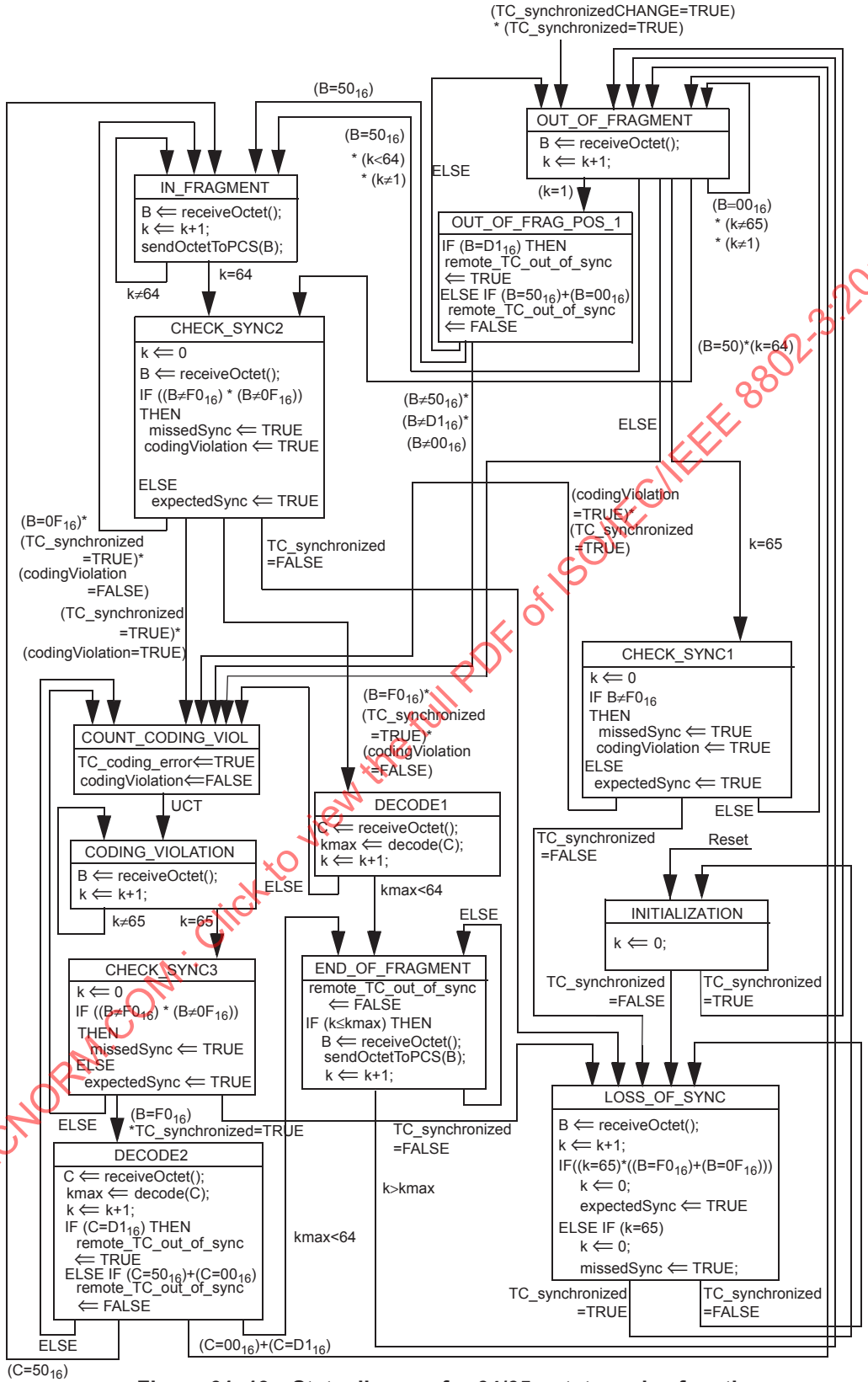

Figure 61–19—State diagram for 64/65-octet receive function

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61.3.3.8 TC sublayer management entity signals

The following TC sublayer signals are mapped to Clause 45 registers or cause Clause 45 counters to increment:

remote_TC_out_of_sync
: (for each PMA, γ-interface) this signal is asserted to indicate that the remote TC has signaled loss-of-sync. See Figure 61–19 and 45.2.6.13.

TC_synchronized
: (for each PMA, γ-interface) this signal is asserted to indicate that the state diagram has achieved codeword synchronization. See Figure 61–17 and 45.2.6.10.

TC_CRC_error
: (for each PMA, γ-interface) this signal is asserted to indicate that the synchronization state diagram has detected a false CRC code for a received frame (see 45.2.6.11).

TC_coding_error
: (for each PMA, γ-interface) this signal is asserted to indicate that a coding violation has been detected in the received octet stream (see 45.2.6.12).

61.4 Handshaking and PHY control specification for type 2BASE-TL and 10PASS-TS

61.4.1 Overview

This subclause defines the startup and handshaking procedures by incorporating ITU-T Recommendation G.994.1 by reference, with the exceptions listed below. Where there is conflict between specifications in G.994.1 and those in this standard, those of this standard will prevail. The G.994.1 parameter values and options to be used by 2BASE-TL and 10PASS-TS are specified here.

At the time of publication, G.994.1 Revision 3 (2004) is in force. Earlier Revisions of this Recommendation shall not be implemented in 2BASE-TL or 10PASS-TS.

61.4.2 Replacement of 1, “Scope”

61.4.2.1 Scope

This subclause defines signals, messages, and procedures for exchanging these between 2BASE-TL and 10PASS-TS port types, when the modes of operation of the equipment need to be automatically established and selected, but before signals are exchanged which are specific to a particular port type.

The startup procedures defined here are compatible with those used by other equipment on the public access network, such as DSL transceivers compliant with ITU-T Recommendations. For interrelationships of this subclause with ITU-T G.99x-series Recommendations, see Recommendation G.995.1 (informative).

The principal characteristics of this subclause are as follows:

a) Use over metallic local loops
b) Provisions to exchange capabilities information between DSL equipment and EFM PHYs to identify common modes of operation
c) Provisions for equipment at either end of the loop to select a common mode of operation or to request the other end to select the mode
d) Provisions for exchanging non-standard information between equipment
e) Provisions to exchange and request service and application related information
f) Support for both duplex and half-duplex transmission modes
g) Support for multi-pair operation
h) Provisions for equipment at the remote end of the loop (xTU-R) to propose a common mode of operation

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61.4.2.2 Purpose

It is the goal of the ITU-T that all specifications for digital transceivers for use on public telephone network copper subscriber lines use G.994.1 for startup. G.994.1 procedures allow for a common mechanism for identification of available features, exchange of capabilities and configuration information, and selection of operating mode. As the two loop endpoints are usually separated by a large distance (e.g., in separate buildings) and often owned and installed by different entities, G.994.1 also aids in diagnosing interoperability problems. G.994.1 codespaces have been assigned by ITU-T to ATIS, ETSI, and IEEE 802.3 in support of this goal.

In private networks, the management entity may additionally use G.994.1 tones or messages to autoconfigure the subtype (CO or CPE) in devices which implement both (see 61.1).

61.4.3 Changes to 6.1, “Description of signals”

NOTE 4 and NOTE 5 are not applicable.

Replace paragraph 3 of 6.1.1, “4.3125 kHz signaling family” with the following.

The carrier sets in this family are mandatory for the port types listed in Table 61–13. One or more carriers listed in Reference Table 1 or Reference Table 3 may be transmitted in addition to the mandatory carrier set listed in Table 61–13. Carriers not listed in Reference Table 1 or Reference Table 3 shall not be transmitted.

Table 61–13—Mandatory carrier sets

Port Types	Carrier set designation
10PASS-TS	V43

Replace paragraph 3 of section 6.1.2, “4 kHz signaling family” with the following.

The carrier sets in this family are mandatory for the port types listed in Table 61–14. One or more carriers listed in Reference Table 1 or Reference Table 3 may be transmitted in addition to the mandatory carrier set listed in Table 61–14. Carriers not listed in Reference Table 1 or Reference Table 3 shall not be transmitted.

Table 61–14—Mandatory carrier sets

Port Types	Carrier set designation
2BASE-TL	A4

61.4.4 Changes to 9.4, “Standard information field (S)”

Paragraphs 1–5: referenced as is.

Table 11.1 to Table 11.52 and Table 11.57 and beyond are not applicable.

The Standard information field (S) codepoints specified in Annex 61B shall be used in the transactions specified in this subclause.

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61.4.5 Changes to 9.5, “Non-standard information field (NS)”

Add this paragraph: The contents of the NS information field are outside the scope of this standard.

61.4.6 Applicability of Annex A–B and Appendix I–VI

Annex A / G.994.1—Support for legacy non-G.994.1 devices—Not applicable

Annex B / G.994.1—Operation over multiple wire pairs—Not applicable to the multipair operation for EFM

Appendix I / G.994.1—Not applicable

Appendix II / G.994.1—Provider Code contact Information —Referenced as is

Appendix III / G.994.1—Support for legacy DMT-based devices —Not applicable

Appendix IV / G.994.1—Procedure for the assignment of additional G.994.1 parameters—Not applicable

Appendix V / G.994.1—Rules for code point table numbering—Not applicable

Appendix VI / G.994.1—Bibliography

61.4.7 PME Aggregation – remote access of PME Aggregation registers

As the CO-subtype accesses PME Aggregation registers (i.e., remote_discovery_register and PME_Aggregate_register) in the CPE-subtype prior to training and establishment of the PMD-to-PMD link, it is performed using G.994.1 handshake messages.

The G.994.1 handshake messages described in this subclause shall assert the “Ethernet bonding” NPar(2) codepoint if and only if PAF_available is asserted. The “TDIM Bonding” NPar(2) bit shall be deasserted. In addition, the “Ethernet bonding” NPar(2) codepoint shall be asserted by the -O device in an MS message if and only if PAF_enable is asserted.

NOTE 1—A G.994.1 session including configuration of the PME Aggregation Function may violate the maximum activation time specified for SHDSL transceivers by ITU-T Recommendation G.991.2.

NOTE 2—In the transactions specified in this subclause, each CLR message may be preceded by MR/REQ-CLR messages. Each CL message is followed by an ACK(1). These messages are not shown in the diagrams.

61.4.7.1 Remote_discovery_register

2BASE-TL-R and 10PASS-TS-R PHYs shall assert the PME Aggregation Discovery SPar(2) bit in all G.994.1 CLR messages, if and only if its local PAF_available bit is set. CPE-subtypes shall place the contents of the remote_discovery_register in the corresponding NPar(3) bits in the outgoing CLR message, with the “Clear if Same” NPar(3) set to zero.

In response to a “Get” command, the CO-subtype shall perform a G.994.1 capabilities exchange with the CPE-subtype. The contents of the NPar(3) remote_discovery_register bits in the CLR message received from the CPE-subtype shall be reported as the result. The CL message sent by the CO-subtype in response to the CLR shall have the PME Aggregation Discovery SPar(2) bit set to zero.

In response to a “Set if Clear” command, the CO-subtype shall perform two back-to-back G.994.1 capabilities exchanges with the CPE-subtype. The contents of the NPar(3) remote_discovery_register bits in the first CLR message received from the CPE-subtype shall be ignored. The CL message sent by the CO-subtype in response to this first CLR shall have the PME Aggregation Discovery SPar(2) bit set to one, the Clear if Same NPar(3) bit set to zero, and the NPar(3) remote_discovery_register bits set to the CO-subtype

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PME Aggregation Discovery Code register. The CPE-subtype shall set the remote_discovery register to this value if it is currently clear. The contents of the NPar(3) remote_discovery_register bits in the CLR message received from the CPE-subtype during the second capabilities exchange shall be reported as the result. The CL message sent by the CO-subtype in response to this second CLR shall have the PME Aggregation Discovery SPar(2) bit set to zero.

In response to a “Clear if Same” command, the CO-subtype shall perform two back-to-back G.994.1 capabilities exchanges with the CPE-subtype. The contents of the NPar(3) remote_discovery_register bits in the first CLR message received from the CPE-subtype shall be ignored. The CL message sent by the CO-subtype in response to this first CLR shall have the PME Aggregation Discovery SPar(2) bit set to one, the Clear if Same NPar(3) bit set to one, and the NPar(3) remote_discovery_register bits set to the CO-subtype PME Aggregation Discovery Code register. The CPE-subtype shall clear the remote_discovery register if it is currently equal to this value. The contents of the NPar(3) remote_discovery_register bits in the CLR message received from the CPE-subtype during the second capabilities exchange shall be reported as the result. The CL message sent by the CO-subtype in response to this second CLR shall have the PME Aggregation Discovery SPar(2) bit set to zero.

Figure 61–20 illustrates the relevant sequences of G.994.1 transactions.

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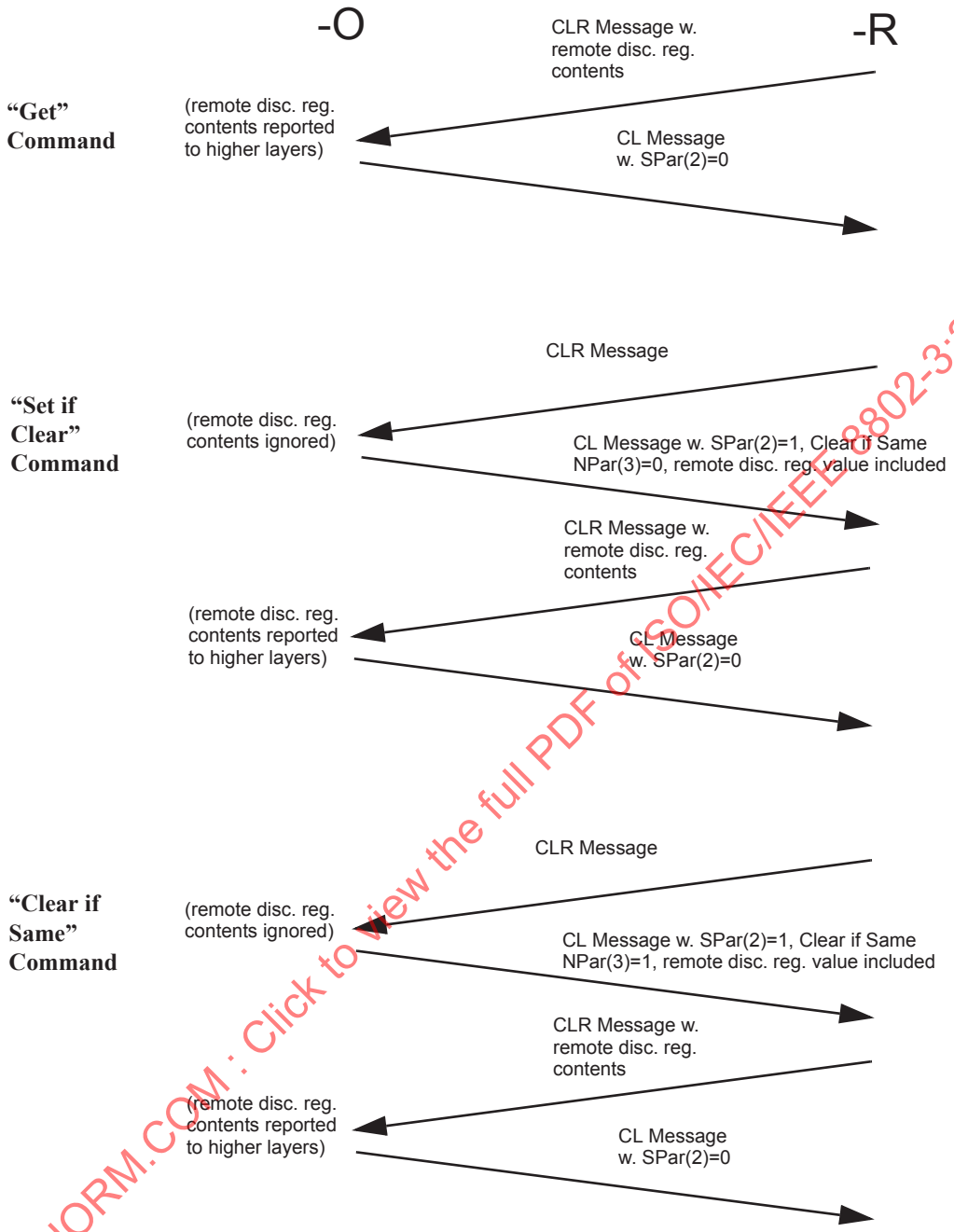

Figure 61–20—G.994.1 transactions for remote_discovery_register access

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61.4.7.2 PME_Aggregate_register

2BASE-TL-R and 10PASS-TS-R PHYs shall assert the PME Aggregation SPar(2) bit in all G.994.1 CLR messages, if and only if its local PAF_available bit is set. CPE-subtypes shall place the contents of the PME_Aggregate_register in the corresponding NPar(3) bits in the outgoing CLR message.

In response to a "get" command, the CO-subtype shall perform a G.994.1 capabilities exchange with the CPE-subtype. The contents of the NPar(3) PME_Aggregate_register bits in the CLR message received from the CPE-subtype shall be reported as the result. The CL message sent by the CO-subtype in response to the CLR shall have the PME Aggregation SPar(2) bit set to zero.

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In response to a "set" command, the CO-subtype shall perform two back-to-back G.994.1 capabilities exchanges with the CPE-subtype. The contents of the NPar(3) PME_Aggregate_register bits in the first CLR message received from the CPE-subtype shall be ignored. The CL message sent by the CO-subtype in response to this first CLR shall have the PME Aggregation SPar(2) bit set to one and the NPar(3) PME_Aggregate_register bit zero. The -R device sets the bit position in the PME_Aggregate_register corresponding to the PME upon which the G.994.1 exchange takes place. The contents of the NPar(3) PME_Aggregate_register bits in the CLR message received from the CPE-subtype during the second capabilities exchange shall be reported as the result. The CL message sent by the CO-subtype in response to this second CLR shall have the PME Aggregation SPar(2) bit set to zero.

61.4.7.3 Timing and preferred transactions

This subclause is applicable to devices in which 10PASS-TS and/or 2BASE-TL are the only G.994.1-initiated PHYs implemented and enabled. Start-up procedures for devices that include additional G.994.1-initiated modes of operation are outside the scope of this standard.

NOTE 1—Handshake operations specified in this subclause occur autonomously in the PHY, without intervention of the STA. They may however be triggered by an STA using the management interface.

If the PMA/PMD link control bit is set to 1 in the -O device (Table 45–18), or discovery register operations are initiated (Table 45–189), or link partner aggregation register operations are initiated (Table 45–192), the -O device initiates G.994.1 startup procedures by transmitting C-TONES.

If the PMA/PMD link control bit is set to 1 in the -R device (Table 45–18), the -R device initiates G.994.1 startup procedures by transmitting R-TONES-REQ.

At the conclusion of G.994.1 startup, the -R device shall begin G.994.1 transactions by transmitting an MR message. The -O device responds by sending C-TONES if the Ignore incoming handshake register bit (see 45.2.1.11) is set to 0_b.

If the G.994.1 session was initiated by the PMA/PMD link control bit (signifying that the link is to be brought up) in either the -O or -R device, then the -O device shall respond with an MS message specifying the configured mode of operation. However, if the PMA/PMD type selection bits in the -O device are set to the value 0011 or 0100, and a capabilities exchange has not previously taken place, the -O device shall instead respond with an REQ-CLR so that a capabilities exchange is performed. Following the final message of the capabilities exchange [i.e., an ACK(1)], the -R device once again sends an MR message. The -O device shall respond with an MS message specifying the configured mode of operation.

If the G.994.1 session was initiated in response to discovery register operations (Table 45–189), or link partner aggregation register operations (Table 45–192), then the -O device shall respond with an REQ-CLR message (MR received before) or with a CL message (CLR received before). This is then followed by one or two capability exchanges as described in the previous two subclauses. Following the final message of the final capabilities exchange [i.e., an ACK(1)], the CPE device once again sends an MR message. If neither the PMA/PMD control bit nor the discovery or link partner aggregation register operations are activated within the next 0.5 seconds, the -O shall transmit an MS message with the SPar(1) silent bit set.

NOTE 2—It is understood that the entire activation sequence consisting of PAF Discovery, PAF and line activation is time-consuming, therefore 2BASE-TL and 10PASS-TS devices are encouraged to exchange only relevant information in G.994.1 sessions during various stages of initialization.

61.5 Link segment characteristics

As stated in 61.1, the channel characteristics of voice grade copper are very diverse. Some typical channels are defined as part of the Performance Guidelines contained in Annex 62B (for 10PASS-TS) and Annex 63B (for 2BASE-TL). These annexes also define the reference performance levels for each PHY in these conditions. Behavior in other voicegrade installations may be interpolated or extrapolated from that set of references.

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61.6 MDI specification

The MDI interface for 10PASS-TS and the Service Splitter and Electrical Characteristics for 10PASS-TS are defined in 62.3.5.

The Electrical Characteristics of the MDI interface for 2BASE-TL are defined in 63.3.2.

The local regulations may dictate interface characteristics in addition to or in place of some or all of these requirements.

61.7 System considerations

Both EFM Copper port types are defined for full duplex operation only, although certain MACs may still require to be configured for half duplex operation in order to respond to the carrier Sense signal, as required by the specification of MAC-PHY Rate Matching. The requirements of 31B.1 restrict the transmission of PAUSE frames to DTEs configured to the full duplex mode of operation. If PAUSE frames are used on an EFM Copper link, consideration should be given to the link latency, and the fact that the MAC-PHY Rate Matching mechanism can interfere with the expected operation of the PAUSE frame mechanism.

NOTE—It is recognized that an EFM Copper system may have to comply with additional requirements and/or restrictions outside the scope of this standard (see 61.6 and 61.8 for examples) in order to be allowed to be connected to a public infrastructure in a certain geographic area or regulatory environment. These additional requirements and/or restrictions may prohibit operation under certain profiles, or degrade the performance of the system when working under certain profiles.This may limit the system's compliance with this standard, as compliant systems support all profiles (see Annex 62A for 10PASS-TS and Annex 63A for 2BASE-TL) and meet all performance guidelines (see Annex 62B for 10PASS-TS and Annex 63B for 2BASE-TL).

A compliant CPE-side system cannot distinguish a CO-side system designed to operate under a limited set of profiles from a fully compliant CO-side system, as the selection of profiles is under control of the CO-side. A CPE-side system designed to operate under a limited set of profiles cannot be guaranteed to correctly interoperate with compliant CO-side systems.

It is recommended that vendors of systems that support a limited set of profiles provide PICS forms to indicate which profiles are supported, in order to allow users to assess the impact on interoperability.

61.8 Environmental specifications

The requirements of 14.7 should be considered as baseline Environmental Specifications for types 10PASS-TS and type 2BASE-TL. Since equipment specified in this Clause will typically be deployed into public network environments, the specific requirements of the network operator or the local authority having jurisdiction shall prevail in all cases, and shall be considered in the development of such equipment. Such requirements may be statutory and may include product safety, electromagnetic compatibility and protection of the public network against harms from attached equipment.

61.9 PHY labeling

It is recommended that PHY equipment (and supporting documentation) be labeled in a manner visible to the user with at least the following parameters:

a) PMA/PMD (sub-)type. A type (e.g., 10PASS-TS) can be specified if both -O and -R subtypes are supported. A subtype should be specified (e.g. 10PASS-TS-R) if only a single subtype is supported.
b) PAF capability if supported. The following information should be provided: number of MII/PCS ports provided; maximum number of PMEs per MII/PCS; total number of PMEs. For example:
    1) x8 or 1x8:8 for a single MII port with 8 PMEs
    2) 2x2:4 for a device with 2 MII ports and 4 PMEs, which can be aggregated up to 2 PMEs per port
    3) 4x4:4 for a device with 4 MII ports and 4 PMEs, which can be aggregated up to 4 PMEs per port
c) Homologation information
d) Applicable safety warnings

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61.10 Protocol implementation conformance statement (PICS) proforma for Clause 61, Physical Coding Sublayer (PCS), Transmission Convergence (TC) sublayer, and common specifications type 10PASS-TS, 2BASE-TL[15]

61.10.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 61, Physical Coding Sublayer (PCS), Transmission Convergence (TC) sublayer, and common specifications type 10PASS-TS, 2BASE-TL, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

61.10.2 Identification

61.10.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification--e.g., names and versions for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

61.10.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 61, Physical Coding Sublayer (PCS) and common specifications, type 10PASS-TS and 2BASE-TL.
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	No [ ] Yes [ ]
Date of Statement	

[15] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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61.10.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
RM	MAC-PHY Rate Matching	61.2.1	CRS deference mechanism supported.	M	Yes [ ]
TC	64/65-octet Encapsulation	61.3	The Ethernet-specific TPS-TC, between α(β)-interface and γ-interface is implemented.	M	Yes [ ]
*PAF	PME Aggregation	61.2.2	Up to 32 PMA/PMD instances can be aggregated into a single MAC.	O	Yes [ ] No [ ]
HS	Support for G.994.1 handshake	61.4	PHY uses G.994.1 handshake to identify remote transceiver and exchange capabilities.	M	Yes [ ]
*2BO	2BASE-TL-O subtype	61, 63	The 2BASE-TL CO subtype is implemented.	O.1	Yes [ ] No [ ]
*2BR	2BASE-TL-R subtype	61, 63	The 2BASE-TL CPE subtype is implemented.	O.1	Yes [ ] No [ ]
*10PO	10PASS-TS-O subtype	61, 62	The 10PASS-TS CO subtype is implemented.	O.1	Yes [ ] No [ ]
*10PR	10PASS-TS-R subtype	61, 62	The 10PASS-TS CPE subtype is implemented.	O.1	Yes [ ] No [ ]

61.10.4 PICS proforma tables for the Physical Coding Sublayer (PCS), Transmission Convergence (TC) sublayer, and common specifications type 10PASS-TS, 2BASE-TL

61.10.4.1 MAC-PHY Rate Matching

Item	Feature	Subclause	Value/Comment	Status	Support
RM-1	MAC-PHY Rate Matching functions	61.2.1.1	The PHY uses CRS to match the MAC's faster rate of data transmission to the PHY's slower rate.	M	Yes [ ]
RM-2	MAC-PHY Rate Matching functions	61.2.1.1	Upon receipt of a MAC frame from the MII, the PHY discards the Preamble and SFD fields, and transmits the resulting data frame across the physical link.	M	Yes [ ]
RM-3	MAC-PHY Rate Matching functions	61.2.1.1	The PHY prepends the Preamble and the SFD fields to a received frame before sending it to the MAC.	M	Yes [ ]
RM-4	MAC-PHY Rate Matching functions	61.2.1.1	The PHY supports a mode of operation where it does not send data to the MAC while the MAC is transmitting.	M	Yes [ ]

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61.10.4.2 64/65-octet Encapsulation

Item	Feature	Subclause	Value/Comment	Status	Support
TC-1	The γ-interface	61.3.1	The PAF asserts Tx_Avbl when it has a whole data fragment available for transmission, and de-assert Tx_Avbl when there are no data fragments to transmit.	M	Yes [ ]
TC-2	TC functions	61.3.3	The TC provides full transparent transfer of data frames between γ_O-interface and γ_R-interface.	M	Yes [ ]
TC-3	TC functions	61.3.3	The TC provides fragment integrity and fragment error monitoring capability.	M	Yes [ ]
TC-4	TC functions	61.3.3	The bit rate of data transport in the upstream and downstream directions are set independently of each other to any eligible value up to the maximum rate determined by the PMD.	M	Yes [ ]
TC-5	TC Encapsulation and Coding	61.3.3.1	When a frame arrives from the γ-interface while an End of Frame codeword is being transmitted, a Start of Frame octet is inserted prior to the transmission of data octets belonging to the next frame.	M	Yes [ ]
TC-6	Sync detection	61.3.3.5	The synchronization is acquired from the incoming data stream.	M	Yes [ ]
TC-7	Sync detection	61.3.3.5.2	The receiver implements the sync detect state diagram shown in Figure 61–17.	M	Yes [ ]
TC-8	Receive control	61.3.3.6	If TC_synchronized = false then signal RX_Enbl is de-asserted.	M	Yes [ ]
TC-9	Receive control	61.3.3.6	If a TC-CRC error is detected, the receive controller asserts signal RX_Err during at least one octet of the fragment as it is passed up across the γ-interface.	M	Yes [ ]
TC-10	Receive control	61.3.3.6	If the fragment contains data from a block in which the PMA detected errors but did not correct them, the receive controller asserts signal RX_Err during at least one octet of a fragment as it is passed up across the γ-interface.	M	Yes [ ]

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61.10.4.3 PME Aggregation[16]

Item	Feature	Subclause	Value/Comment	Status	Support
PAF-1	PME Aggregation Receive function	61.2.2.4	When the link state is changed to UP, the expected sequence number is unknown and no frame sequence errors are recorded.	*PAF:M	Yes [ ]
PAF-2	PME Aggregation Transmit Function Restrictions	61.2.2.6	The differential latency between any two PMEs in an aggregated group is no more than 15 000 bit times.	*PAF:M	Yes [ ]
PAF-3	PME Aggregation Transmit Function Restrictions	61.2.2.6	Fragments are not less than 64 octets.	*PAF:M	Yes [ ]
PAF-4	PME Aggregation Transmit Function Restrictions	61.2.2.6	Fragments are not more than 512 octets.	*PAF:M	Yes [ ]
PAF-5	PME Aggregation Transmit Function Restrictions	61.2.2.6	The highest ratio of speeds between any two aggregated links is 4.	*PAF:M	Yes [ ]
PAF-6	PME Aggregation Transmit Function Restrictions	61.2.2.6	The fragment size is a multiple of 4 octets except for the last fragment of a data frame.	*PAF:M	Yes [ ]
PAF-7	Error-detecting Rules	61.2.2.7	For each PMA, the per-PMA buffering mechanism discards the fragment if any of the listed conditions occur, and asserts the PAF error flags as appropriate. If the packet assembly function was mid-frame, the first part of the frame is transferred across the MII, then the RX_ER signal is asserted on the MII, the frame transfer is aborted and PMA buffers are flushed until the next Start of Packet is received.	*PAF:M	Yes [ ]
PAF-8	Error-detecting Rules	61.2.2.7	If a fragment is received with the StartOfPacket bit asserted while the packet assembly function was mid-frame, the first part of the frame is transferred across the MII, then the RX_ER signal is asserted on the MII, the frame transfer is aborted and PMA buffers are flushed until the next Start of Packet is received.	*PAF:M	Yes [ ]
PAF-9	PME aggregation register functions	61.2.2.8.3	The remote_discovery_register and Aggregation_link_state_register are implemented.	*PAF:M	Yes [ ]
PAF-10	PME aggregation register functions	61.2.2.8.3	The PME_Available_register is read-only.	*PAF: *2BO:M *10PO:M	Yes [ ]

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PAF-11	PME aggregation register functions	61.2.2.8.3	The PME_Available_register is writeable.	*PAF: *2BR:O *10PR:O	Yes [ ] No [ ]
PAF-12	PME aggregation register functions	61.2.2.8.3	For a device that does not support aggregation of multiple PMEs, a single bit of the PME_Available_register is set and all other bits clear.	*PAF:M	Yes [ ]
PAF-13	PME aggregation register functions	61.2.2.8.3	The PME_Available_register is read-only.	*PAF: *2BO:M *10PO:M	Yes [ ]
PAF-14	PME aggregation register functions	61.2.2.8.3	The PME_Available_register is writeable.	*PAF: *2BR:O *10PR:O	Yes [ ] No [ ]
PAF-15	PME aggregation register functions	61.2.2.8.3	For CPE-subtype devices, PMD links are not enabled until the PME_Available_register has been set to limit the connectivity such that each PME maps to one, and only one MII.	*PAF:M	Yes [ ]
PAF-16	PME aggregation register functions	61.2.2.8.3	If the remote_discovery_register is clear then the PME_Aggregate_register is cleared.	*PAF:M	Yes [ ]
PAF-17	PME aggregation register functions	61.2.2.8.3	The remote_discovery_register is implemented for CPE-subtype devices.	*PAF: *2BR:M *10PR:M	Yes [ ]
PAF-18	PME aggregation register functions	61.2.2.8.3	The remote_discovery_register supports atomic write operations and reads from remote devices via the remote access signals passed across the γ-interface from the PMA.	*PAF:M	Yes [ ]
PAF-19	PME aggregation register functions	61.2.2.8.3	If multiple write_remote_discovery_reg signals are asserted they are acted upon serially.	*PAF:M	Yes [ ]
PAF-20	PME aggregation register functions	61.2.2.8.3	If the logical AND of the Aggregation_link_state_register and the PME_Aggregate_register is clear then a time-out counter is started. If this condition continues for 30 seconds then the remote_discovery_register is cleared.	*PAF:M	Yes [ ]
PAF-21	Remote access of PME Aggregation registers	61.4.7	The “TDIM Bonding” SPar(1) bit is deasserted.	*PAF:M	Yes [ ]

[16]All items listed in this section are only applicable if the optional PME Aggregation Function is supported.

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PAF-22	Remote_discovery_register	61.4.7.1	2BASE-TL-R and 10PASS-TS-R PHYs assert the PME Aggregation Discovery SPar bit in all G.994.1 CLR messages, if and only if its local PAF_available bit is set.	*PAF:M	Yes [ ]
PAF-23	Remote_discovery_register	61.4.7.1	CPE-subtypes place the contents of the remote_discovery_register in the corresponding NPar bits in the outgoing CLR message, with the “Clear if Same” NPar set to zero.	*PAF:M	Yes [ ]
PAF-24	Remote_discovery_register	61.4.7.1	In response to a “Get” command, the CO-subtype performs a G.994.1 capabilities exchange with the CPE-subtype. The contents of the NPar remote_discovery_register bits in the CLR message received from the CPE-subtype are reported as the result.	*PAF:M	Yes [ ]
PAF-25	Remote_discovery_register	61.4.7.1	The CL message sent by the CO-subtype in response to the CLR has the PME Aggregation Discovery SPar bit set to zero.	*PAF:M	Yes [ ]
PAF-26	Remote_discovery_register	61.4.7.1	In response to a “Set if Clear” command, the CO-subtype performs two back-to-back G.994.1 capabilities exchanges with the CPE-subtype. The contents of the NPar remote_discovery_register bits in the first CLR message received from the CPE-subtype are ignored.	*PAF:M	Yes [ ]
PAF-27	Remote_discovery_register	61.4.7.1	The CL message sent by the CO-subtype in response to the first CLR has the PME Aggregation Discovery SPar bit set to one, the Clear if Same NPar bit set to zero, and the NPar remote_discovery_register bits set to the CO-subtype PME Aggregation Discovery Code register.	*PAF:M	Yes [ ]
PAF-28	Remote_discovery_register	61.4.7.1	In a set-if-clear exchange, the CPE-subtype sets the remote_discovery register to the value of the Remote Discovery register NPar(3) if it is currently clear.	*PAF:M	Yes [ ]

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PAF-29	Remote_discovery_register	61.4.7.1	The contents of the NPar remote_discovery_register bits in the CLR message received from the CPE-subtype during the second capabilities exchange are reported as the result.	*PAF:M	Yes [ ]
PAF-30	Remote_discovery_register	61.4.7.1	The CL message sent by the CO-subtype in response to the second CLR has the PME Aggregation Discovery SPar bit set to zero.	*PAF:M	Yes [ ]
PAF-31	Remote_discovery_register	61.4.7.1	In response to a “Clear if Same” command, the CO-subtype performs two back-to-back G.994.1 capabilities exchanges with the CPE-subtype. The contents of the NPar remote_discovery_register bits in the first CLR message received from the CPE-subtype are ignored.	*PAF:M	Yes [ ]
PAF-32	Remote_discovery_register	61.4.7.1	The CL message sent by the CO-subtype in response to the first CLR has the PME Aggregation Discovery SPar bit set to one, the Clear if Same NPar bit set to one, and the NPar remote_discovery_register bits set to the CO-subtype PME Aggregation Discovery Code register.	*PAF:M	Yes [ ]
PAF-33	Remote_discovery_register	61.4.7.1	In a clear-if-same exchange, the CPE-subtype clears the remote_discovery register if it is currently equal to the value of the Remote Discovery register NPar(3).	*PAF:M	Yes [ ]
PAF-34	Remote_discovery_register	61.4.7.1	The contents of the NPar remote_discovery_register bits in the CLR message received from the CPE-subtype during the second capabilities exchange are reported as the result.	*PAF:M	Yes [ ]
PAF-35	Remote_discovery_register	61.4.7.1	The CL message sent by the CO-subtype in response to the second CLR has the PME Aggregation Discovery SPar bit set to zero.	*PAF:M	Yes [ ]
PAF-36	PME_Aggregate_register	61.4.7.2	2BASE-TL-R and 10PASS-TS-R PHYs assert the PME Aggregation SPar bit in all G.994.1 CLR messages, if and only if their local PAF_available bit is set.	*PAF:M	Yes [ ]

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PAF-37	PME_Aggregate_register	61.4.7.2	CPE-subtypes place the contents of the PME_Aggregate_register in the corresponding NPar bits in the outgoing CLR message.	*PAF:M	Yes [ ]
PAF-38	PME_Aggregate_register	61.4.7.2	In response to a “get” command, the CO-subtype performs a G.994.1 capabilities exchange with the CPE-subtype. The contents of the NPar PME_Aggregate_register bits in the CLR message received from the CPE-subtype are reported as the result.	*PAF:M	Yes [ ]
PAF-39	PME_Aggregate_register	61.4.7.2	The CL message sent by the CO-subtype in response to the CLR has the PME Aggregation SPar bit set to zero.	*PAF:M	Yes [ ]
PAF-40	PME_Aggregate_register	61.4.7.2	In response to a “set” command, the CO-subtype performs two back-to-back G.994.1 capabilities exchanges with the CPE-subtype. The contents of the NPar PME_Aggregate_register bits in the first CLR message received from the CPE-subtype are ignored.	*PAF:M	Yes [ ]
PAF-41	PME_Aggregate_register	61.4.7.2	The CL message sent by the CO-subtype in response to the first CLR has the PME Aggregation SPar bit set to one and the NPar PME_Aggregate_register bit zero.	*PAF:M	Yes [ ]
PAF-42	PME_Aggregate_register	61.4.7.2	The contents of the NPar PME_Aggregate_register bits in the CLR message received from the CPE-subtype during the second capabilities exchange are reported as the result.	*PAF:M	Yes [ ]
PAF-43	PME_Aggregate_register	61.4.7.2	The CL message sent by the CO-subtype in response to the second CLR has the PME Aggregation SPar bit set to zero.	*PAF:M	Yes [ ]
PAF-44	Timing and preferred transactions	61.4.7.3	At the conclusion of G.994.1 startup, the -R device begins G.994.1 transactions by transmitting an MR message.	*PAF:M	Yes [ ]
PAF-45	Timing and preferred transactions	61.4.7.3	If the G.994.1 session was initiated by the PMA/PMD link control bit in either the -O or -R device, then the -O device responds with an MS message specifying the configured mode of operation.	*PAF:M	Yes [ ]

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PAF-46	Timing and preferred transactions	61.4.7.3	If the PMA/PMD type selection bits in the -O device are set to the value 0011 or 0100, and a capabilities exchange has not previously taken place, the -O device instead responds with an REQ-CLR so that a capabilities is performed.	*PAF:M	Yes [ ]
PAF-47	Timing and preferred transactions	61.4.7.3	The -O device responds with an MS message specifying the configured mode of operation.	*PAF:M	Yes [ ]
PAF-48	Timing and preferred transactions	61.4.7.3	If the G.994.1 session was initiated in response to discovery register operations, or link partner aggregation register operations, then the -O device responds with an REQ-CLR message or with a CL message.	*PAF:M	Yes [ ]
PAF-49	Timing and preferred transactions	61.4.7.3	If neither the PMA/PMD control bit nor the discovery or link partner aggregation register operations are activated within 0.5 seconds after an MR message, the -O transmits an MS message with the SPar silent bit set.	*PAF:M	Yes [ ]

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61.10.4.4 Handshaking

Item	Feature	Subclause	Value/Comment	Status	Support
HS-1	Revision number: reference G.994.1 section 9.3.2	61.4.1	G.994.1 Revision Number 3 or higher is implemented.	M	Yes [ ]
HS-2	Summary of handshaking and PHY control specification	61.1.4.3	Devices implementing both 2BASE-TL and 10PASS-TS port types use G.994.1 to determine a common mode of operation.	O	Yes [ ] No [ ]
HS-3	4.3125 kHz signaling family: reference G.994.1 section 6.1.1	61.4.3	The mandatory carrier set listed in Table 61–13 is transmitted.	10PR:M 10PO:M	Yes [ ]
HS-4	4 kHz signaling family: reference G.994.1 section 6.1.2	61.4.3	The mandatory carrier set listed in Table 61–14 is transmitted.	2BR:M 2BO:M	Yes [ ]
HS-5	Prohibited carrier sets	61.4.3	Carriers not listed in Reference Table 1 or Reference Table 3 are not transmitted.	M	Yes [ ]
HS-6	Optional carrier sets	61.4.3	One or more carriers listed in Reference Table 1 or Reference Table 3 are transmitted in addition to a mandatory carrier set listed in Table 61–13 or Table 61–14.	O	Yes [ ] No [ ]
HS-7	Standard information field coding	61.4.4	The Standard information field (SI) codepoints specified in Annex 61B are used in the transactions specified in 61.4.4.	M	Yes [ ]

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62. Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 10PASS-TS

62.1 Overview

62.1.1 Scope

This clause specifies the 10PASS-TS Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD) for voice grade twisted-pair wiring. In order to form a complete 10PASS-TS PHY, the 10PASS-TS PMA and PMD are integrated with the TC and PCS of Clause 61. Parts of register 3.0, parts of register 3.4, and registers 3.60 through 3.73 specified in Clause 45 may be used to control the PCS of Clause 61. Parts of register 6.0 and registers 6.16 through 6.23 specified in Clause 45 may be used to control the TC sublayer of Clause 61. Registers 1.16 through 1.71 may be used to control the 10PASS-TS PMA and PMD.

62.1.2 Objectives

The following are the objectives for the 10PASS-TS PMA and PMD:

a) To provide 10Mb/s encapsulated packet data rate at the α(β)-interface.
b) To provide full duplex operation.
c) To provide for operating over non-loaded voice grade twisted pair cable at distances up to 750 m.
d) To provide a communication channel with a mean bit error ratio, at the α(β)-interface, of less than one part in 10^7 with 6 dB noise margin.

62.1.3 Relation of 10PASS-TS to other standards

The specifications of 10PASS-TS PMA and PMD are based on the VDSL transceiver specified in ANSI T1.424.

62.1.4 Summary of Physical Medium Attachment (PMA) specification

This layer is defined by the α(β)-interface and the I-interface.

62.1.4.1 α(β)-interface

A complete definition of the α(β)-interface is contained in 61.3.2.

62.1.4.2 I-interface

The I_O and I_R reference points define interfaces between the PMA and PMD in the 10PASS-TS-O and 10PASS-TS-R, respectively. Both interfaces are functional, application independent and identical. Both interfaces are defined by the following signal flows:

a) Data flow
b) Synchronization flow

62.1.4.2.1 I Data Flow

The data flow consists of the following two octet-oriented streams, both with the PMA frame format, with the bit rates defined by the PMD transmission profile:

a) Transmitted data (Tx)
b) Received data (Rx)

If data streams are implemented serially, the MSB of each octet is sent first.

Each stream bit rate value is set during PMD configuration.

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62.1.4.2.2 I Synchronization Flow

The synchronization flow consists of the transmitted and received octet synchronization signals (Clko_t, Clko_r). Optional transmit and receive bit-synchronization signals (Clkp_t, Clkp_r) are defined too.

Synchronization signals are asserted by the PMD and directed towards the PMA.

The synchronization flow signals are described in Table 62–1.

Table 62–1—I-interface signals

Signal(s)	Description	Direction	Notes
Data signals			
Tx	Transmitted data stream	PMA → PMD	Transmission frame format.
Rx	Received data stream	PMA ← PMD	
Synchronization signals			
Clko_t	Transmitted octet timing	PMA ← PMD	
Clko_r	Received octet timing	PMA ← PMD	
Clkp_t	Transmitted bit timing	PMA ← PMD	Optional
Clkp_r	Received bit timing	PMA ← PMD	Optional

62.2 PMA functional specifications

For the purpose of transmission over a serial implementation of the α(β)-interface or the I-interface, bit b_8 as defined in Figure 61–16 is considered MSB and shall therefore be transmitted first. However, for the purpose of all serial processing (e.g., scrambling, CRC calculation) bit b_8 is considered LSB and shall therefore be the first bit processed. Thus, the outside world MSB is considered as the 10PASS-TS LSB.

62.2.1 PMA functional diagram

Figure 62–1 shows a diagram of the PMA sublayer.

62.2.2 PMA functional specifications

The 10PASS-TS PMA is specified by incorporating the VDSL standard, ANSI T1.424, by reference, with the modifications noted below. This standard provides support for voice-grade twisted pair. For improved legibility in this clause, ANSI T1.424, will henceforth be referred to as MCM-VDSL.

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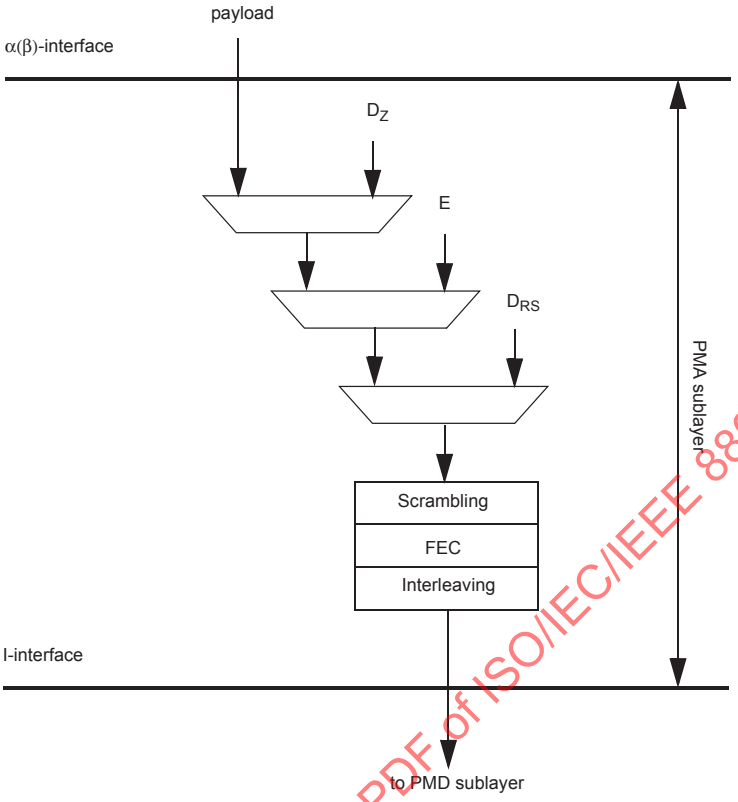

Figure 62–1—Diagram of PMA sublayer

62.2.3 General exceptions

The 10PASS-TS PMA is precisely the PMS-TC specified in MCM-VDSL, with the following general modifications:

a) There are minor terminology differences between this standard and MCM-VDSL that do not cause ambiguity. The terminology used in 10PASS-TS was chosen to be consistent with other IEEE 802 standards, rather than with MCM-VDSL. Terminology is both defined and consistent within each standard. Special note should be made of the interpretations shown in Table 62–2.
b) The 10PASS-TS PMA does not support the “fast path”.

Table 62–2—Interpretation of general MCM-VDSL terms and concepts

MCM-VDSL term or concept	Interpretation for 10PASS-TS
PMS-TC	PMA
VTU-O, LT	10PASS-TS-O
VTU-R, NT	10PASS-TS-R
Transmission medium dependent interface	MDI
U1-interface (splitter present)	
U2-interface (splitter absent)	

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62.2.4 Specific requirements and exceptions

The 10PASS-TS PMA shall comply to the requirements of MCM-VDSL Section 9.3 with the exceptions listed below. Where there is conflict between specifications in MCM-VDSL and those in this standard, those of this standard shall prevail.

62.2.4.1 Replacement of 9.3.1, "PMS-TC functional diagram"

Replace 9.3.1 of MCM-VDSL by the PMA functional diagram in 62.2.1.

62.2.4.2 Changes to 9.3.3, "Forward error correction"

Referenced as is, with the exception of required Reed-Solomon encoder and interleaver settings.

The mandatory settings in MCM-VDSL (144,128) and (240,224) shall be supported. Other values are out of scope.

The following interleaver parameters shall be supported:

a) For (N,K)=(144,128) the following values for M and I shall be supported: I=36 and M between 2 and 52
b) For (N,K)=(240,224) the following values for M and I shall be supported: I=30 and M between 2 and 62

Other settings for M and I are out of scope.

62.2.4.3 Changes to 9.3.5, "Framing"

Referenced as is, with following exceptions:

a) The "fast" buffer is not supported
b) There shall be 1 VOC byte per packet; other values of V as defined in 9.3.5.5 are outside the scope of this standard
c) 9.3.5.5.4 (NTR) is not applicable
d) In Table 9-4 (9.3.5.5.3), following changes apply
    1) bits B2, B3 of Byte #2 are reserved
    2) bits B1, B2, B3, B4 of Byte #3 shall be set to 0

Additional text: the signal PMA_receive_synchronized, defined in 61.3.2.2, shall be asserted when 10PASS-TS is in the state "STEADY_STATE_TRANSMISSION" (see Figure 62–4), and deasserted when 10PASS-TS is in any other state.

62.3 PMD functional specifications

62.3.1 PMD Overview

The 10PASS-TS PMD functional model is presented in Figure 62–2. In the transmit direction, the PMD layer receives frames from the PMA layer. It sends a DMT modulated signal towards the physical medium over the MDI.

The bytes within the frame are encoded to a set of QAM constellation points that are used to modulate the carriers of the DMT symbol. The time-domain symbol is cyclically extended and then windowed to reduce sidelobe energy.

In the receive direction, a modulated signal is received from the transmission medium over the MDI. The PMD layer outputs a data frame to the PMA layer. The receiver is responsible for equalization and demodulation of the signal.

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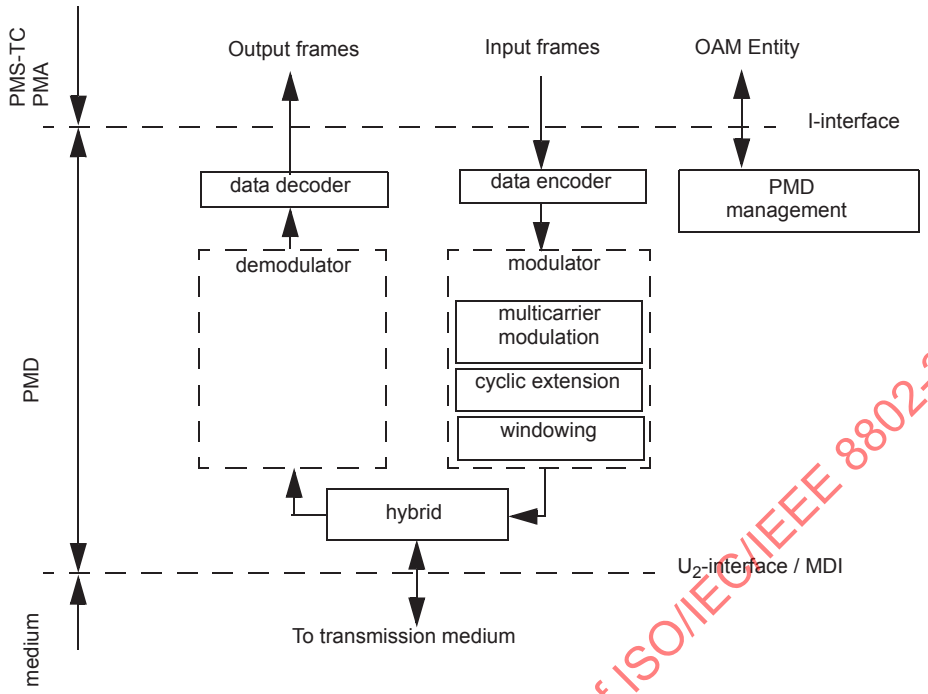

Figure 62–2—Functional diagram of PMD sublayer

62.3.2 PMD functional specifications

The 10PASS-TS PMD (and MDI) is specified by incorporating the MCM-VDSL standard, ANSI T1.424, by reference, with the modifications noted below. This standard provides support for voice-grade twisted pair.

62.3.3 General exceptions

The 10PASS-TS PMD is precisely the PMD specified as MCM-VDSL, with the following general modifications:

There are minor terminology differences between this standard and MCM-VDSL that do not cause ambiguity. The terminology used in 10PASS-TS was chosen to be consistent with other IEEE 802 standards, rather than with MCM-VDSL. Terminology is both defined and consistent within each standard. Special note should be made of the interpretations shown in Table 62–3.

Table 62–3—Interpretation of general MCM-VDSL terms and concepts

MCM-VDSL term or concept	Interpretation for 10PASS-TS
PMS-TC	PMA
VTU-O, LT	10PASS-TS-O
VTU-R, NT	10PASS-TS-R
Transmission medium dependent interface	MDI
U1-interface (splitter present)	
U2-interface (splitter absent)	

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62.3.4 Specific requirements and exceptions

The 10PASS-TS PMD (including MDI) shall comply to the requirements of MCM-VDSL Section 8 [Physical medium dependent (PMD) sublayer], Section 10 (Operations and maintenance), Section 11 (Link activation and deactivation) and Section 18 (Normative Annex 4—Handshake procedure for VDSL) with the exceptions listed below. Section 12 (Test procedures and requirements), Section 13 (Physical conditions), Section 14 (Environmental conditions), Section 15 (Normative Annex 1: International amateur bands), Section 16 (Informative Annex 2: VDSL PSD templates figures), Section 17 (Informative Annex 3: Utopia implementation of the ATM-TC interface), Section 19 (Informative Annex 5: FMT implementation), Section 20 (Informative Annex 6: 8.625 kHz tone spacing), Section 21 (Normative Annex 7: Electrical characteristics of service splitter at remote subscriber end), Section 22 (Informative Annex 8: Electrical characteristics of service splitter at network end), and Section 23 (Informative Annex 9: Alien crosstalk descriptions), are outside the scope of this standard. Where there is conflict between specifications in MCM-VDSL and those in this standard, those of this standard shall prevail. Optional specifications in MCM-VDSL are out of scope unless explicitly referenced in this document as mandatory. If out-of-scope optional features are implemented, the mode of operation of the PHY cannot be labeled "10PASS-TS" when these features are activated.

NOTE—If optional features are implemented, their use is negotiated during initialization.

62.3.4.1 Replacement of 8.2.1, "Multi-carrier Modulation"

10PASS-TS transceivers shall use Frequency Division Duplexing (FDD) to separate upstream and downstream transmission. 10PASS-TS transceivers shall support modulation of N_{SC} = 4096 subcarriers (n = 4). Disjoint subsets of the N_{SC} subcarriers shall be defined for use in the downstream and upstream directions. These subsets are determined by the choice of frequency plan. The exact subsets of subcarriers used to modulate data in each direction shall be determined during initialization and shall be based on management system settings and the signal-to-noise ratios (SNRs) of the subchannels. In many cases the number of subcarriers used in a direction will be less than the maximum number allowed by the partitioning.

Frequency plans are defined in Annex 62A. In standard frequency plans, frequency bands are allocated as shown in Figure 62–3. The values of the splitting frequencies are given in Annex 62A. Adherence to a particular frequency plan may be mandatory under local regulations when 10PASS-TS is deployed in public networks. Other frequency plans, for use in private networks, can be supported by means of Clause 45 register settings (see Annex 62C for examples).

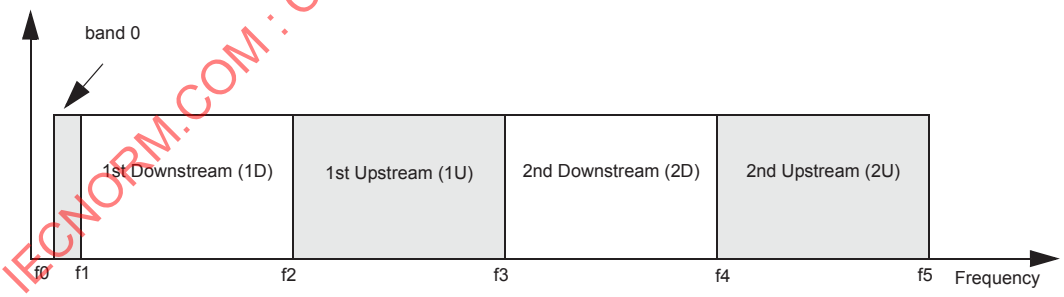

Figure 62–3—10PASS-TS band allocation

8.2.1.1 (Tone Spacing) is referenced as is.

8.2.1.2 (Data Sub Carriers) is referenced as is.

8.2.1.3 (IDFT modulation) is referenced as is.

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62.3.4.2 Changes to 8.2.2, “Cyclic extension”

8.2.2 of MCM-VDSL is further restricted by the following normative text:

The cyclic extension length is specified by the value of parameter *m*. In 10PASS-TS, support for the values $m = 10$, $m = 20$, and $m = 40$ is mandatory. The value $m=20$ is the default setting. Support for other values is out of scope.

62.3.4.3 Changes to 8.2.3, “Synchronization”

8.2.3.1 of MCM-VDSL is further clarified by the following text:

Support for pilot tones is mandatory. 10PASS-TS-O PHYs shall support the transmission of a pilot tone on any downstream tone.

8.2.3.2 (Loop Timing) is referenced as is.

8.2.3.3 (Timing Advance) is referenced as is.

8.2.3.4 of MCM-VDSL is replaced with the following:

The use of synchronous mode as defined in MCM-VDSL 8.2.3.4 may improve operation in certain binder environments and is a system implementation item that is outside the scope of this standard.

62.3.4.4 Replacement of 8.2.4, “Power back-off in the upstream direction”

To mitigate the effects of FEXT from short lines into long lines in distributed cable topologies, upstream power back-off shall be applied. Transceivers shall be capable of performing frequency-dependent power back-off.

It shall be possible to temporarily disable UPBO for performance testing purposes (as required by Annex 62B). In normal operation, only one UPBO mode shall be supported as described below:

a) It shall be possible for the network management system to set the limiting transmit PSD template PSD_0 for the 10PASS-TS-R to one of the standard transmit PSD templates as defined in the applicable section of 62A.3.3.
b) The 10PASS-TS-R shall perform UPBO autonomously, i.e., without sending any significant information to the 10PASS-TS-O until the UPBO is applied.
c) After UPBO has been applied as described in item b), the 10PASS-TS-O shall be capable of adjusting the transmit PSD selected by the 10PASS-TS-R; the adjusted transmit PSD shall be subject to the limitations given in the applicable section of 62A.3.3.

To enable the 10PASS-TS-R to initiate a connection with the 10PASS-TS-O, which will occur before UPBO has been applied, the 10PASS-TS-R shall be allowed to cause more degradation to other loops than expected when using the mode described below.

NOTE—Initiation refers to a request from the 10PASS-TS-R to start the initialization of the link. The particular method is in MCM-VDSL 11.2.

The 10PASS-TS-R shall explicitly estimate the electrical length of its line, kl_0, and use this value to calculate the transmit PSD template $TxPSD(kl_0,f)$. The 10PASS-TS-R shall then adapt its transmit signal PSD to conform to the template $TxPSD(kl_0,f)$ and the corresponding PSD mask, which is defined in the applicable section of 62A.3.3.

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The transmit PSD template shall be calculated as shown in Equation (62–1):

$$TxPSD(kl_0,f) = \min (PSD_REF(f) + LOSS(kl_0,f), PSD_0), \text{ in dBm/Hz} \quad (62–1)$$

where PSD_0 as defined in item a) in the previous list, and:

$$LOSS = kl_0 \, \text{sqrt}(f), \text{ in dB} \quad (62–2)$$

where the *LOSS* function is an approximation of the loop attenuation (insertion loss).

NOTE—The estimation of the electrical length should be sufficiently accurate to avoid spectrum management problems and additional performance loss.

PSD_REF will depend on the limiting transmit PSD template PSD_0 and on the noise model that is relevant for a given deployment scenario. The values of *PSD_REF* depend on the selected UPBO Reference PSD profile, as shown in Table 62A-3. The same bandwidth as for all regular transmit PSD masks defined in the applicable section of 62A.3.3 shall be used to check the conformance of *TxPSD* with power back-off. The general methodology for testing PSD conformance is defined in 6.1 of T1.417. Conformance with the PSD template shall be verified using a 100 kHz sliding window in the in-band frequency range below 1 MHz and a 1 MHz sliding window in the in-band frequency range above 1 MHz.

PSD_REF shall be input via the management interface (by means of the UPBO Reference PSD field in the 10P tone control parameter register, see 45.2.1.39) and shall be transmitted from the 10PASS-TS-O to the 10PASS-TS-R.

The 10PASS-TS-R shall estimate the insertion losses of the upstream bands based on the received downstream signals. From this, the shape of the *LOSS* function (or, equivalently, the electrical length) as defined above shall be derived. The 10PASS-TS-R shall then compute the transmit PSD by dividing the reference PSD in the upstream bands by the estimated *LOSS* function. Next, the 10PASS-TS-R shall take a tone-by-tone minimum of this computed PSD and the maximum allowed transmit PSD in the upstream direction. The result shall be used as the initial upstream transmit PSD. The PSD received by the 10PASS-TS-O should approximate the reference PSD. Upon receiving signals from the 10PASS-TS-R, the 10PASS-TS-O shall compare the actual received PSD to the reference PSD. If necessary, it shall instruct the 10PASS-TS-R to fine-tune its PSD.

The 10PASS-TS-O shall also have the capability to directly impose a maximum allowed transmit PSD at the 10PASS-TS-R. This maximum transmit PSD shall also be input via the management interface and shall be transmitted from 10PASS-TS-O to 10PASS-TS-R in the early stages of the initialization. The 10PASS-TS-O shall allow the operator to select one of these two methods. If the PBO is defined as a maximum transmit PSD at the 10PASS-TS-R, the 10PASS-TS-R shall adjust its transmit PSD such that it does not exceed the maximum allowed transmit PSD. The restrictions specified in the previous paragraph shall also apply in this case (i.e., the 10PASS-TS-O shall not impose a transmit PSD mask that violates the mask specified there).

62.3.4.5 Changes to 8.2.5, “Constellation encoder”

In 8.2.5 of MCM-VDSL, the constraints on B_{max_d} and B_{max_u} are replaced by the following constraints:

$$B_{max_d} = 12 \quad (62–3)$$

$$B_{max_u} = 12 \quad (62–4)$$

62.3.4.6 Changes to 8.2.8, “U-interface characteristics”

8.2.8 is replaced with the requirements specified in 62A.3.5.

All other subclauses in MCM-VDSL Clause 8 are referenced as is.

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62.3.4.7 Changes to section 10, “Operations and maintenance”

Referenced as is, with the addition of the mapping between VTU-R data registers and Clause 45 register access shown in Table 62–4.

Table 62–4—Mapping of VTU-R data registers to Clause 45

VTU-R data register (eoc)		Clause 45 register access 10PASS-TS-O		Clause 45 register access 10PASS-TS-R	
Register number	**Description[a]**	**register**	**Subclause**	**Clause 45 register**	**Subclause**
0_{16}	VTU-R vendor ID	not applicable			
1_{16}	VTU-R revision number	not applicable			
2_{16}	VTU-R serial number	not applicable			
3_{16}	Self-test results	PMA/PMD link status[b]	45.2.1.16.4	PMA/PMD link status[c]	45.2.1.16.4
4_{16}	Performance[d]	bytes 00_{16}–03_{16}: attainable DS rate	45.2.1.45	bytes 00_{16}–03_{16}: attainable DS rate	45.2.1.45
		bytes 04_{16}–05_{16}: FEC correctable errors	45.2.1.28	bytes 04_{16}–05_{16}: FEC correctable errors	45.2.1.26
		bytes 08_{16}–09_{16}: FEC uncorrectable errors	45.2.1.29	bytes 08_{16}–09_{16}: FEC uncorrectable errors	45.2.1.27
5_{16}	Vendor-discretionary	not applicable			
6_{16}	Loop attenuation	10P/2B line attenuation	45.2.1.23	10P/2B line attenuation	45.2.1.22
7_{16}	SNR margin	10P/2B RX SNR margin	45.2.1.21	10P/2B RX SNR margin	45.2.1.20
8_{16}	VTU-R configuration	not applicable			
9-F_{16}	For future use	not applicable			

[a]This is the description of the VTU-R data registers as given in MCM-VDSL.
[b]A non-zero value of the Self-test results register shall cause PMA/PMD link status to be cleared to 0.
[c]A non-zero value of the Self-test results register shall cause PMA/PMD link status to be cleared to 0.
[d]This field contains 16 bytes in total. The bytes that are not mapped to a Clause 45 register in this table, are reserved.

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62.3.4.8 Changes to 11.1, "VDSL Link State and Timing Diagram"

See Figure 62–4.

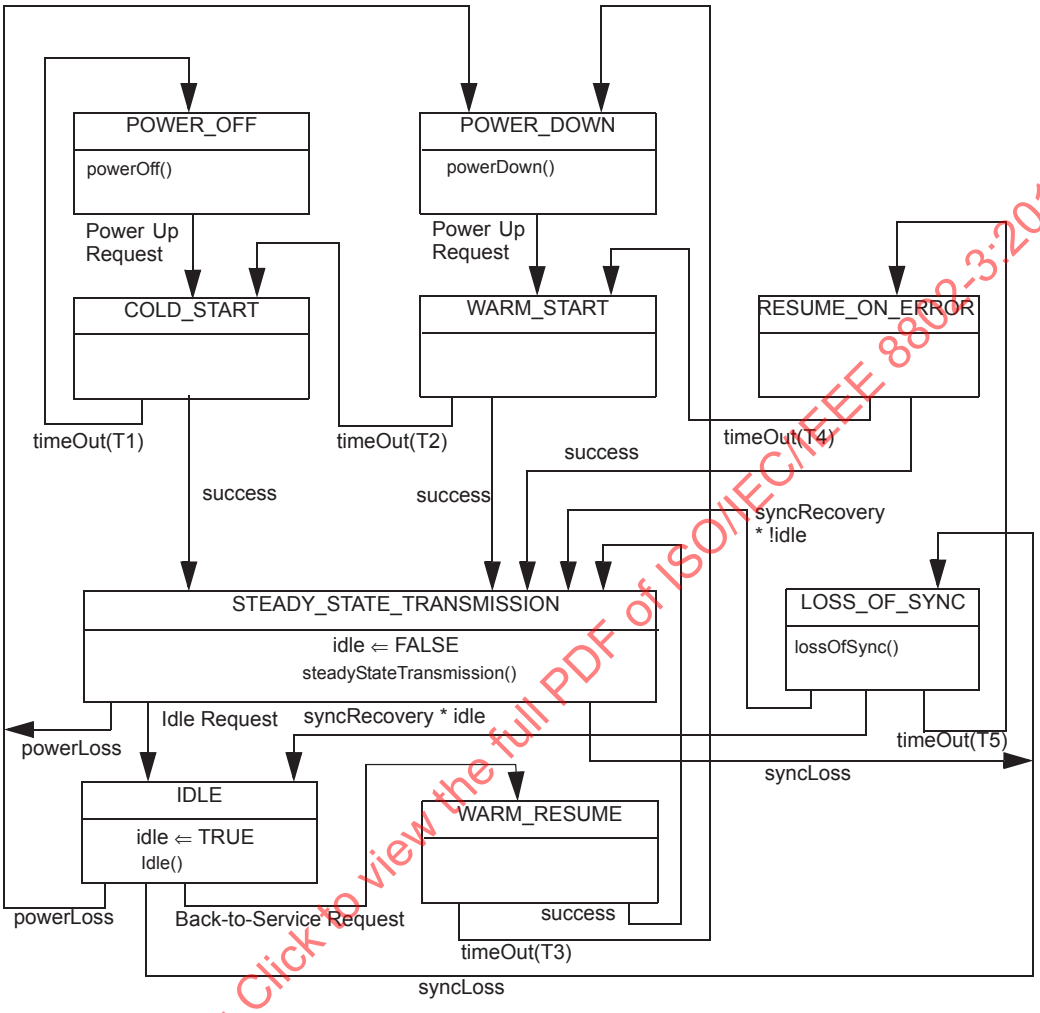

Figure 62–4—Link state and timing diagram

The function timeOut (time) returns FALSE upon entry of the associated state, and returns TRUE as soon as the interval specified by the argument "time" has expired. In addition, the state diagram uses following variables and constants:

T1
: Constant indicating the maximum cold-start activation time, equal to 10 000 ms

T2
: Constant indicating the maximum warm-start activation time, equal to 5000 ms

T3
: Constant indicating the maximum warm-resume activation time, equal to 100 ms

T4
: Constant indicating the maximum resume-on-error activation time, equal to 300 ms

T5
: Constant indicating the maximum sync-loss recovery time, equal to 200 ms

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idle Variable that indicates if the PMD has transitioned from STEADY_STATE_TRANSMISSION to IDLE. The idle variable becomes TRUE when the PMD enters the IDLE state, and becomes FALSE when the PMD enters the STEADY_STATE_TRANSMISSION mode.

success
Variable that is TRUE if and only if the procedures in the associated state were completed without error.

The following procedures are introduced to represent the actions associated with various states, as defined in MCM-VDSL.

powerOff()
See description of *Power-off* in MCM-VDSL section 11.1.1.1

steadyStateTransmission()
See description of *Steady-State Transmission* in MCM-VDSL section 11.1.1.1

lossOfSync()
See description of *Loss of Sync (Loss of Signal)* in MCM-VDSL section 11.1.1.1

powerDown()
See description of *Power Down* in MCM-VDSL section 11.1.1.1

idle()
See description of *Idle* in MCM-VDSL section 11.1.1.1

The remaining actions and transitions are documented in MCM-VDSL section 11.1, referenced as is.

62.3.4.9 Changes to section 18 (Annex 4), "Handshake procedure for VDSL"

62.3.4.9.1 Replacement of 18.1, "Introduction"

The 10PASS-TS handshake procedure is based on ITU-T Recommendation G.994.1 (G.hs). The carrier set used is specified in 61.3. During the handshake procedure, the following parameters shall be transmitted:

a) The size of IDFT/DFT;
b) the initial length of the cyclic extension;
c) flags indicating the use of the optional band, 25–138 kHz.

The parameters above shall be encoded using the information fields specified in 61.4.

62.3.4.9.2 Replacement of 18.2, "Description of signals"

The carrier set and signals used are specified in 61.4.

62.3.4.9.3 Replacement of 18.3, "Message coding format"

The message coding format and field definition tables are specified in 61.4.

62.3.4.9.4 Replacement of 18.4.1, "Handshake - 10PASS-TS-O"

The detailed procedures for handshake at the 10PASS-TS-O are defined in Recommendation G.994.1. A 10PASS-TS-O, after power-up, loss of signal, recovery from errors during the initialization procedure, shall enter the initial G.994.1 state C-SILENT1. The 10PASS-TS-O may transition to the Initialization Reset Procedure under instruction from the network. From either state, operation shall proceed according to the procedures defined in G.994.1.

If Recommendation G.994.1 procedures select 10PASS-TS as the mode of operation, the10PASS-TS-O shall transition to state O-QUIET at the conclusion of G.994.1 operation.

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A 10PASS-TS-O wishing to indicate 10PASS-TS capabilities during in a G.994.1 CL message shall do so by setting to 1_b the Level 1 SPar(1)10PASS-TS bit as defined in G.994.1. The NPar(2) and SPar(2) fields corresponding to the "10PASS-TS" Level 1 bit are defined in 61.4. For each Level 2 SPar(2) bit set to 1_b, a corresponding NPar(3) field shall also be present. These NPar(3) fields are defined in 61.4. The Level 2 bits in a CL message are defined in Table 62–5 and Table 62–6.

Table 62–5—10PASS-TS-O CL message NPar(2) bit definitions

NPar(2) bit	Definition
Upstream use of 25 kHz–138 kHz band	If set to 1_b, signifies that the 10PASS-TS-O is capable of using the band between 25 kHz and 138 kHz and that the band can be used for the upstream transmission.
Downstream use of 25 kHz–138 kHz band	If set to 1_b, signifies that the 10PASS-TS-O is capable of using the band between 25 kHz and 138 kHz and that the band can be used for the downstream transmission.
EOC-Clear	If set to 1_b, signifies that the 10PASS-TS-O supports transmission and reception of G.997.1 OAM frames.

Table 62–6—10PASS-TS-O CL message SPar(2) bit definitions

NPar(2) bit	Definition
Used bands in upstream	The use of this bit is optional. If set to 1_b, indicates the used upstream bands. The optional band between 25 kHz and 138 kHz shall not be included.
Used bands in downstream	The use of this bit is optional. If set to 1_b, indicates the used downstream bands. The optional band between 25 kHz and 138 kHz shall not be included.
IDFT/DFT size	Always set to 1_b in a CL message. Indicates the maximum IDFT/DFT size that 10PASS-TS-O can support. The value shall be present in the corresponding NPar(3) field.
Initial length of *CE*	If set to 0_b, it signifies that the 10PASS-TS-O can support only the mandatory cyclic extension length of $40*2^n$ for a number of tones equal to $256*2^n$. If set to 1_b in a CL message, it indicates the initial sample length of the cyclic extension that 10PASS-TS-O can support. It also signifies that the 10PASS-TS-O can support CE lengths other than the mandatory length. The value shall be present in the corresponding NPar(3) field. If one of the modems supports only the mandatory value, then this value shall be used.
RFI bands	The use of this bit is optional. If set to 1_b, indicates the RFI bands.

A PHY selecting 10PASS-TS mode of operation in a G.994.1 MS message shall do so by setting to 1_b the Level 1 SPar(1) 10PASS-TS-O bit as defined in G.994.1. The NPar(2) and SPar(2) fields corresponding to this bit are defined in 61.3. For each Level 2 SPar(2) bit set to 1b, a corresponding NPar(3) field shall also be present, as defined in 61.3. The Level 2 bits in an MS message from the 10PASS-TS-O are defined in Table 62–7 and Table 62–8.

If both bits Upstream use of optional band and Downstream use of optional band are enabled in the CL and CLR message, one and only one of the bits shall be set to 1_b in an MS message sent from the 10PASS-TS-O, and the use of the band between 25 kHz and 138 kHz is at the 10PASS-TS-O's discretion. If the 10PASS-TS-O and 10PASS-TS-R have no common usage of the optional band, both bits shall be set to 0_b in an MS message sent from the 10PASS-TS-O.

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Table 62–7—10PASS-TS-O MS message NPar(2) bit definitions

NPar(2) bit	Definition
Upstream use of 25 kHz–138 kHz band	Set to 1_b if and only if this bit was set to 1_b in both the last previous CL message and the last previous CLR message. It signifies that the band between 25 kHz and 138 kHz shall be used for the upstream transmission.
Downstream use of 25 kHz–138 kHz band	Set to 1_b if and only if this bit was set to 1_b in both the last previous CL message and the last previous CLR message. It signifies that the band between 25 kHz and 138 kHz shall be used for the downstream transmission.
EOC-Clear	Set to 1_b if and only if this bit was set to 1_b in both the last previous CL message and the last previous CLR message. Signifies that both 10PASS-TS-O and 10PASS-TS-R may transmit and receive G.997.1 OAM frames.

Table 62–8—10PASS-TS-O MS message SPar(2) bit definitions

NPar(2) bit	Definition
Used bands in upstream	Always set to 0_b in an MS message.
Used bands in downstream	Always set to 0_b in an MS message.
IDFT/DFT size	Always set to 1_b in an MS message. Indicates the maximum IDFT/DFT size that both 10PASS-TS-O and 10PASS-TS-R can support. The value shall be present in the corresponding NPar(3) field.
Initial length of *CE*	Set to 0_b if and only if this bit was set to 0_b in the last previous CL message or the last previous CLR message, or both. It signifies that both 10PASS-TS-O and 10PASS-TS-R shall use only the mandatory cyclic extension length. Set to 1_b if and only if this bit was set to 1_b in both the last previous CL message and the last previous CLR message. It indicates the initial sample length of the cyclic extension. It also signifies that both 10PASS-TS-O and 10PASS-TS-R can support CE lengths other than the mandatory length. The value shall be given in the corresponding NPar(3) field.
RFI bands	Always set to 0_b in an MS message.

62.3.4.9.5 Replacement of 18.4.2, “Handshake - 10PASS-TS-R”

The detailed procedures for handshake at the 10PASS-TS-R are defined in Recommendation G.994.1. An 10PASS-TS-R, after power-up, loss of signal, recovery from errors during the initialization procedure, shall enter the initial G.994.1 state R-SILENT0. Upon command from the host controller, the 10PASS-TS-R shall initiate handshaking by invoking the Initialization Reset Procedure. Operation shall then proceed according to the procedures defined in G.994.1.

If Recommendation G.994.1 procedures select 10PASS-TS as the mode of operation, the 10PASS-TS-R shall transition to state R-QUIET at the conclusion of G.994.1 operation.

A 10PASS-TS-R wishing to indicate 10PASS-TS capabilities during in a G.994.1 CLR message shall do so by setting to 1_b the Level 1 SPar(1) 10PASS-TS bit as defined in G.994.1. The NPar(2) and SPar(2) fields corresponding to the “10PASS-TS” Level 1 bit are defined in 61.4. For each Level 2 SPar(2) bit set to 1_b, a corresponding NPar(3) field shall also be present. These NPar(3) fields are defined in 61.4. The Level 2 bits in a CLR message are defined in Table 62–9 and Table 62–10.

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Table 62–9—10PASS-TS-R CLR message NPar(2) bit definitions

NPar(2) bit	Definition
Upstream use of 25 kHz–138 kHz band	If set to 1_b, signifies that the 10PASS-TS-R is capable of using the band between 25 kHz and 138 kHz and that the band can be used for the upstream transmission.
Downstream use of 25 kHz–138 kHz band	If set to 1_b, signifies that the 10PASS-TS-R is capable of using the band between 25 kHz and 138 kHz and that the band can be used for the downstream transmission.
EOC-Clear	If set to 1_b, signifies that the 10PASS-TS-R supports transmission and reception of G.997.1 OAM frames.

Table 62–10—10PASS-TS-R CLR message SPar(2) bit definitions

NPar(2) bit	Definition
Used bands in upstream	Always set to 0_b in a CLR message.
Used bands in downstream	Always set to 0_b in a CLR message.
IDFT/DFT size	Always set to 1_b in a CLR message. Indicates the maximum IDFT/DFT size that 10PASS-TS-R can support. The value shall be present in the corresponding NPar(3) field.
Initial length of *CE*	If set to 0_b, it signifies that the 10PASS-TS-R can support only the mandatory cyclic extension length of 40×2^n for a number of tones equal to 256×2^n. If set to 1_b in a CLR message, it indicates the initial sample length of the cyclic extension that 10PASS-TS-R can support. It also signifies that the 10PASS-TS-R can support CE lengths other than the mandatory length. The value shall be present in the corresponding NPar(3) field. If one of the modems supports only the mandatory value, then this value shall be used.
RFI bands	Always set to 0_b in a CLR message.

A 10PASS-TS-R selecting 10PASS-TS mode of operation in a G.994.1 MS message shall do so by setting to 1_b the Level 1 SPar(1) 10PASS-TS bit as defined in G.994.1. The NPar(2) and SPar(2) fields corresponding to this bit are defined in 61.4. For each Level 2 SPar(2) bit set to 1_b, a corresponding NPar(3) field shall also be present, as defined in 61.4. The Level 2 bits in an MS message from the 10PASS-TS-R are defined in Table 62–11 and Table 62–12.

If both bits Upstream use of optional band and Downstream use of optional band are enabled in the CL and CLR message, one and only one of the bits shall be set to 1_b in an MS message sent from the 10PASS-TS-R, and the use of the band between 25 kHz and 138 kHz shall be at the 10PASS-TS-R's discretion. If the 10PASS-TS-O and 10PASS-TS-R have no common usage of the optional band, both bits shall be set to 0_b in an MS message sent from the 10PASS-TS-R.

62.3.5 Transmission medium interface characteristics

This subclause specifies the interface between the transceiver and the transmission medium (U2 reference point). The interface at U1 reference point (see MCM-VDSL Section 5.1 for VDSL reference model) is specified by the corresponding characteristics of the service splitter. The definition of the service splitter is outside the scope of this standard. Relevant specifications may be found in MCM-VDSL Clause 21 and Clause 22.

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Table 62–11—10PASS-TS-R MS message NPar(2) bit definitions

NPar(2) bit	Definition
Upstream use of 25 kHz–138 kHz band	Set to 1_b if and only if this bit was set to 1_b in both the last previous CL message and the last previous CLR message. It signifies that the band between 25 kHz and 138 kHz shall be used for the upstream transmission.
Downstream use of 25 kHz–138 kHz band	Set to 1_b if and only if this bit was set to 1_b in both the last previous CL message and the last previous CLR message. It signifies that the band between 25 kHz and 138 kHz shall be used for the downstream transmission.
EOC-Clear	Set to 1_b if and only if this bit was set to 1_b in both the last previous CL message and the last previous CLR message. Signifies that both 10PASS-TS-O and 10PASS-TS-R may transmit and receive G.997.1 OAM frames.

Table 62–12—10PASS-TS-R MS message SPar(2) bit definitions

NPar(2) bit	Definition
Used bands in upstream	Always set to 0_b in an MS message.
Used bands in downstream	Always set to 0_b in an MS message.
IDFT/DFT size	Always set to 1_b in an MS message. Indicates the maximum IDFT/DFT size that both 10PASS-TS-O and 10PASS-TS-R can support. The value shall be present in the corresponding NPar(3) field.
Initial length of *CE*	Set to 0_b if and only if this bit was set to 0_b in the last previous CL message or the last previous CLR message, or both. It signifies that both 10PASS-TS-O and 10PASS-TS-R shall use only the mandatory cyclic extension length. Set to 1_b if and only if this bit was set to 1_b in both the last previous CL message and the last previous CLR message. It indicates the initial sample length of the cyclic extension. It also signifies that both 10PASS-TS-O and 10PASS-TS-R can support CE lengths other than the mandatory length. The value shall be given in the corresponding NPar(3) field.
RFI bands	Always set to 0_b in an MS message.

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62.3.5.1 Transmit signal characteristics

62.3.5.1.1 Wide-band power

The average wide-band power of the transmitted 10PASS-TS signal measured over the frequency range between 25 kHz to 12 MHz shall be no greater than the values listed in Table 62–13 when terminated with resistive impedance of $R_V = 100\ \Omega$.

NOTE 1—For compliance with this requirement, the 10PASS-TS transceiver is terminated with the impedance R_V and configured to transmit pseudo-random data with any repetitive framing patterns enabled.

NOTE 2—Power is measured across the termination resistance of R_V. No energy is inserted into the POTS/ISDN port of the splitter (if applied) during this test.

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Table 62–13—10PASS-TS maximum transmit power

Central office deployment scenario		Cabinet deployment scenario	
Downstream [dBm]	Upstream [dBm]	Downstream [dBm]	Upstream [dBm]
14.5	14.5	11.5	14.5

62.3.5.1.2 Power spectral density (PSD)

Transmit PSD is characterized by the PSD template and PSD mask. PSD templates and masks are defined in Annex 62A.

62.3.5.1.3 Egress control

To avoid potential harm to amateur radio service due to radiated emission from 10PASS-TS, it shall be possible to reduce the PSD of the transmit signal within the amateur radio bands. Specifications for egress power control are described in Annex 62A.

62.3.5.2 Termination impedance

A termination impedance of $R_v = 100\ \Omega$ (purely resistive, either source or load) shall be used over the entire 10PASS-TS frequency band for both the 10PASS-TS-O and 10PASS-TS-R when matching to the metallic wire-pair.

This termination impedance approximates (and is based upon) the insertion-point impedance of the 10PASS-TS test loop. It enables a compromise high-frequency impedance match to the various types of unshielded cable in metallic access networks.

62.3.5.3 Return loss

The return loss requirement is defined to limit signal power uncertainties due to the tolerance of the line interface impedance. The return loss *RL* specifies the amount of reflected differential signal upon a reference impedance R_V

$$RL = 20 \times \log\left|\frac{Z + R_V}{Z - R_V}\right| \tag{62–5}$$

where Z is the internal impedance of the VTU. Note that in Equation (62–5), the log is taken to base 10, such that *RL* is expressed in dB.

The in-band return loss value of the 10PASS-TS transceiver shall be greater than or equal to 12 dB. The out-of-band return loss value shall be greater than or equal or 3 dB. In-band and out-of-band frequencies are defined by the frequency plan as shown in Figure 62–3 and by the transmit direction.

The value of 12 dB assumes a flat transmit PSD is applied over the entire in-band region. Requirements may be relaxed in the frequency ranges of reduced PSD values. The exact value requirements are outside the scope of this standard.

The return loss shall be measured on a resistive test load of $R_V = 100\ \Omega$ while the tested implementation of the 10PASS-TS transceiver is powered.

NOTE—If a splitter is used, the return-loss requirements should be met for the full range of possible values of the POTS/ISDN port termination.

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62.3.5.4 Output signal balance

Output signal balance (*OSB*) is a measure of unwanted longitudinal signals at the output of the transceiver, as defined by Equation (62–6). The longitudinal output voltage (V_{cm}) to the differential output voltage (V_{diff}) ratio shall be measured while the 10PASS-TS transmitter is active in accordance with ITU-T Recommendation G.117 and ITU-T Recommendation O.9.

$$OSB = 20\log\left|\frac{V_{diff}}{V_{cm}}\right| \quad (62–6)$$

The *OSB* of the 10PASS-TS transceiver shall be equal to or greater than 35 dB in the entire 10PASS-TS band.

NOTE—The equipment balance should be better than the anticipated cable balance in order to minimize the unwanted emissions and susceptibility to external RFI. The typical worst case balance for an aerial drop-wire has been observed to be in the range 30 dB – 35 dB, therefore the balance of the 10PASS-TS equipment should be equal or better.

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62.4 Protocol implementation conformance statement (PICS) proforma for Clause 62, Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 10PASS-TS[17]

62.4.1 Introduction

The supplier of a protocol implementation that claimed to conform to Clause 62, Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 10PASS-TS, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

62.4.2 Identification

62.4.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification--e.g., names and versions for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

62.4.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 62, Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 10PASS-TS.
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	
Date of Statement	

[17] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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62.4.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
10PPMA	MCM-VDSL based PMA	62.2	The PMA based on the PMS-TC specified in American National Standard T1.424 is implemented.	M	Yes [ ]
10PPMD	MCM-VDSL based PMD	62.3	The PMD based on the PMD specified in American National Standard T1.424 is implemented.	M	Yes [ ]

62.4.4 PICS proforma tables for the Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 10PASS-TS

62.4.4.1 MCM-VDSL based PMA

Item	Feature	Subclause	Value/Comment	Status	Support
10PPMA-1	DMT PMA functional specifications	62.2	All data bytes are transmitted MSB first.	M	Yes [ ]
10PPMA-2	DMT PMA functional specifications	62.2	All serial processing is performed LSB first, with the outside world MSB considered as the VDSL LSB.	M	Yes [ ]
10PPMA-3	Specific requirements and exceptions	62.2.4	The 10PASS-TS PMA complies to the requirements of MCM-VDSL Section 9.3, with the exception of support for the fast path, support for V>1, NTR, and TPS-TC specific bits as listed.	M	Yes [ ]
10PPMA-4	Specific requirements and exceptions: Reed-Solomon	62.2.4.2	The 10PASS-TS PMA supports Reed-Solomon settings (144,128) and (240, 224).	M	Yes [ ]
10PPMA-5	Specific requirements and exceptions: Interleaver	62.2.4.2	For (N,K) = (144,128) the following values for M and I are supported: I=36 and M between 2 and 52. For (N,K)=(240,224) the following values for M and I are supported: I=30 and M between 2 and 62.	M	Yes [ ]

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62.4.4.2 MCM-VDSL based PMD

Item	Feature	Subclause	Value/Comment	Status	Support
10PPMD-1	Specific requirements and exceptions	62.3.4	The PMD complies to the requirements of MCM-VDSL Section 8, Section 10, Section 11, and Section 12, with the exceptions listed.	M	Yes [ ]
10PPMD-2	Duplexing and Modulation	62.3.4.1	The PMD uses Frequency Division Duplexing to separate upstream and downstream transmission.	M	Yes [ ]
10PPMD-3	Duplexing and Modulation	62.3.4.1	The PMD supports modulation of $N_{SC} = 4096$ subcarriers.	M	Yes [ ]
10PPMD-4	Duplexing and Modulation	62.3.4.1	The PMD supports modulation of $B_{max_d} = 12$ bits per downstream subcarrier and $B_{max_u} = 12$ bits per upstream subcarrier.	M	Yes [ ]
10PPMD-5	Duplexing and Modulation	62.3.4.1	Disjoint subsets of the N_{SC} subcarriers are defined for use in the downstream and upstream directions.	M	Yes [ ]
10PPMD-6	Duplexing and Modulation	62.3.4.1	The exact subsets of subcarriers used to modulate data in each direction are determined during initialization, based on management system settings and the signal-to-noise ratios of the subchannels.	M	Yes [ ]
10PPMD-7	Duplexing and Modulation	62.3.4.1	The use of the band between 25 kHz and 138 kHz is negotiated during the initialization to indicate if the capability exists and select one of the following options: use for upstream transmission, use for downstream transmission, not used.	M	Yes [ ]
10PPMD-8	Duplexing and Modulation	62.3.4.1	10PASS-TS-O PMD supports the transmission of a pilot tone on any downstream tone.	M	Yes [ ]
10PPMD-9	Upstream Power Back-Off	62.3.4.1	Upstream power back-off is applied to mitigate the effects of FEXT from short lines into long lines in distributed cable topologies.	M	Yes [ ]
10PPMD-10	Upstream Power Back-Off	62.3.4.1	The PMD is capable of performing frequency-dependent power back-off.	M	Yes [ ]
10PPMD-11	Upstream Power Back-Off	62.3.4.1	It is possible for the network management system to set the limiting transmit PSD template PSD_0 for the 10PASS-TS-R to one of the standard transmit PSD templates as defined in the applicable section of 62A.3.4.	M	Yes [ ]
10PPMD-12	Upstream Power Back-Off	62.3.4.1	The 10PASS-TS-R PMD performs UPBO autonomously, i.e., without sending any significant information to the 10PASS-TS-O until the UPBO is applied.	M	Yes [ ]
10PPMD-13	Upstream Power Back-Off	62.3.4.1	The 10PASS-TS-O is capable of adjusting the transmit PSD selected by the 10PASS-TS-R, after UPBO has been applied. The adjusted transmit PSD is subject to the limitations given in the applicable section of 62A.3.3.	M	Yes [ ]

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10PPMD-14	Upstream Power Back-Off	62.3.4.1	The 10PASS-TS-R estimates the insertion losses of the upstream bands based on the received downstream signals. The 10PASS-TS-R explicitly estimates the electrical length of its line, kl_0, and uses this value to calculate the transmit PSD template TxPSD per Equation (62–1) and Equation (62–2).	M	Yes [ ]
10PPMD-15	Upstream Power Back-Off	62.3.4.1	The 10PASS-TS-R adapts its transmit signal PSD to conform to the template TxPSD and the corresponding PSD mask which is defined in the applicable section of 62A.3.3. The same bandwidth as for all regular transmit PSD masks defined in the applicable section of 62A.3.3 are used to check the conformance of TxPSD with power back-off. Conformance with the PSD template is verified using a 100 kHz sliding window in the in-band frequency range below 1 MHz and a 1 MHz sliding window in the in-band frequency range above 1 MHz.	M	Yes [ ]
10PPMD-16	Upstream Power Back-Off	62.3.4.1	PSD_REF is input via the management interface.	M	Yes [ ]
10PPMD-17	Upstream Power Back-Off	62.3.4.1	PSD_REF is transmitted from the 10PASS-TS-O to the 10PASS-TS-R.	M	Yes [ ]
10PPMD-18	Upstream Power Back-Off	62.3.4.1	The 10PASS-TS-R takes a tone-by-tone minimum of its computed PSD and the maximum allowed transmit PSD in the upstream direction. The result is used as the initial upstream transmit PSD.	M	Yes [ ]
10PPMD-19	Upstream Power Back-Off	62.3.4.1	Upon receiving signals from the 10PASS-TS-R, the 10PASS-TS-O compares the actual received PSD to the reference PSD. If necessary, it instructs the 10PASS-TS-R to fine-tune its PSD.	M	Yes [ ]
10PPMD-20	Upstream Power Back-Off	62.3.4.1	The 10PASS-TS-O has the capability to directly impose a maximum allowed transmit PSD at the 10PASS-TS-R.	M	Yes [ ]
10PPMD-21	Upstream Power Back-Off	62.3.4.1	The maximum transmit PSD is input via the management interface.	M	Yes [ ]
10PPMD-22	Upstream Power Back-Off	62.3.4.1	The maximum transmit PSD is transmitted from 10PASS-TS-O to 10PASS-TS-R during initialization.	M	Yes [ ]
10PPMD-23	Upstream Power Back-Off	62.3.4.1	The 10PASS-TS-O allows the operator to select between the UPBO method based on Reference PSD and the UPBO method based on maximum transmit PSD.	M	Yes [ ]
10PPMD-24	Handshake	62.3.4.9	The handshake uses the 4.3125 kHz signaling family and the duplex transmission mode.	M	Yes [ ]

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10PPMD-25	Handshake	62.3.4.9	The handshake proceeds as specified in 61.4.	M	Yes [ ]
10PPMD-26	Wide-band power	62.3.5.1.1	The average wide-band power of the transmitted 10PASS-TS signal measured over the frequency range between 25 kHz to 12 MHz is no greater than the values listed in Table 62–13 when terminated with resistive impedance of RV = 100 Ohm.	M	Yes [ ]
10PPMD-27	Egress control	62.3.5.1.3	To avoid potential harm to amateur radio service due to radiated emission from 10PASS-TS, it is possible to reduce the PSD of the transmit signal within the amateur radio bands.	M	Yes [ ]
10PPMD-28	Termination impedance	62.3.5.2	A termination impedance of Rv = 100 Ohm is used over the entire 10PASS-TS frequency band for both the 10PASS-TS-O and 10PASS-TS-R when matching to the metallic wire-pair.	M	Yes [ ]
10PPMD-29	Return loss	62.3.5.3	The in-band return loss value of the 10PASS-TS transceiver are greater than or equal to 12 dB.	M	Yes [ ]
10PPMD-30	Return loss	62.3.5.3	The out-of-band return loss value are greater than or equal or 3 dB.	M	Yes [ ]
10PPMD-31	Return loss	62.3.5.3	Requirements are relaxed in the frequency ranges of reduced PSD values.	O	Yes [ ] No [ ]
10PPMD-32	Return loss	62.3.5.3	The return loss are measured on a resistive test load of R_V = 100 Ohm while the tested implementation of the 10PASS-TS transceiver is powered.	M	Yes [ ]
10PPMD-33	Output signal balance	62.3.5.4	The longitudinal output voltage to the differential output voltage ratio is measured while the VTU transmitter is active in accordance with ITU-T Recommendation G.117 and ITU-T Recommendation O.9.	M	Yes [ ]
10PPMD-34	Output signal balance	62.3.5.4	The OSB of the 10PASS-TS transceiver is equal to or greater than 35 dB in the entire 10PASS-TS band.	M	Yes [ ]

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63. Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 2BASE-TL

63.1 2BASE-TL Overview

63.1.1 Scope

This clause specifies the 2BASE-TL Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD) sublayer for voice grade twisted-pair wiring. In order to form a complete 2BASE-TL PHY, the 2BASE-TL PMA and PMD are integrated with the TC and PCS of Clause 61. Parts of register 3.0, parts of register 3.4 and registers 3.60 through 3.73 specified in Clause 45 may be used to control the PCS of Clause 61. Parts of register 6.0 and registers 6.16 through 6.23 specified in Clause 45 may be used to control the TC sublayer of Clause 61. Registers 1.16 through 1.42 and 1.80 through 1.109 specified in Clause 45 may be used to control the 2BASE-TL PMA and PMD.

63.1.2 Objectives

The following are the objectives for the 2BASE-TL PMA and PMD:

a) To provide 2 Mb/s encapsulated packet data rate at the α(β)-interface.

b) To provide full duplex operation.

c) To provide for operating over non-loaded voice grade twisted pair cable at distances up to 2700 m.

d) To provide a communication channel with a mean bit error ratio, at the α(β)-interface, of less than one part in 10^7 with 5 dB noise margin.

63.1.3 Relation of 2BASE-TL to other standards

The specifications of the 2BASE-TL PMA and PMD are based on the SHDSL transceiver (PMD and PMS-TC) specified in ITU-T Recommendation G.991.2.

Item	Feature	Subclause	Value/Comment	Status	Support

63.1.4 Summary of Physical Medium Attachment (PMA) specification

This layer is defined by the α(β)-interface and the I-interface. Figure 63–1 shows a functional diagram of the 2BASE-TL PMA layer functionality. The payload is formed into a 2BASE-TL PMA frame with overhead added (for example, the PME aggregation Header). The framed data is then scrambled and sent to the PMD sublayer. One distinguishes between the data mode PMA specification that is used during normal data operation and the activation PMA specification that is used when the PMD is training.

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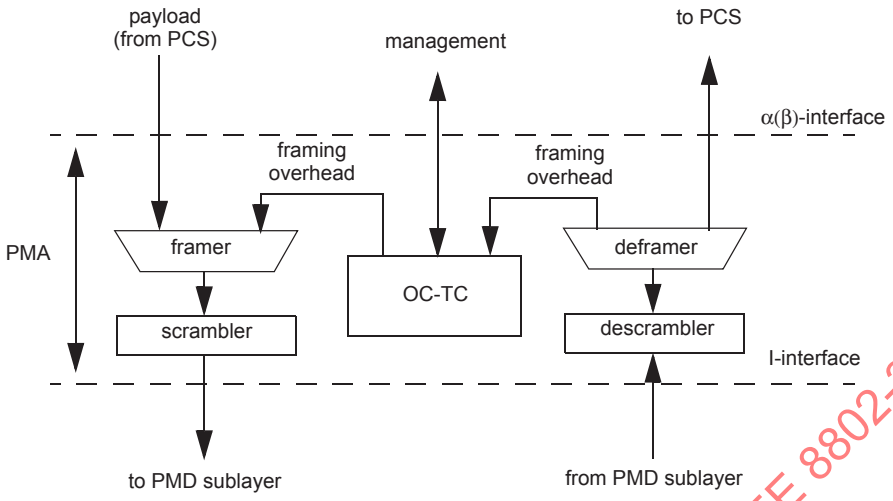

Figure 63–1—Diagram of PMA sublayer

63.1.4.1 α(β)-interface

A complete definition of the α(β)-interface is contained in 61.3.2. The signal PMA_receive_synchronized, defined in 61.3.2.2, shall be asserted when the LOSW bit is set to 0 (see 63.2.2.2), and deasserted when the LOSW is set to 1.

63.1.4.2 The I-interface

The I_O and I_R reference points define interfaces between the PMA and PMD in the 2BASE-TL-O and 2BASE-TL-R, respectively. Both interfaces are functional, application independent and identical. Both interfaces are defined by the following signal flows:

a) Data flow
b) Synchronization flow

The specification of the I-interface is implicit in ITU-T Recommendation G.991.2.

63.1.4.2.1 The I Data Flow

The data flow consists of two octet-oriented streams, both with the PMA frame format, with the bit rates defined by the PMD transmission profile:

a) Transmit data (Tx)
b) Receive data (Rx)

If data streams are implemented serially, the LSB of each octet (i.e., b_8 of Figure 61–16) shall be sent first. In section 7.1.1 of G.991.2, with i = 0, the payload blocks are made of a stream of octets. Each octet consists of 8 bits. The first bit of each octet (i.e., lowest frame bit number in an octet) maps to b_8 in Figure 61–16 and the last bit of each octet maps to b_1 of Figure 61–16.

Each stream bit rate value is set during PMD configuration.

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63.1.4.2.2 I Synchronization Flow

The synchronization flow consists of the transmitted and received octet synchronization signals (Clko_t, Clko_r). Optional transmit and receive bit-synchronization signals (Clkp_t, Clkp_r) are defined too.

Synchronization signals are asserted by the PMD and directed towards the PMA.

The synchronization signals are described in Table 63–1.

Table 63–1—I-interface signals

Signal(s)	Description	Direction	Notes
Data Signals			
Tx	Transmit data stream	PMA → PMD	Transmission frame format.
Rx	Receive data stream	PMA ← PMD	
Synchronization Signals			
Clko_t	Transmitted octet timing	PMA ← PMD	
Clko_r	Received octet timing	PMA ← PMD	
Clkp_t	Transmitted bit timing	PMA ← PMD	Optional
Clkp_r	Received bit timing	PMA ← PMD	Optional

63.1.4.3 Operation Channel (OC)

The OC-TC function of the PMA shall receive the EOC and overhead indicators over the OC-TC interface. For each 2BASE-TL PMA frame, the OC shall deliver a fixed number of embedded operations channel (EOC) and overhead indicators bits to the framer. These bits shall be included in the overhead sections of the 2BASE-TL PMA frames.

63.1.5 Summary of Physical Medium Dependent (PMD) specification

The PMD specification is based on Pulse Amplitude Modulation (PAM) and is divided into three consecutive phases, summarized as follows:

a) Preactivation: during this phase, the PMDs determine each other capabilities and the bit rate they will operate at in data mode. Reference section 6.3.1 (included in this standard per 63.3.2.2) describes the preactivation reference model. The preactivation uses G.994.1 as a handshake mechanism to exchange parameters in accordance with the specifications in 61.4. It also offers an optional line probing capability. The line probe uses 2-level PAM signals to determine a suitable bit rate to run at on the copper link.

b) Activation: during this phase, the PMDs train and exchange information necessary to adapt and operate the various filters and processes necessary during data mode operation. Reference section 6.2.1 describes the Activation reference model. The activation uses 2-level PAM to train the various filters.

c) Data Mode: once pre-activation and activation are complete, the PMD can start transmitting payload data. Reference section 6.1.1 describes the Data Mode reference model.

NOTE—Line activation takes place after entire discovery and PME aggregation operation.

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63.2 2BASE-TL PMA functional specifications

The 2BASE-TL PMA is specified by incorporating the SHDSL standard, ITU-T Recommendation G.991.2 (02/2001) with the changes specified in G.991.2 Amendment 1 (11/2001), by reference, with the modifications noted below. This standard provides support for voice-grade twisted pair. For improved legibility in this clause, ITU-T Recommendation G.991.2 and G.991.2 Amendment 1, will henceforth be referred to as G.991.2.

63.2.1 General exceptions

The 2BASE-TL PMA is precisely the PMS-TC specified in G.991.2, with the following general modifications:

a) There are minor terminology differences between this standard and G.991.2 that do not cause ambiguity. The terminology used in 2BASE-TL was chosen to be consistent with other IEEE 802 standards, rather than with G.991.2. Terminology is both defined and consistent within each standard. Special note should be made of the interpretations shown in Table 63–2.

Table 63–2—Interpretation of general G.991.2 terms and concepts

G.991.2 term or concept	Interpretation for 2BASE-TL
PMS-TC	PMA
STU-C, LT	2BASE-TL-O
STU-R, NT	2BASE-TL-R
Transmission medium dependent interface, U-interface	MDI
byte	octet

b) The 2BASE-TL PMA supports only one channel of user data with an associated γ-interface.
c) The 2BASE-TL PMA does not support the optional “four-wire mode”. Operation over multiple pairs is optional; if implemented, multi-pair operation shall comply to the specifications in 61.2.2.
d) The 2BASE-TL PMA does not support “plesiochronous mode”.
e) The 2BASE-TL PMA shall be octet oriented; hence, the bit oriented parameter *i* defined for Equation (63–1) shall be equal to *0* in all cases.
f) The 2BASE-TL PMA does not support the notion of “sub-blocks” in the Payload Block. Each payload block consists of a contiguous sequence of 12*n* octets, with parameter *n* as defined for Equation (63–1).

63.2.2 Specific requirements and exceptions

The 2BASE-TL PMA shall comply to the requirements of G.991.2 Section 7 and Section 9 with the exceptions listed below. Where there is conflict between specifications in G.991.2 and those in this standard, those of this standard shall prevail.

Implementation of optional specifications in G.991.2 is not required for compliance with this standard. Reference Section 8 (TPS-TC Layer Functional Characteristics), Reference Annex D (Signal Regenerator Operation), Reference Annex E (Application-specific TPS-TC Framing) and Reference Appendices I, II, and III are out of scope for 2BASE-TL PMA. Deployment of compatible versions of G.991.2 Annex D is an implementation specific option for the purposes of 2BASE-TL.

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63.2.2.1 Changes to 7.1, “Data Mode Operation”

Reference 7.1.1 (Frame Structure) is replaced with the following:

Table 7-1 of the Reference summarizes the SHDSL frame structure. Complete bit definitions may be found in Reference 7.1.2. The size of each payload block is defined as k bits, where $k = 96n$. The payload rate r (in kb/s) is given by Equation (63–1) and Equation (63–3), with $i = 0$. The value of n is limited by Equation (63–2) and Equation (63–4).

Reference 7.1.2.6 (Stuff Indicator bits) is replaced with the following:

2BASE-TL operates in synchronous mode, therefore *sbid1* and *sbid2* are spare bits.

Reference 7.1.2.7 (Stuffing Bits) is replaced with the following:

2BASE-TL operates in synchronous mode, therefore *stb1* and *stb2* shall be present in every frame, and *stb3* and *stb4* shall not be present.

Reference 7.1.4 (Frame synchronization) is replaced with the following:

The precise manner in which frame synchronization is acquired or maintained is the choice of the receiver designer. Since different frame synchronization algorithms may require different values for the bits of the FSW, a provision has been made to allow the receiver to inform the far-end transmitter of the particular values that are to be used for this field in the transmitted PMS-TC frame.

All other subsections of Reference 7.1 are referenced as is.

63.2.2.2 Changes to Section 9, “Management”

Referenced as is, with the exception of 9.5.5.6 where Message IDs 17 “ATM Cell Status Request”, 20 “ISDN Request”, 145 “ATM Cell Status Information” and 148 “ISDN Response” are out of scope.

63.2.2.3 Relation between the 2BASE-TL registers and the SHDSL management functions

The parameters of the various 2BASE-TL registers of the -R device, defined in Clause 45, are gathered via the SHDSL management. SNR margin, code violations, ES, SES, LOSW, UAS, SNR margin defect, Loop attenuation defect and loss of sync word failure shall be obtained in the following way:

The 2BASE-TL-O shall send a Status Request (Msg ID 11) EOC message. If there has been any change in performance status other than SNR margin since the last time a unit was polled, the peer 2BASE-TL-R shall respond with an SHDSL Network Side Performance Status (Msg ID 140) EOC message.

The following octets and bits are then mapped to the Clause 45 registers (see Table 63–3):

Otherwise, the peer 2BASE-TL-R shall respond with a Status/SNR (Msg ID 139) EOC message, in which the SNR margin is communicated in octet 2.

Loop attenuation and SNR margin threshold for both 2BASE-TL-O and 2BASE-TL-R devices shall be set in the Clause 45 register of the 2BASE-TL-O device; the 2BASE-TL-R thresholds will be passed to the 2BASE-TL-R using message ID 3.

The segment defect is defined in section 9.2.4 and uses a dedicated framing bit rather than the EOC messaging.

The retrieval of the remote vendor ID is defined in G.997.1. The use of this mechanism is outside the scope of this standard.

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Table 63–3—Mapping of registers to "Network Side Performance Status" EOC message octets

register	octets / bits
LOSW failure	octet 2 / bit 1
Loop attenuation defect	octet 2 / bit 2
SNR margin defect	octet 2 / bit 3
SNR margin	octet 3
Loop attenuation	octet 4
ES	octet 5
SES	octet 6
Code violations	octet 7 and 8
LOSW	octet 9
UAS	octet 10
See footnote[a]	octet 11

[a]Bit 6 and 7 of octet 11 indicate that either an overflow or reset condition has occurred on any of the code violations / ES/ SES / LOSW / UAS registers.

NOTE—The code violation, ES, SES, LOSW, and UAS in SHDSL are modulo counters. The absolute value of the counter is meaningless, however the difference in between two consecutive readings provides the change in code violation/ES/SES/LOSW/UAS. If there are no changes in the performance registers, message ID 139 rather than 140 will be sent by the 2BASE-TL-R. It only contains the SNR value and none of the other parameters.

63.3 2BASE-TL PMD functional specifications

The 2BASE-TL PMD (and MDI) is specified by incorporating the SHDSL standard, ITU-T Recommendation G.991.2 (02/2001) with the changes specified in G.991.2 Amendment 1 (11/2001), by reference, with the modifications noted below. This standard provides support for voice-grade twisted pair. For improved legibility in this clause, ITU-T Recommendation G.991.2 and G.991.2 Amendment 1, will henceforth be referred to as G.991.2.

63.3.1 General exceptions

The 2BASE-TL PMD is precisely the PMD specified in G.991.2, with the following general modifications:

a) There are minor terminology differences between this standard and G.991.2 that do not cause ambiguity. The terminology used in 2BASE-TL was chosen to be consistent with other IEEE 802 standards, rather than with G.991.2. Terminology is both defined and consistent within each standard. Special note should be made of the interpretations shown in Table 63–4.
b) The 2BASE-TL PMD does not support the optional "four-wire mode". Operation over multiple pairs is optional; if implemented, multi-pair operation shall comply to the specifications in 61.2.2.
c) The 2BASE-TL PMD does not support "plesiochronous mode".
d) The 2BASE-TL PMD shall be octet oriented; hence, the bit oriented parameter *i* defined for Equation (63–1) shall be equal to *0* in all cases.
e) The 2BASE-TL PMD shall support the use of the 32-TCPAM constellation for specific rates (see 63.3.2.1).
f) The 2BASE-TL PMD shall support the use of the enhanced SHDSL[18] extended bandwidths.

[18]"Enhanced SHDSL" refers to 32TC-PAM modulation and higher values of n as defined in Equation (63–2) and Equation (63–4), which are not part of ITU-T Recommendation G.991.2.

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Table 63–4—Interpretation of general G.991.2 terms and concepts

G.991.2 term or concept	Interpretation for 2BASE-TL
PMS-TC	PMA
STU-C, LT	2BASE-TL-O
STU-R, NT	2BASE-TL-R
Transmission medium dependent interface, U-interface	MDI

63.3.2 Specific requirements and exceptions

The 2BASE-TL PMD (including MDI) shall comply to the requirements of G.991.2 Section 5 (Transport Capacity), Section 6 (PMD Layer Functional Characteristics), Section 10 (Clock Architecture), Section 11 (Electrical Characteristics), Section 12 (Conformance Testing) with the exceptions listed below. The 2BASE-TL PMD supports the requirements of G.991.2 Annex A (Regional Requirements - Region 1) and Annex B (Regional Requirements - Region 2) with the exception of performance requirements, which are replaced by Annex 63B. Where there is conflict between specifications in G.991.2 and those in this standard, those of this standard shall prevail.

Implementation of optional specifications in G.991.2 is not required for compliance with this standard. Reference Section 8 (TPS-TC Layer Functional Characteristics), Reference Annex D (Signal Regenerator Operation), Reference Annex E (Application-specific TPS-TC Framing), and Reference Appendices I, II, and III are out of scope for the 2BASE-TL PMD.

63.3.2.1 Replacement of section 5, “Transport Capacity”

This recommendation specifies a two-wire operational mode for 2BASE-TL transceivers that is capable of supporting user (payload) data rates from 192 kb/s to 3.840 Mb/s, using the 16-TCPAM constellation, and 768 kb/s to 5.696 Mb/s, using the 32-TCPAM constellation. The allowed rates r (in kb/s), using the 16-TCPAM constellation, are given by Equation (63–1):

$$r = n \times 64 + i \times 8 \tag{63–1}$$

where

$$3 \le n \le 60\ . \tag{63–2}$$

The allowed rates r (in kb/s), using the 32-TCPAM constellation, are given by Equation (63–3):

$$r = n \times 64 + i \times 8 \tag{63–3}$$

where

$$12 \le n \le 89 \tag{63–4}$$

In all cases, i is restricted to the value of 0. See 63.3.2.4, 63.3.2.5 and 63.3.2.6 for details of specific regional requirements.

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63.3.2.2 Changes to section 6, "PMD Layer Functional Characteristics"

Referenced as is, with the exception of subsection 6.4 (G.994.1 Preactivation Sequence), which is supplanted by 61.4.

Section 6.1.2.3 is superseded by the following text:

Mapper:

The $K + 1$ bits $Y_K(m), \ldots, Y_1(m)$, and $Y_0(m)$ shall be mapped to a level $x(m)$. In section 6.1.2.3 of G.991.2, the mapper function is specified for 16-TCPAM. This text extends that mapping to include both 16- and 32-TCPAM encodings. Table 63–5 shows the bit to level mapping for 16 and 32 level mapping.

Table 63–5—Mapping of bits to PAM levels

$Y_4(m)$	$Y_3(m)$	$Y_2(m)$	$Y_1(m)$	$Y_0(m)$	32-PAM (5 Bits)	16-PAM (4 Bits)
0	0	0	0	0	–31/32	–15/16
0	0	0	0	1	–29/32	–13/16
0	0	0	1	0	–27/32	–11/16
0	0	0	1	1	–25/32	–9/16
0	0	1	0	0	–23/32	–7/16
0	0	1	0	1	–21/32	–5/16
0	0	1	1	0	–19/32	–3/16
0	0	1	1	1	–17/32	–1/16
0	1	1	0	0	–15/32	1/16
0	1	1	0	1	–13/32	3/16
0	1	1	1	0	–11/32	5/16
0	1	1	1	1	–9/32	7/16
0	1	0	0	0	–7/32	9/16
0	1	0	0	1	–5/32	11/16
0	1	0	1	0	–3/32	13/16
0	1	0	1	1	–1/32	15/16
1	1	0	0	0	1/32	—
1	1	0	0	1	3/32	—
1	1	0	1	0	5/32	—
1	1	0	1	1	7/32	—
1	1	1	0	0	9/32	—
1	1	1	0	1	11/32	—

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Table 63–5—Mapping of bits to PAM levels *(continued)*

$Y_4(m)$	$Y_3(m)$	$Y_2(m)$	$Y_1(m)$	$Y_0(m)$	32-PAM (5 Bits)	16-PAM (4 Bits)
1	1	1	1	0	13/32	—
1	1	1	1	1	15/32	—
1	0	1	0	0	17/32	—
1	0	1	0	1	19/32	—
1	0	1	1	0	21/32	—
1	0	1	1	1	23/32	—
1	0	0	0	0	25/32	—
1	0	0	0	1	27/32	—
1	0	0	1	0	29/32	—
1	0	0	1	1	31/32	—

63.3.2.3 Changes to section 10, “Clock Architecture”

Referenced as is, with the exception of Reference Table 10-1, which is replaced by Table 63–6.

Table 63–6—Clock synchronization configurations

Mode number	2BASE-TL-O symbol clock reference	2BASE-TL-R symbol clock reference	Example application	Mode
3a	Transmit data clock	Received symbol clock	Main application is synchronous transport in both directions.	Synchronous

63.3.2.4 Changes to Annex A, “Regional Requirements—Region 1”

63.3.2.4.1 General Changes

Referenced as is, with the exception of optional support for asymmetric PSD masks. Asymmetric PSD masks are not supported by 2BASE-TL.

Section A.5.3 “Span Powering” is out of scope.

63.3.2.4.2 Additional requirement: wetting current

The 2BASE-TL-R shall be capable of sustaining 20 mA of wetting (sealing) current. The maximum rate of change of the wetting current shall be no more than 20 mA per second.

NOTE—The -R device cannot be guaranteed to operate correctly if more than 20 mA (tip to ring) is sourced.

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63.3.2.5 Changes to Annex B, "Regional Requirements—Region 2"

63.3.2.5.1 General changes

Referenced as is, with the exception of optional support for asymmetric PSD masks. Asymmetric PSD masks are not supported by 2BASE-TL.

Section B.5.3. "Span Powering" is out of scope.

The RL_{min} value of section B.5.2 is modified from 14 to 12 dB for the purpose of 2BASE-TL.

63.3.2.5.2 Additional requirement: wetting current

The 2BASE-TL-R shall be capable of sustaining 20 mA of wetting (sealing) current. The maximum rate of change of the wetting current shall be no more than 20 mA per second.

NOTE—The -R device cannot be guaranteed to operate correctly if more than 20 mA (tip to ring) is sourced.

63.3.2.6 Changes to Annex C, "Regional Requirements – Region 3"

Referenced as is, with the exception of optional support for asymmetric PSD masks. Asymmetric PSD masks are not supported by 2BASE-TL.

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63.4 Protocol implementation conformance statement (PICS) proforma for Clause 63, Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 2BASE-TL[19]

63.4.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 63, Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 2BASE-TL, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

63.4.2 Identification

63.4.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., names and versions for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

63.4.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 63, Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD), type 2BASE-TL.
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	
Date of Statement	

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[19]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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63.4.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
2BPMA	SHDSL based PMA	63.2	The PMA based on the PMS-TC specified in ITU-T Recommendation G.991.2 is implemented.	M	Yes [ ]
2BPMD	SHDSL based PMD	63.3	The PMD based on the PMD specified in ITU-T Recommendation G.991.2 is implemented.	M	Yes [ ]

63.4.4 PICS proforma tables for the Physical Medium Attachment (PMA) and Physical Medium Dependent (PMD) sublayers, type 2BASE-TL

63.4.4.1 SHDSL based PMA

Item	Feature	Subclause	Value/Comment	Status	Support
2BPMA-1	α(β)-interface	63.1.4.1	The PMA_receive_synchronized is asserted when LOSW is “0” and deasserted when LOSW is “1”.	M	Yes [ ]
2BPMA-2	The I-data flow	63.1.4.2.1	If data streams are implemented serially, the LSB of each octet (i.e., b_8 of Figure 61–16) is sent first.	M	Yes [ ]
2BPMA-3	Operation Channel	63.1.4.3	The OC-TC function of the PMA receives the EOC and overhead indicators over the OC-TC interface.	M	Yes [ ]
2BPMA-4	Operation Channel	63.1.4.3	The EOC and overhead indicators are included in the overhead sections of the 2BASE-TL PMA frames.	M	Yes [ ]
2BPMA-5	General exceptions	63.2.1	The 2BASE-TL PMA is octet oriented.	M	Yes [ ]
2BPMA-6	General exceptions	63.2.1	The bit oriented parameter i defined for Equation (63–1) and Equation (63–3) is equal to 0 in all cases.	M	Yes [ ]
2BPMA-7	Specific requirements and exceptions	63.2.2	The 2BASE-TL PMA complies to the requirements of G.991.2 Section 7.	M	Yes [ ]
2BPMA-8	Specific requirements and exceptions	63.2.2	The 2BASE-TL PMA complies to the requirements of G.991.2 Section 9.	M	Yes [ ]
2BPMA-9	Reference 7.1	63.2.2.1	2BASE-TL operates in synchronous mode. Bits stb1 and stb2 are present in every frame, and stb3 and stb4 are not present.	M	Yes [ ]
2BPMA-10	Reference 7.1	63.2.2.1	Since different frame synchronization algorithms require different values for the bits of the FSW, a provision has been made to allow the receiver to inform the far end transmitter of the particular values that are to be used for this field according to 61.4.	M	Yes [ ]

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63.4.4.2 SHDSL based PMD

Item	Feature	Subclause	Value/Comment	Status	Support
2BPMD-1	General exceptions	63.3.1	The 2BASE-TL PMD is octet oriented.	M	Yes [ ]
2BPMD-2	General exceptions	63.3.1	The 2BASE-TL PMD supports the use of the 32-TCPAM constellation for specific rates.	M	Yes [ ]
2BPMD-4	General exceptions	63.3.1	The 2BASE-TL PMD supports the use of the enhanced SHDSL extended bandwidths.	M	Yes [ ]
2BPMD-5	General exceptions	63.3.1	The bit oriented parameter *i* defined for Equation (63–1) and Equation (63–3) is equal to 0 in all cases.	M	Yes [ ]
2BPMD-6	Specific requirements and exceptions	63.3.2	The 2BASE-TL PMD complies to the requirements of G.991.2 Section 5, Section 6, Section 10, Section 11, Section 12.	M	Yes [ ]
2BPMD-7	Specific requirements and exceptions	63.3.2	The 2BASE-TL PMD complies to at least one of the three regional annexes: Annex A, Annex B, or Annex C with the exception of performance, which is defined in Annex 63B.	M	Yes [ ]
2BPMD-8	Reference section 6	63.3.2.2	The 16 and 32 TC-PAM mappings are per Table 63–5.	M	Yes [ ]
2BPMD-9	Changes to Annex A/B	63.3.2.4.2 63.3.2.5.2	The DC resistance of the 2BASE-TL-R is 1000 ohms plus or minus 10%.	M	Yes [ ]
2BPMD-10	Changes to Annex A/B	63.3.2.4.2 63.3.2.5.2	The 2BASE-TL-R is capable of sustaining 20 mA of wetting (sealing) current.	M	Yes [ ]

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64. Multipoint MAC Control

64.1 Overview

This clause deals with the mechanism and control protocols required in order to reconcile the P2MP topology into the Ethernet framework. The P2MP medium is a passive optical network (PON), an optical network with no active elements in the signal's paths from source to destination. The only interior elements used in a PON are passive optical components, such as optical fiber, splices, and splitters. When combined with the Ethernet protocol, such a network is referred to as Ethernet passive optical network (EPON).

P2MP is an asymmetrical medium based on a tree (or tree-and-branch) topology. The DTE connected to the trunk of the tree is called optical line terminal (OLT) and the DTEs connected at the branches of the tree are called optical network units (ONU). The OLT typically resides at the service provider's facility, while the ONUs are located at the subscriber premises.

In the downstream direction (from the OLT to an ONU), signals transmitted by the OLT pass through a 1:N passive splitter (or cascade of splitters) and reach each ONU. In the upstream direction (from the ONUs to the OLT), the signal transmitted by an ONU would only reach the OLT, but not other ONUs. To avoid data collisions and increase the efficiency of the subscriber access network, ONU's transmissions are arbitrated. This arbitration is achieved by allocating a transmission window (grant) to each ONU. An ONU defers transmission until its grant arrives. When the grant arrives, the ONU transmits frames at wire speed during its assigned time slot.

A simplified P2MP topology example is depicted in Figure 64–1. Clause 67 provides additional examples of P2MP topologies.

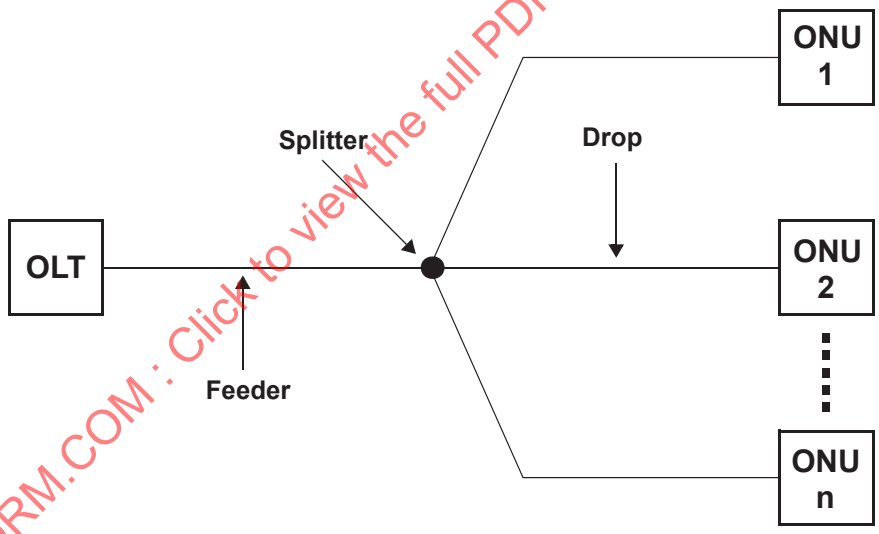

Figure 64–1—PON topology example

Topics dealt with in this clause include allocation of upstream transmission resources to different ONUs, discovery and registration of ONUs into the network, and reporting of congestion to higher layers to allow for dynamic bandwidth allocation schemes and statistical multiplexing across the PON.

This clause does not deal with topics including bandwidth allocation strategies, authentication of end-devices, quality-of-service definition, provisioning, or management.

This clause specifies the multipoint control protocol (MPCP) to operate an optical multipoint network by defining a Multipoint MAC Control sublayer as an extension of the MAC Control sublayer defined in Clause 31, and supporting current and future operations as defined in Clause 31 and annexes.

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Each PON consists of a node located at the root of the tree assuming the role of OLT, and multiple nodes located at the tree leaves assuming roles of ONUs. The network operates by allowing only a single ONU to transmit in the upstream direction at a time. The MPCP located at the OLT is responsible for timing the different transmissions. Reporting of congestion by the different ONUs may assist in optimally allocating the bandwidth across the PON.

Automatic discovery of end stations is performed, culminating in registration through binding of an ONU to an OLT port by allocation of a Logical Link ID (see LLID in 65.1.3.3.2), and dynamic binding to a MAC connected to the OLT.

The Multipoint MAC Control functionality shall be implemented for subscriber access devices containing point-to-multipoint Physical Layer devices defined in Clause 60.

64.1.1 Goals and objectives

The goals and objectives of this clause are the definition of a point-to-multipoint Ethernet network utilizing an optical medium.

Specific objectives met include the following:

a) Support of Point-to-Point Emulation (P2PE) as specified
b) Support multiple LLIDs and MAC Clients at the OLT
c) Support a single LLID per ONU
d) Support a mechanism for single copy broadcast
e) Flexible architecture allowing dynamic allocation of bandwidth
f) Use of 32 bit timestamp for timing distribution
g) MAC Control based architecture
h) Ranging of discovered devices for improved network performance
i) Continuous ranging for compensating round trip time variation

64.1.2 Position of Multipoint MAC Control within the IEEE 802.3 hierarchy

Multipoint MAC Control defines the MAC control operation for optical point-to-multipoint networks. Figure 64–2 depicts the architectural positioning of the Multipoint MAC Control sublayer with respect to the MAC and the MAC Control client. The Multipoint MAC Control sublayer takes the place of the MAC Control sublayer to extend it to support multiple clients and additional MAC control functionality.

Multipoint MAC Control is defined using the mechanisms and precedents of the MAC Control sublayer. The MAC Control sublayer has extensive functionality designed to manage the real-time control and manipulation of MAC sublayer operation. This clause specifies the extension of the MAC Control mechanism to manipulate multiple underlying MACs simultaneously. This clause also specifies a specific protocol implementation for MAC Control.

The Multipoint MAC Control sublayer is specified such that it can support new functions to be implemented and added to this standard in the future. MultiPoint Control Protocol (MPCP), the management protocol for P2MP is one of these protocols. Non-real-time, or quasi-static control (e.g., configuration of MAC operational parameters) is provided by Layer Management. Operation of the Multipoint MAC Control sublayer is transparent to the MAC.

As depicted in Figure 64–2, the layered system instantiates multiple MAC entities, using a single Physical Layer. The individual MAC instances offer a Point-to-point emulation service between the OLT and the ONU. An additional MAC is instantiated to communicate to all ONUs at once. This instance takes maximum advantage of the broadcast nature of the downstream channel by sending a single copy of a frame that is received by all ONUs. This MAC instance is referred to as single copy broadcast (SCB).

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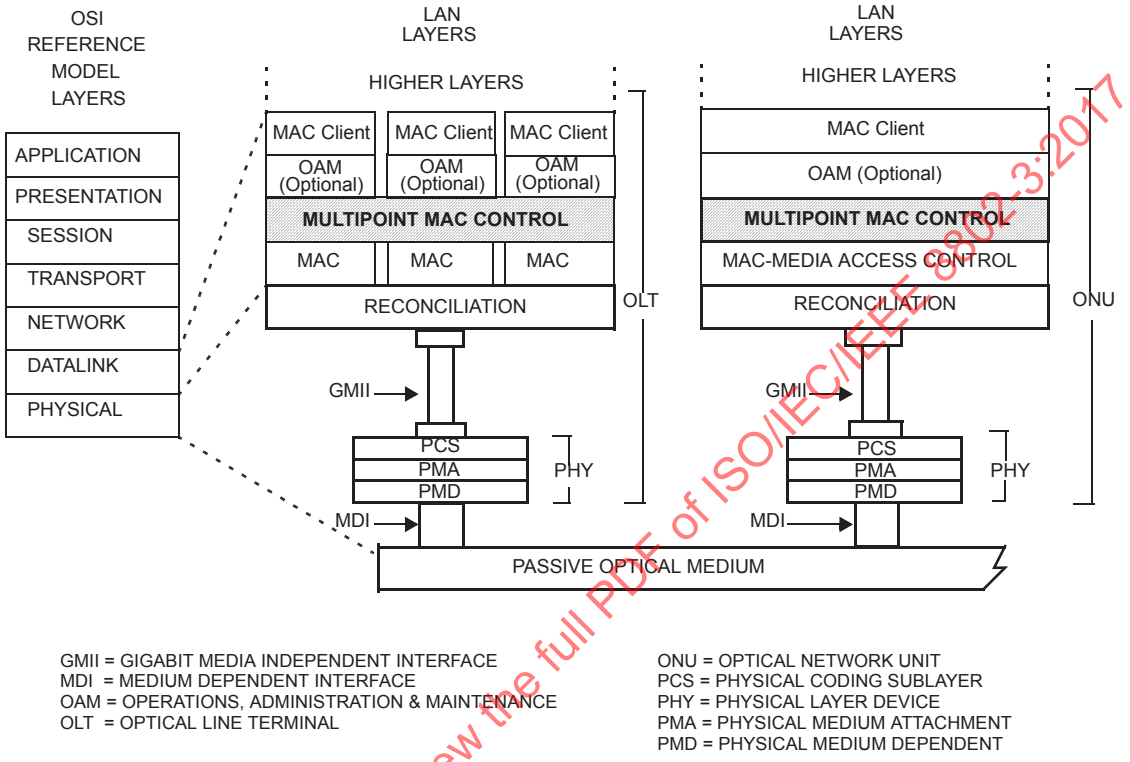
The ONU only requires one MAC instance since frame filtering operations are done at the RS layer before reaching the MAC. Therefore, MAC and layers above are emulation-agnostic at the ONU (see 65.1.3.3).

Although Figure 64–2 and supporting text describe multiple MACs within the OLT, a single unicast MAC address may be used by the OLT. Within the EPON Network, MACs are uniquely identified by their LLID which is dynamically assigned by the registration process.



GMII = GIGABIT MEDIA INDEPENDENT INTERFACE
MDI = MEDIUM DEPENDENT INTERFACE
OAM = OPERATIONS, ADMINISTRATION & MAINTENANCE
OLT = OPTICAL LINE TERMINAL

ONU = OPTICAL NETWORK UNIT
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

Figure 64–2—Relationship of Multipoint MAC Control and the OSI protocol stack

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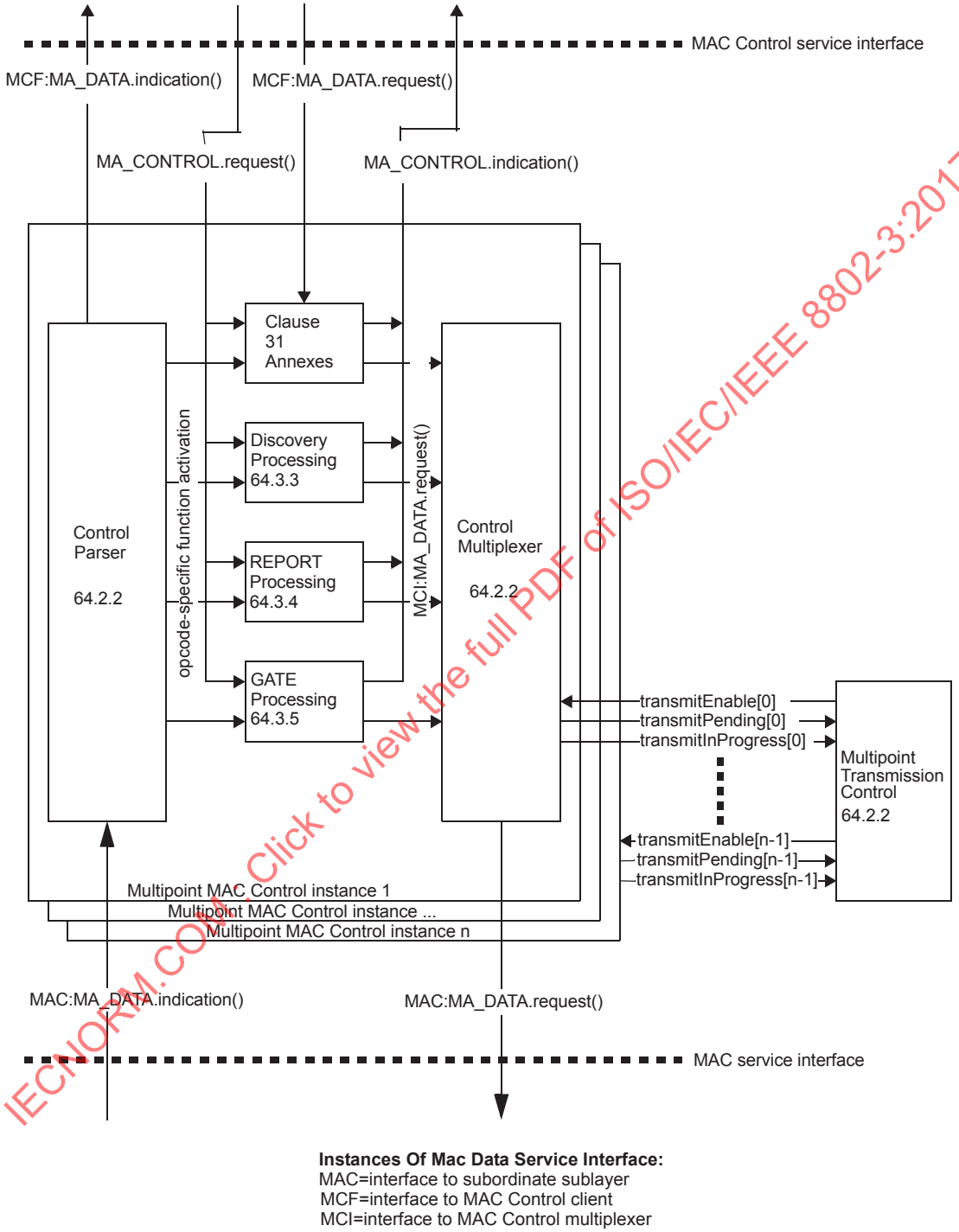
64.1.3 Functional block diagram

Figure 64–3 provides a functional block diagram of the Multipoint MAC Control architecture.



Instances Of Mac Data Service Interface:
MAC=interface to subordinate sublayer
MCF=interface to MAC Control client
MCI=interface to MAC Control multiplexer

Figure 64–3—Multipoint MAC Control functional block diagram

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64.1.4 Service interfaces

The MAC Client communicates with the Control Multiplexer using the standard service interface specified in 2.3. Multipoint MAC Control communicates with the underlying MAC sublayer using the standard service interface specified in 4A.3.2. Similarly, Multipoint MAC Control communicates internally using primitives and interfaces consistent with definitions in Clause 31.

64.1.5 State diagram conventions

The body of this standard comprises state diagrams, including the associated definitions of variables, constants, and functions. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

The notation used in the state diagrams follows the conventions of 21.5. State diagram timers follow the conventions of 14.2.3.2 augmented as follows:

a) [start x_timer, y] sets expiration of *y* to timer *x_timer*.
b) [stop x_timer] aborts the timer operation for *x_timer* asserting *x_timer_not_done* indefinitely.

The state diagrams use an abbreviation MACR as a shorthand form for MA_CONTROL.request and MACI as a shorthand form for MA_CONTROL.indication.

The vector notations used in the state diagrams for bit vector use 0 to mark the first received bit and so on (for example data[0:15]), following the conventions of 3.1 for bit ordering. When referring to an octet vector, 0 is used to mark the first received octet and so on (for example m_sdu[0..1]).

a < *b*: A function that is used to compare two (cyclic) time values. Returned value is true when *b* is larger than *a* allowing for wrap around of *a* and *b*. The comparison is made by subtracting *b* from *a* and testing the MSB. When MSB(*a*-*b*) = 1 the value true is returned, else false is returned. In addition, the following functions are defined in terms of *a* < *b*:
a > *b* is equivalent to !(*a* < *b* or *a* = *b*)
a ≥ *b* is equivalent to !(*a* < *b*)
a ≤ *b* is equivalent to !(*a* > *b*)

64.2 Multipoint MAC Control operation

As depicted in Figure 64–3, the Multipoint MAC Control functional block comprises the following functions:

a) *Multipoint Transmission Control*. This block is responsible for synchronizing Multipoint MAC Control instances associated with the Multipoint MAC Control. This block maintains the Multipoint MAC Control state and controls the multiplexing functions of the instantiated MACs.
b) *Multipoint MAC Control Instance n*. This block is instantiated for each MAC and respective MAC and MAC Control clients associated with the Multipoint MAC Control. It holds all the variables and state associated with operating all MAC Control protocols for the instance.
c) *Control Parser*. This block is responsible for parsing MAC Control frames, and interfacing with Clause 31 entities, the opcode specific blocks, and the MAC Client.
d) *Control Multiplexer*. This block is responsible for selecting the source of the forwarded frames.
e) *Clause 31 Annexes*. This block holds MAC Control actions as defined in Clause 31 annexes for support of legacy and future services.
f) *Discovery, Report and Gate Processing*. These blocks are responsible for handling the MPCP in the context of the MAC.

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64.2.1 Principles of Multipoint MAC Control

As depicted in Figure 64–3, Multipoint MAC Control sublayer may instantiate multiple Multipoint MAC Control instances in order to interface multiple MAC and MAC Control clients above with multiple MACs below. A unique unicast MAC instance is used at the OLT to communicate with each ONU. The individual MAC instances utilize the point-to-point emulation service between the OLT and the ONU as defined in 65.1.

At the ONU, a single MAC instance is used to communicate with a MAC instance at the OLT. In that case, the Multipoint MAC Control contains only a single instance of the Control Parser/Multiplexer function.

Multipoint MAC Control protocol supports several MAC and client interfaces. Only a single MAC interface and Client interface is enabled for transmission at a time. There is a tight mapping between a MAC service interface and a Client service interface. In particular, the assertion of the MAC:MA_DATA.indication primitive in MAC *j* leads to the assertion of the MCF:MA_DATA.indication primitive to Client *j*. Conversely, the assertion of the request service interface in Client *i* leads to the assertion of the MAC:MA_DATA.request primitive of MAC *i*. Note that the Multipoint MAC sublayer need not receive and transmit packets associated with the same interface at the same time. Thus the Multipoint MAC Control acts like multiple MAC Controls bound together with common elements.

The scheduling algorithm is implementation dependent, and is not specified for the case where multiple transmit requests happen at the same time.

The reception operation is as follows. The Multipoint MAC Control instances generate MAC:MA_DATA.indication service primitives continuously to the underlying MAC instances. Since these MACs are receiving frames from a single PHY only one frame is passed from the MAC instances to Multipoint MAC Control. The MAC instance responding to the MAC:MA_DATA.indication is referred to as the enabled MAC, and its service interface is referred to as the enabled MAC interface. The MAC passes to the Multipoint MAC Control sublayer all valid frames. Invalid frames, as specified in 3.4, are not passed to the Multipoint MAC Control sublayer in response to a MAC:MA_DATA.indication service primitive.

The enabling of a transmit service interface is performed by the Multipoint MAC Control instance in collaboration with the Multipoint Transmission Control. Frames generated in the MAC Control are given priority over MAC Client frames, in effect, prioritizing the MA_CONTROL primitive over the MCF:MA_DATA primitive, and for this purpose MCF:MA_DATA.request primitives may be delayed, discarded or modified in order to perform the requested MAC Control function. For the transmission of this frame, the Multipoint MAC Control instance enables forwarding by the MAC Control functions, but the MAC Client interface is not enabled. The reception of a frame in a MAC results in generation of the MAC:MA_DATA.indication primitive on that MAC's interface. Only one receive MAC interface will be enabled at any given time since there is only one PHY interface.

The information of the enabled interfaces is stored in the controller state variables, and accessed by the Multiplexing Control block.

The Multipoint MAC Control sublayer uses the services of the underlying MAC sublayer to exchange both data and control frames.

Receive operation (MAC:MA_DATA.indication) at each instance:

a) A frame is received from the underlying MAC.
b) The frame is parsed according to Length/Type field
c) MAC Control frames are demultiplexed according to opcode and forwarded to the relevant processing functions
d) Data frames (see 31.5.1) are forwarded to the MAC Client by asserting MCF:MA_DATA.indication primitives

Transmit operation (MAC:MA_DATA.request) at each instance:

e) The MAC Client signals a frame transmission by asserting MCF:MA_DATA.request, or

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f) A protocol processing block attempts to issue a frame, as a result of a previous MA_CONTROL.request or as a result of an MPCP event that generates a frame.
g) When allowed to transmit by the Multipoint Transmission Control block, the frame is forwarded.

64.2.1.1 Ranging and Timing Process

Both the OLT and the ONU have 32-bit counters that increment every 16 ns. These counters provide a local time stamp. When either device transmits an MPCPDU, it maps its counter value into the timestamp field. The time of transmission of the first octet of the MPCPDU frame from the MAC Control to the MAC is taken as the reference time used for setting the timestamp value.

When the ONU receives MPCPDUs, it sets its counter according to the value in the timestamp field in the received MPCPDU.

When the OLT receives MPCPDUs, it uses the received timestamp value to calculate or verify a round trip time between the OLT and the ONU. The RTT is equal to the difference between the time value and the value in the timestamp field. The calculated RTT is notified to the client via the MA_CONTROL.indication primitive. The client can use this RTT for the ranging process.

A condition of *timestamp drift error* occurs when the difference between OLT's and ONU's clocks exceeds some predefined threshold. This condition can be independently detected by the OLT or an ONU. The OLT detects this condition when an absolute difference between new and old RTT values measured for a given ONU exceeds the value of guardThresholdOLT (see 64.2.2.1), as shown in Figure 64–10. An ONU detects the timestamp drift error condition when absolute difference between a timestamp received in an MPCPDU and the localTime counter exceeds guardThresholdONU (see 64.2.2.1), as is shown in Figure 64–11.

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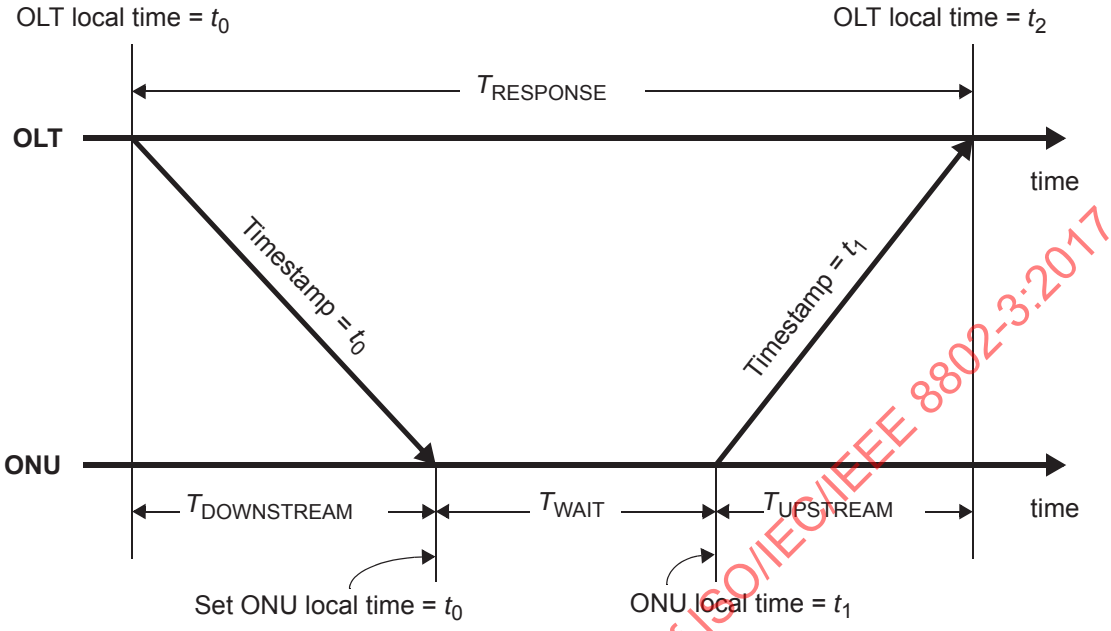

$T_{DOWNSTREAM}$ = downstream propagation delay

$T_{UPSTREAM}$ = upstream propagation delay

T_{WAIT} = wait time at ONU = $t_1 - t_0$

$T_{RESPONSE}$ = response time at OLT = $t_2 - t_0$

$$RTT = T_{DOWNSTREAM} + T_{UPSTREAM} = T_{RESPONSE} - T_{WAIT} = (t_2 - t_0) - (t_1 - t_0) = t_2 - t_1$$

Figure 64–4—Round trip time calculation

64.2.2 Multipoint transmission control, Control Parser, and Control Multiplexer

The purpose of the multipoint transmission control is to allow only one of the multiple MAC clients to transmit to its associated MAC and subsequently to the RS layer at one time by only asserting one transmitEnable signal at a time.

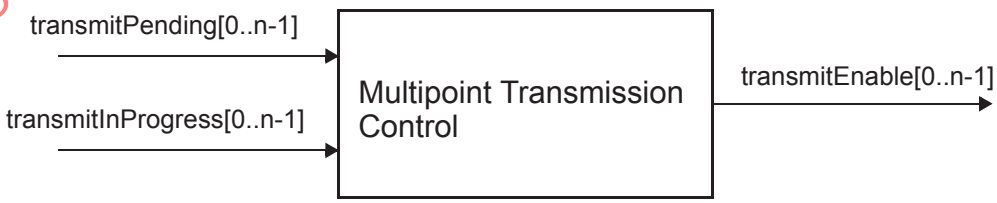

Figure 64–5—Multipoint Transmission Control Service Interfaces

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Multipoint MAC Control Instance n function block communicates with the Multipoint Transmission Control using transmitEnable[n], transmitPending[n], and transmitInProgress[n] state variables (see Figure 64–3).

The Control Parser is responsible for opcode independent parsing of MAC frames in the reception path. By identifying MAC Control frames, demultiplexing into multiple entities for event handling is possible. Interfaces are provided to existing Clause 31 entities, functional blocks associated with MPCP, and the MAC Client.

The Control Multiplexer is responsible for forwarding frames from the MAC Control opcode-specific functions and the MAC Client to the MAC. Multiplexing is performed in the transmission direction. Given multiple MCF:MA_DATA.request service primitives from the MAC Client, and MA_CONTROL.request primitives from the MAC Control Clients, a single MAC:MA_DATA.request service primitive is generated for transmission. At the OLT, multiple MAC instances share the same Multipoint MAC Control, as a result, the transmit block is enabled based on an external control signal housed in Multipoint Transmission Control for transmission overlap avoidance. At the ONU the Gate Processing functional block interfaces for upstream transmission administration.

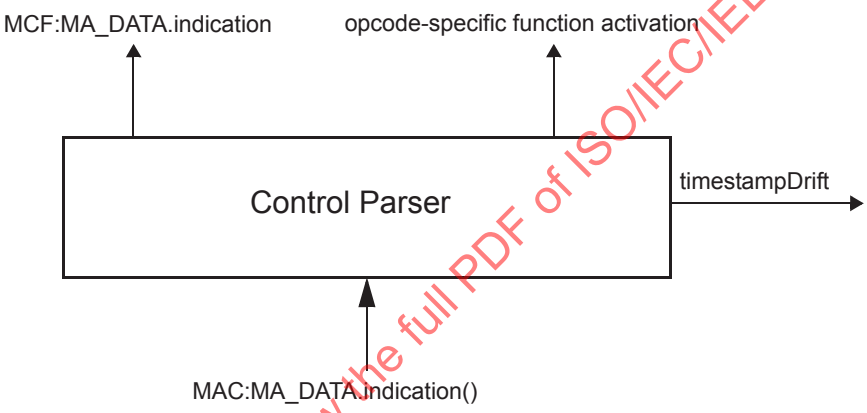

Figure 64–6—Control Parser service interfaces

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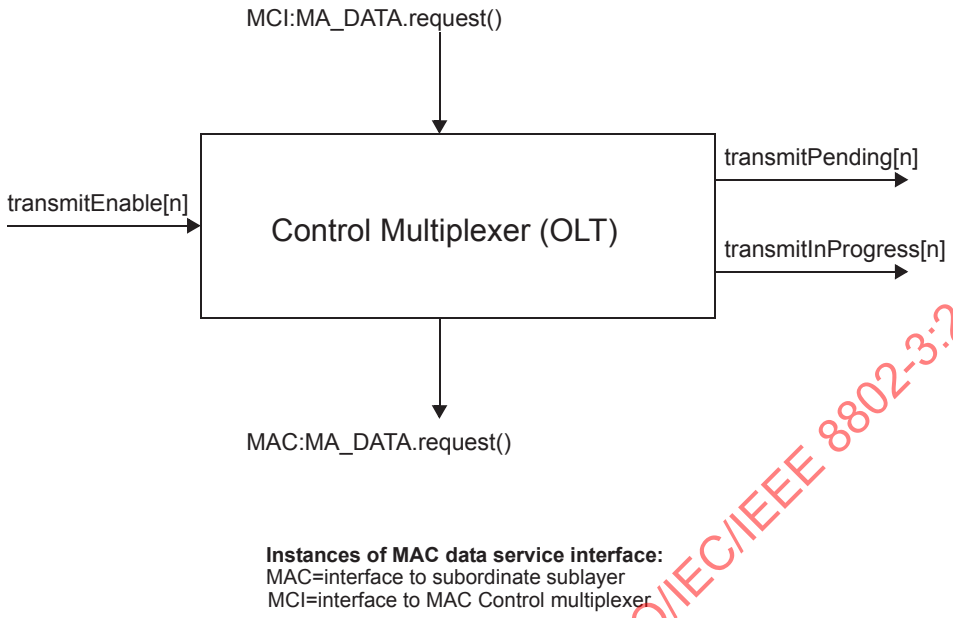
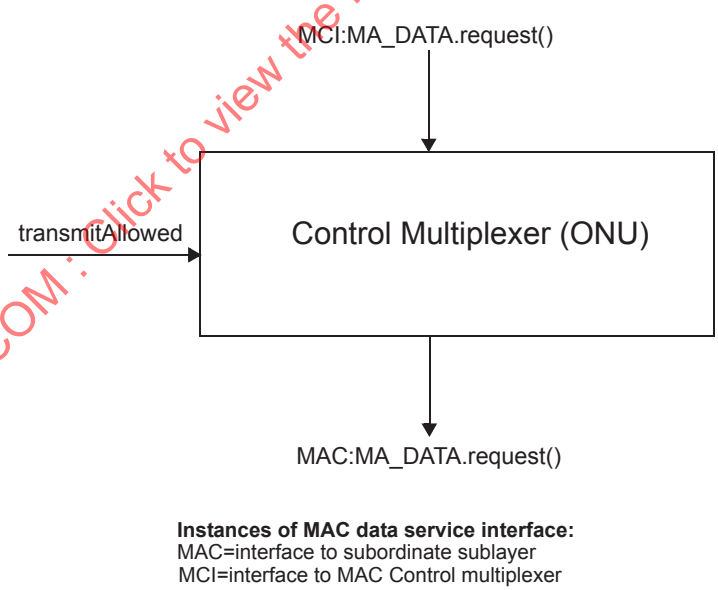


NOTE—MAC:MA_DATA.request primitive may be issued from multiple MAC Control processing blocks.

Figure 64–7—OLT Control Multiplexer service interfaces



NOTE—MAC:MA_DATA.request primitive may be issued from multiple MAC Control processing blocks.

Figure 64–8—ONU Control Multiplexer service interfaces

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64.2.2.1 Constants

defaultOverhead

This constant holds the size of packet transmission overhead. This overhead is measured in units of time quanta.

TYPE: integer
VALUE: 6

guardThresholdOLT

This constant holds the maximal amount of drift allowed for a timestamp received at the OLT. This value is measured in units of time_quantum (16 bit times).

TYPE: integer
VALUE: 12

guardThresholdONU

This constant holds the maximal amount of drift allowed for a timestamp received at the ONU. This value is measured in units of time_quantum (16 bit times)

TYPE: integer
VALUE: 8

MAC_Control_type

The value of the Length/Type field as defined in 31.4.1.3.

TYPE: integer
VALUE: 0x8808

tailGuard

This constant holds the value used to reserve space at the end of the upstream transmission at the ONU in addition to the size of last MAC service data unit (m_sdu) in units of octets. Space is reserved for the MAC overheads including: preamble, SFD, DA, SA, Length/Type, FCS, and the End of Packet Delimiter (EPD). The sizes of the above listed MAC overhead items are described in 3.1.1. The size of the EPD is described in 36.2.4.14.

TYPE: integer
VALUE: 29

time_quantum

The unit of time_quantum is used by all mechanisms synchronized to the advancement of the localTime variable. All variables that represent counters and time intervals are defined using time_quantum. Each time_quantum is 16 ns.

TYPE: integer
VALUE: 16

tqSize

This constant represents time_quantum in octet transmission times.

TYPE: integer
VALUE: 2

64.2.2.2 Counters

localTime

This variable holds the value of the local timer used to control MPCP operation. This variable is advanced by a timer at 62.5 MHz, and counts in time_quanta. At the OLT the counter shall track the transmit clock, while at the ONU the counter shall track the receive clock. For accuracy of receive clock, see 65.3.1.2. It is reloaded with the received timestamp value (from the OLT) by the Control Parser (see Figure 64–11). Changing the value of this variable while running using Layer Management is highly undesirable and is unspecified.

TYPE: 32 bit unsigned

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64.2.2.3 Variables

BEGIN

This variable is used when initiating operation of the functional block state diagram. It is set to true following initialization and every reset.

TYPE: Boolean

data_rx

This variable represents a 0-based bit array corresponding to the payload of a received MPCPDU. This variable is used to parse incoming MPCPDU frames.

TYPE: bit array

data_tx

This variable represents a 0-based bit array corresponding to the payload of an MPCPDU being transmitted. This variable is used to access payload of outgoing MPCPDU frames, for example to set the timestamp value.

TYPE: bit array

fecEnabled

This variable represents whether the FEC function is enabled. If FEC function is enabled, this variable equals true, otherwise it equals false.

TYPE: Boolean

newRTT

This variable temporary holds a newly-measured Round Trip Time to the ONU. The new RTT value is represented in units of time_quanta.

TYPE: 16 bit unsigned

nextTxTime

This variable represents a total transmission time of next packet and is used to check whether the next packet fits in the remainder of ONU's transmission window. The value of nextTxTime includes packet transmission time, tailGuard defined in 64.2.2.1, and FEC parity data overhead, if FEC is enabled. This variable is measured in units of time quanta.

TYPE: 16 bit unsigned

opcode_rx

This variable holds an opcode of the last received MPCPDU.

TYPE: 16 bit unsigned

opcode_tx

This variable holds an opcode of an outgoing MPCPDU.

TYPE: 16 bit unsigned

RTT

This variable holds the measured Round Trip Time to the ONU. The RTT value is represented in units of time_quanta.

TYPE: 16 bit unsigned

stopTime

This variable holds the value of the localTime counter corresponding to the end of the nearest grant. This value is set by the Gate Processing function as described in 64.3.5.

TYPE: 32 bit unsigned

timestamp

This variable holds the value of timestamp of the last received MPCPDU frame.

TYPE: 32 bit unsigned

timestampDrift

This variable is used to indicate whether an error is signaled as a result of uncorrectable timestamp drift.

TYPE: Boolean

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transmitAllowed

This variable is used to control PDU transmission at the ONU. It is set to true when the transmit path is enabled, and is set to false when the transmit path is being shut down. transmitAllowed changes its value according to the state of the Gate Processing functional block.

TYPE: Boolean

transmitEnable[j]

These variables are used to control the transmit path in a Multipoint MAC Control instance at the OLT. Setting them to on indicates that the selected instance is permitted to transmit a frame. Setting it to off inhibits the transmission of frames in the selected instance. Only one of transmitEnable[j] should be set to on at a time.

TYPE: Boolean

transmitInProgress[j]

This variable indicates that the Multipoint MAC Control instance *j* is in a process of transmitting a frame.

TYPE: Boolean

transmitPending[j]

This variable indicates that the Multipoint MAC Control instance *j* is ready to transmit a frame.

TYPE: Boolean

64.2.2.4 Functions

abs(n)

This function returns the absolute value of the parameter n.

Opcode-specific function(opcode)

Functions exported from opcode specific blocks that are invoked on the arrival of a MAC Control message of the appropriate opcode.

FEC_Overhead(length)

This function calculates the size of additional overhead to be added by the FEC encoder while encoding a frame of size length. Parameter length represents the size of an entire frame including preamble, SFD, DA, SA, Length/Type, and FCS. As specified in 65.2.3, FEC encoder adds 16 parity octets for each block of 239 data octets. Additionally, 26 code-groups are required to accommodate IPG and longer start-of-frame and end-of-frame sequences, which are used to allow reliable packet boundary detection in presence of high bit error ratio. The function returns the value of FEC overhead in units of time quanta. The following formula is used to calculate the overhead:

$$FEC_Overhead = 13 + \left\lceil \frac{length}{239} \right\rceil \times 8$$

NOTE—The notation $\lceil x \rceil$ represents a *ceiling* function, which returns the value of its argument *x* rounded up to the nearest integer.

select

This function selects the next Multipoint MAC Control instance allowed to initiate transmission of a frame. The function returns an index to the transmitPending array for which the value is not false. The selection criteria in the presence of multiple active elements in the list is implementation dependent.

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SelectFrame()
: This function enables the interface, which has a pending frame. If multiple interfaces have frames waiting at the same time, only one interface will be enabled. The selection criteria is not specified, except for the case when some of the pending frames have Length/Type = MAC_Control. In this case, one of the interfaces with a pending MAC Control frame shall be enabled.

sizeof(sdu)
: This function returns the size of the sdu in octets.

transmissionPending()
: This function returns true if any of the Multipoint MAC Control instances has a frame waiting to be transmitted. The function can be represented as

```
transmissionPending() =  transmitPending[0] +
                         transmitPending[1] +
                         ... +
                         transmitPending[n-1]
```

where n is the total number of Multipoint MAC Control instances.

64.2.2.5 Timers

packet_initiate_timer
: This timer is used to delay frame transmission from MAC Control to avoid variable MAC delay while MAC enforces IPG after a previous frame. In addition, when FEC is enabled, this timer increases interframe spacing just enough to accommodate the extra parity data to be added by the FEC encoder.

64.2.2.6 Messages

MAC:MA_DATA.indication(DA, SA, m_sdu, receiveStatus)
: The service primitive is defined in 31.3.

MCF:MA_DATA.indication(DA, SA, m_sdu, receiveStatus)
: The service primitive is defined in 31.3.

MAC:MA_DATA.request (DA, SA, m_sdu)
: The service primitive is defined in 31.3. The action invoked by this service primitive is not considered to end until the transmission of the frame by the MAC has concluded. The ability of the MAC control layer to determine this is implementation dependent.

MCF:MA_DATA.request (DA, SA, m_sdu)
: The service primitive is defined in 31.3.

64.2.2.7 State Diagrams

The Multipoint transmission control function in the OLT shall implement state diagram shown in Figure 64–9. Control parser function in the OLT shall implement state diagram shown in Figure 64–10. Control parser function in the ONU shall implement state diagram shown in Figure 64–11. Control multiplexer function in the OLT shall implement state diagram shown in Figure 64–12. Control multiplexer function in the ONU shall implement state diagram shown in Figure 64–13.

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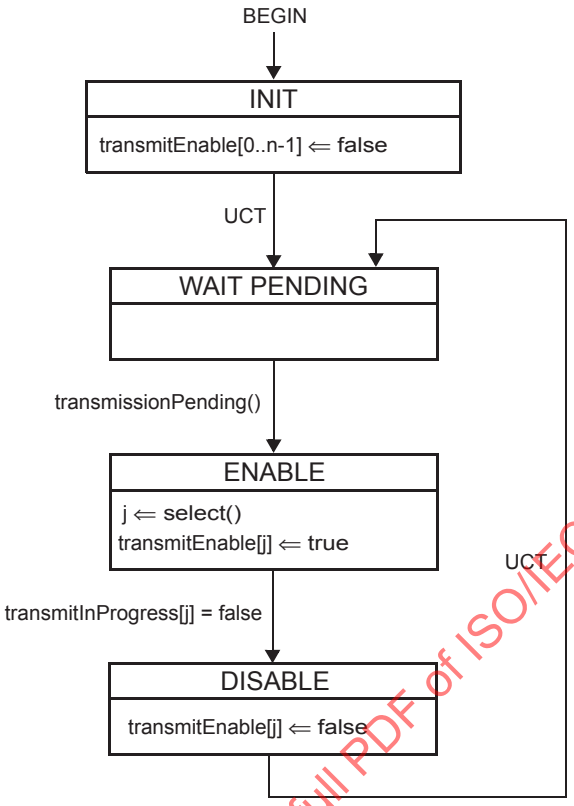

Figure 64–9—OLT Multipoint Transmission Control state diagram

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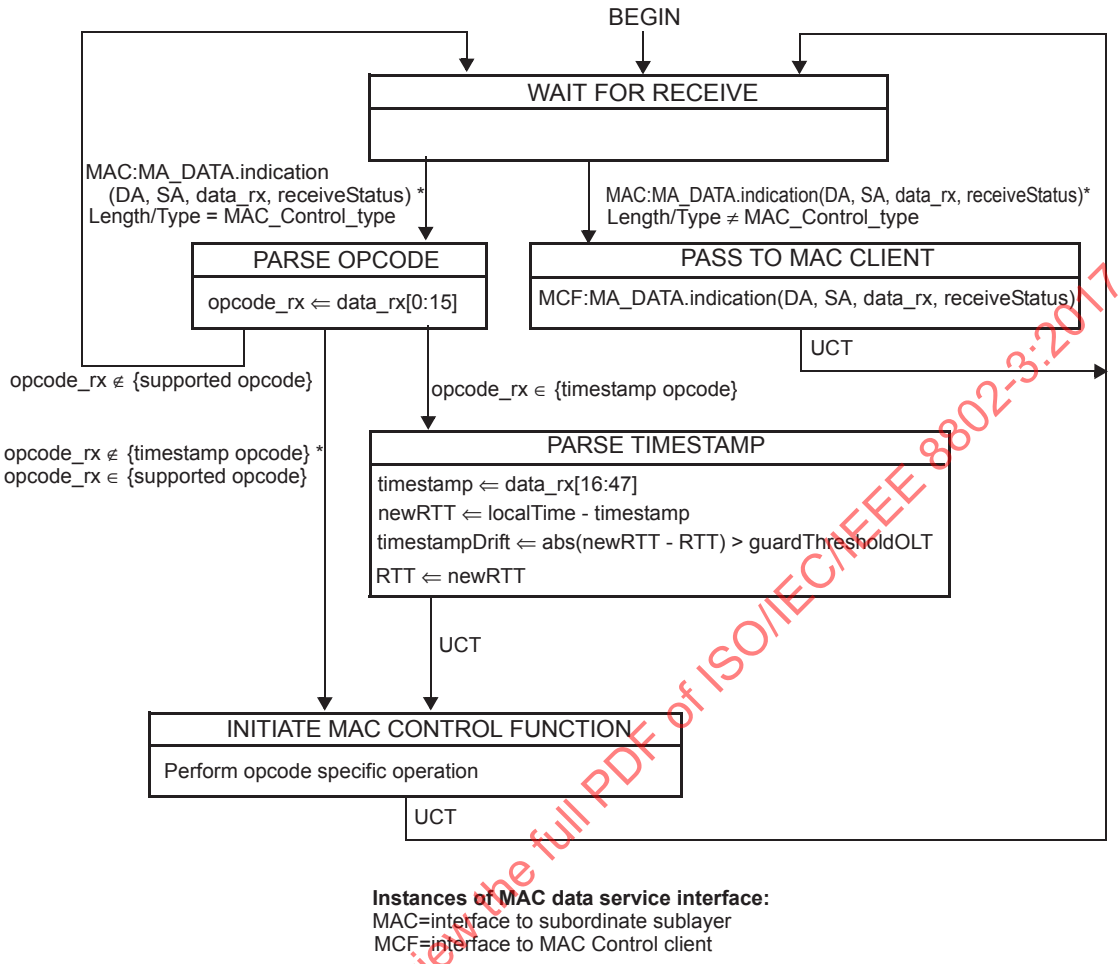

NOTE—The opcode-specific operation is launched as a parallel process by the MAC Control sublayer, and not as a synchronous function. Progress of the generic MAC Control Receive state diagram (as shown in this figure) is not implicitly impeded by the launching of the opcode specific function.

Refer to Annex 31A for list of supported opcodes and timestamp opcodes.

Figure 64–10—OLT Control Parser state diagram

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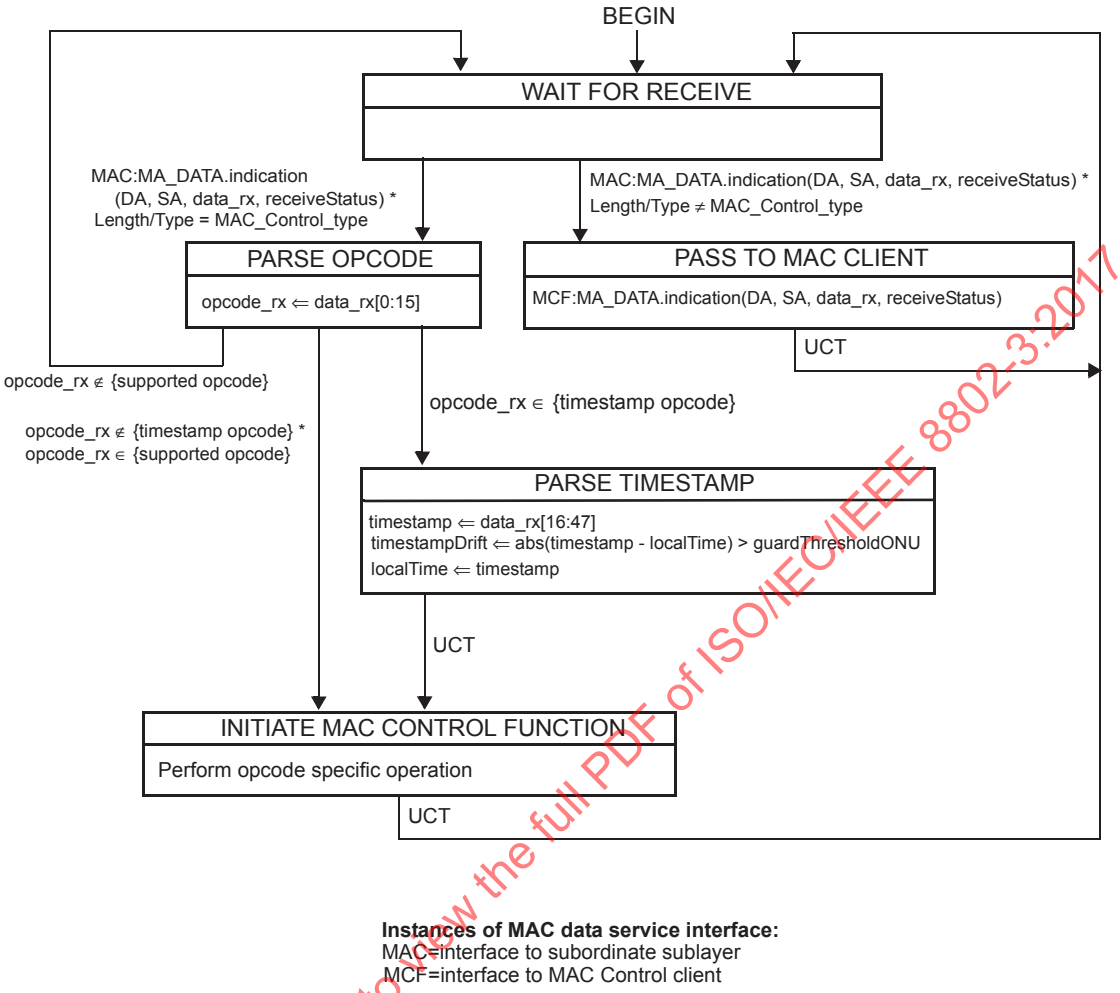

NOTE—The opcode-specific operation is launched as a parallel process by the MAC Control sublayer, and not as a synchronous function. Progress of the generic MAC Control Receive state diagram (as shown in this figure) is not implicitly impeded by the launching of the opcode specific function.

Refer to Annex 31A for list of supported opcodes and timestamp opcodes.

Figure 64–11—ONU Control Parser state diagram

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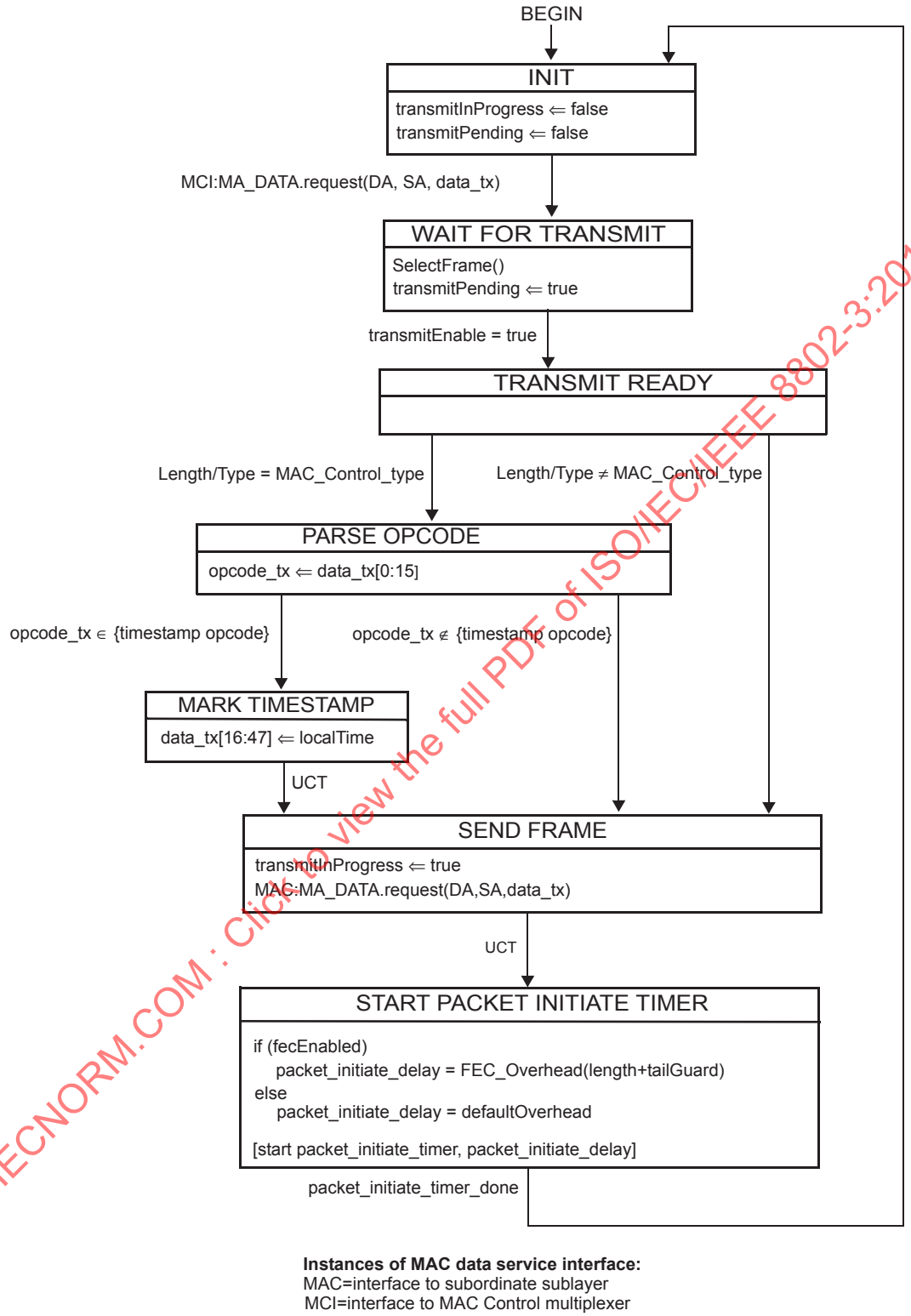

Instances of MAC data service interface:
MAC=interface to subordinate sublayer
MCI=interface to MAC Control multiplexer

Figure 64–12—OLT Control Multiplexer state diagram

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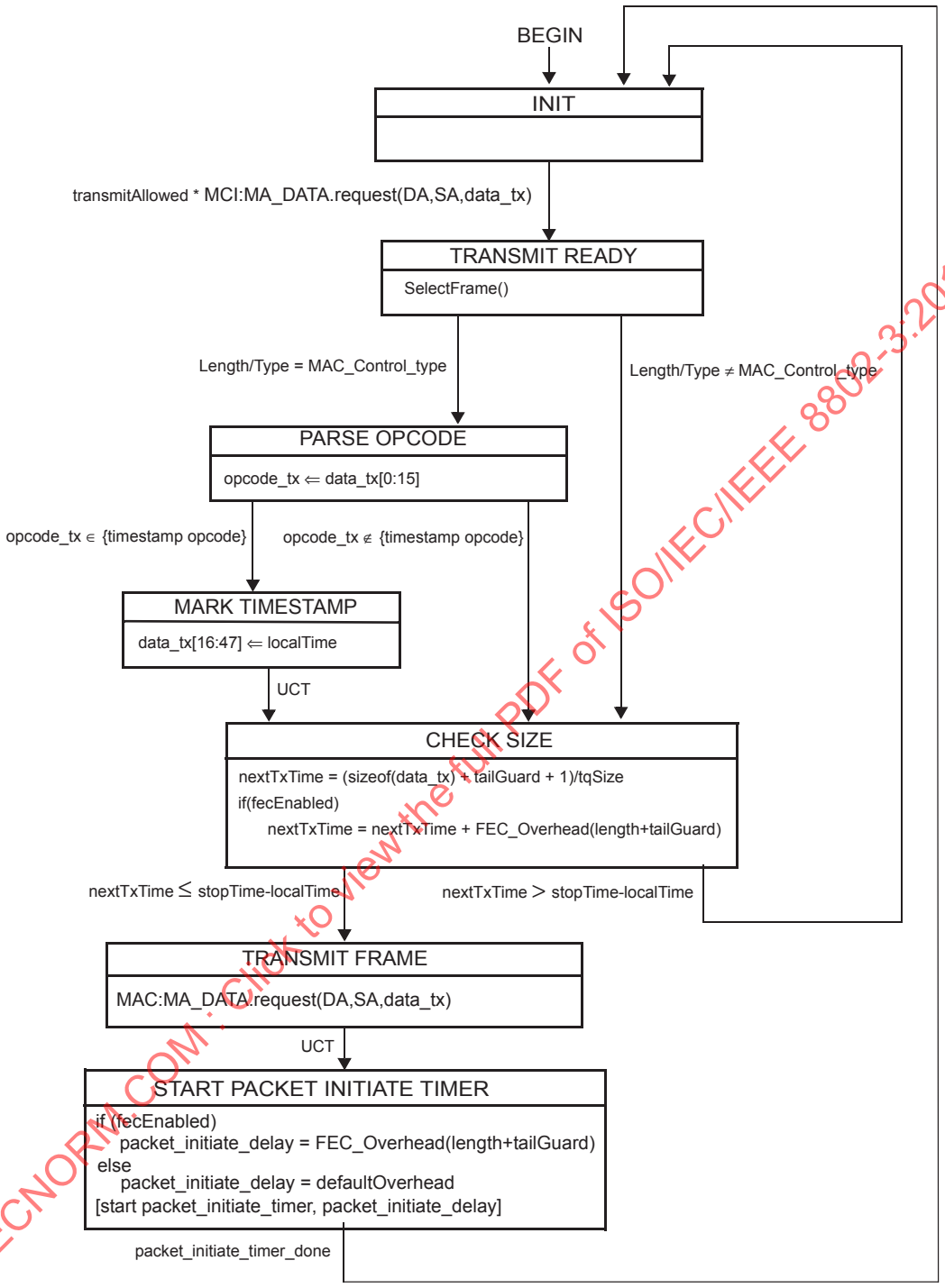

Instances of MAC data service interface:
MAC=interface to subordinate sublayer
MCI=interface to MAC Control multiplexer

Figure 64–13—ONU Control Multiplexer state diagram

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64.3 Multipoint Control Protocol (MPCP)

As depicted in Figure 64–3, the Multipoint MAC Control functional block comprises the following functions:

a) *Discovery Processing*. This block manages the discovery process, through which an ONU is discovered and registered with the network while compensating for RTT.
b) *Report Processing*. This block manages the generation and collection of report messages, through which bandwidth requirements are sent upstream from the ONU to the OLT.
c) *Gate Processing*. This block manages the generation and collection of gate messages, through which multiplexing of multiple transmitters is achieved.

As depicted in Figure 64–3, the layered system may instantiate multiple MAC entities, using a single Physical Layer. Each instantiated MAC communicates with an instance of the opcode specific functional blocks through the Multipoint MAC Control. In addition some global variables are shared across the multiple instances. Common state control is used to synchronize the multiple MACs using MPCP procedures. Operation of the common state control is generally considered outside the scope of this document.

64.3.1 Principles of Multipoint Control Protocol

Multipoint MAC Control enables a MAC Client to participate in a point-to-multipoint optical network by allowing it to transmit and receive frames as if it was connected to a dedicated link. In doing so, it employs the following principles and concepts:

a) A MAC client transmits and receives frames through the Multipoint MAC Control sublayer.
b) The Multipoint MAC Control decides when to allow a frame to be transmitted using the client interface Control Multiplexer.
c) Given a transmission opportunity, the MAC Control may generate control frames that would be transmitted in advance of the MAC Client's frames, utilizing the inherent ability to provide higher priority transmission of MAC Control frames over MAC Client frames.
d) Multiple MACs operate on a shared medium by allowing only a single MAC to transmit upstream at any given time across the network using a time-division multiple access (TDMA) method.
e) Such gating of transmission is orchestrated through the Gate Processing function.
f) New devices are discovered in the network and allowed transmission through the Discovery Processing function.
g) Fine control of the network bandwidth distribution can be achieved using feedback mechanisms supported in the Report Processing function.
h) The operation of P2MP network is asymmetrical, with the OLT assuming the role of master, and the ONU assuming the role of slave.

64.3.2 Compatibility considerations

64.3.2.1 PAUSE operation

Even though MPCP is compatible with flow control, optional use of flow control may not be efficient in the case of large propagation delay. If flow control is implemented, then the timing constraints in Annex 31B supplement the constraints found at 64.3.2.4.

NOTE—MAC at an ONU can receive frames from unicast channel and SCB channel. If the SCB channel is used to broadcast data frames to multiple ONUs, the ONU's MAC may continue receiving data frames from SCB channel even after the ONU has issued a PAUSE request to its unicast remote-end.

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64.3.2.2 Optional Shared LAN Emulation

By combining P2PE, suitable filtering rules at the ONU, and suitable filtering and forwarding rules at the OLT, it is possible to emulate an efficient shared LAN. Support for shared LAN emulation is optional, and requires an additional layer above the MAC, which is out of scope for this document. Thus, shared LAN emulation is introduced here for informational purposes only.

Specific behavior of the filtering layer at the RS is specified in 65.1.3.3.2.

64.3.2.3 Multicast and single copy broadcast support

In the downstream direction, the PON is a broadcast medium. In order to make use of this capability for forwarding broadcast frames from the OLT to multiple recipients without multiple duplication for each ONU, the SCB and multicast LLID support is introduced.

The OLT has at least one MAC associated with every ONU. In addition one more MAC at the OLT is marked as the SCB MAC. Moreover, the OLT has a multicast MAC associated with each defined multicast LLID. The SCB MAC handles all downstream broadcast traffic, but is never used in the upstream direction for client traffic, except for client registration. Similarly, the multicast MACs handle downstream multicast traffic, but are never used in the upstream direction for client traffic. Optional higher layers may be implemented to perform selective broadcast and multicast of frames. Such layers may require additional MACs (multicast MACs) to be instantiated in the OLT for some or all ONUs increasing the total number of MACs beyond the number of ONUs + 1.

When connecting the SCB MAC or a multicast MAC to an IEEE 802.1D bridge port it is possible that loops may be formed due to the broadcast or multicast nature of the associated LLIDs. Thus it is recommended that this MAC not be connected to an IEEE 802.1D bridge port.

SCB channel configuration as well as filtering and marking of frames for support of SCB is defined in 65.1.3.3.2.

64.3.2.4 Delay requirements

The MPCP protocol relies on strict timing based on distribution of timestamps. A compliant implementation needs to guarantee a constant delay through the MAC and PHY in order to maintain the correctness of the timestamping mechanism. The actual delay is implementation dependent, however, a complying implementation shall maintain a delay variation of no more than 16 bit times through the implemented MAC stack.

The OLT shall not grant less than 1024 time_quanta into the future, in order to allow the ONU processing time when it receives a gate message. The ONU shall process all messages in less than this period. The OLT shall not issue more than one message every 1024 time_quanta to a single ONU. The unit of time_quantum is defined as 16 ns.

64.3.3 Discovery Processing

Discovery is the process whereby newly connected or off-line ONUs are provided access to the PON. The process is driven by the OLT, which periodically makes available Discovery Time Windows during which off-line ONUs are given the opportunity to make themselves known to the OLT. The periodicity of these windows is unspecified and left up to the implementer. The OLT signifies that a discovery period is occurring by broadcasting a discovery gate message, which includes the starting time and length of the discovery window. Off-line ONUs, upon receiving this message, wait for the period to begin and then transmit a REGISTER_REQ message to the OLT. Discovery windows are unique in that they are the only times where multiple ONUs can access the PON simultaneously, and transmission overlap can occur. In

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order to reduce transmission overlaps, a contention algorithm is used by all ONUs. Measures are taken to reduce the probability for overlaps by artificially simulating a random distribution of distances from the OLT. Each ONU shall wait a random amount of time before transmitting the REGISTER_REQ message that is shorter than the length of the discovery time window. It should be noted that multiple valid REGISTER_REQ messages can be received by the OLT during a single discovery time period. Included in the REGISTER_REQ message is the ONU's MAC address and number of maximum pending grants. Upon receipt of a valid REGISTER_REQ message, the OLT registers the ONU, allocating and assigning new port identities (LLIDs), and bonding corresponding MACs to the LLIDs.

The next step in the process is for the OLT to transmit a Register message to the newly discovered ONU, which contains the ONU's LLID, and the OLT's required synchronization time. Also, the OLT echoes the maximum number of pending grants. The OLT now has enough information to schedule the ONU for access to the PON and transmits a standard GATE message allowing the ONU to transmit a REGISTER_ACK. Upon receipt of the REGISTER_ACK, the discovery process for that ONU is complete, the ONU is registered and normal message traffic can begin. It is the responsibility of Layer Management to perform the MAC bonding, and start transmission from/to the newly registered ONU. The discovery message exchange is illustrated in Figure 64–14.

There may exist situations when the OLT requires that an ONU go through the discovery sequence again and reregister. Similarly, there may be situations where an ONU needs to inform the OLT of its desire to deregister. The ONU can then reregister by going through the discovery sequence. For the OLT, the REGISTER message may indicate a value, Reregister or Deregister, that if either is specified will force the receiving ONU into reregistering. For the ONU, the REGISTER_REQ message contains the Deregister bit that signifies to the OLT that this ONU should be deregistered.

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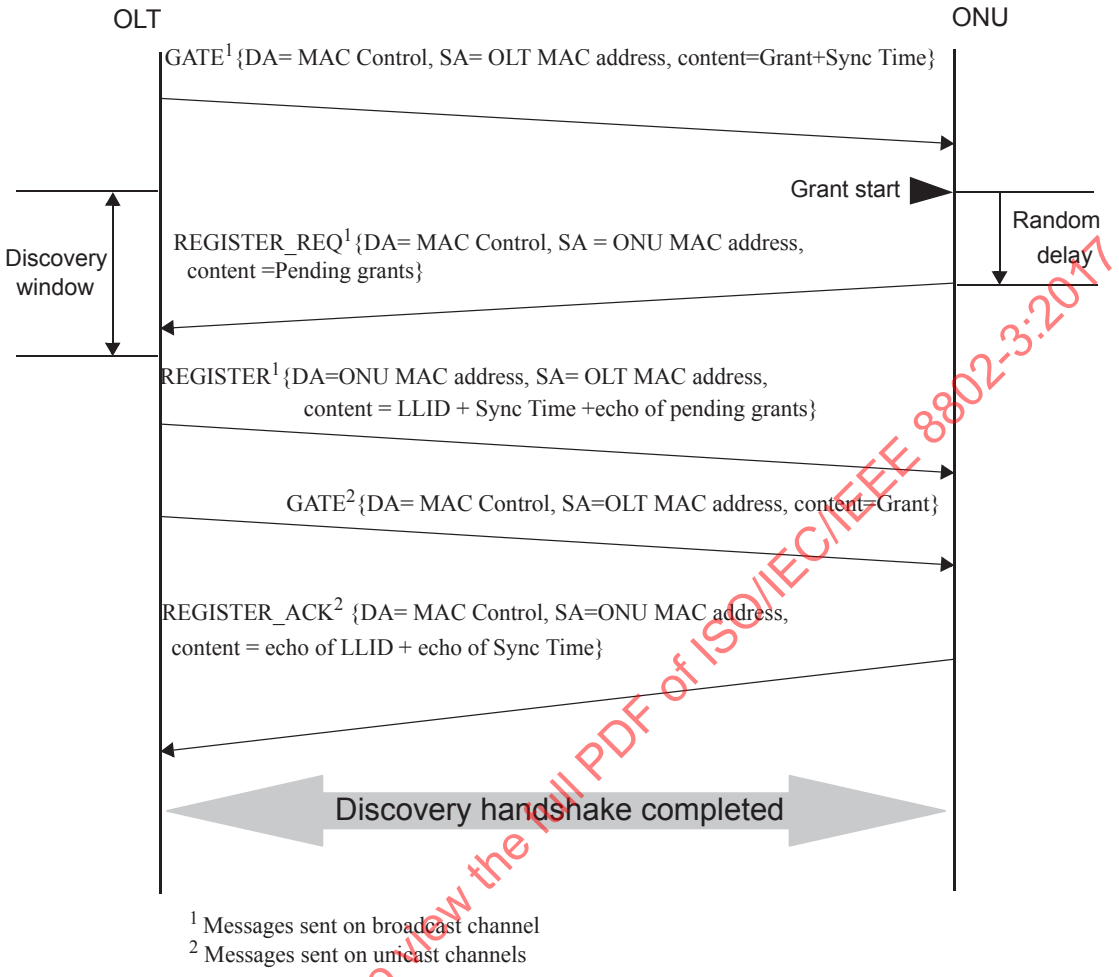

Figure 64–14—Discovery Handshake Message Exchange

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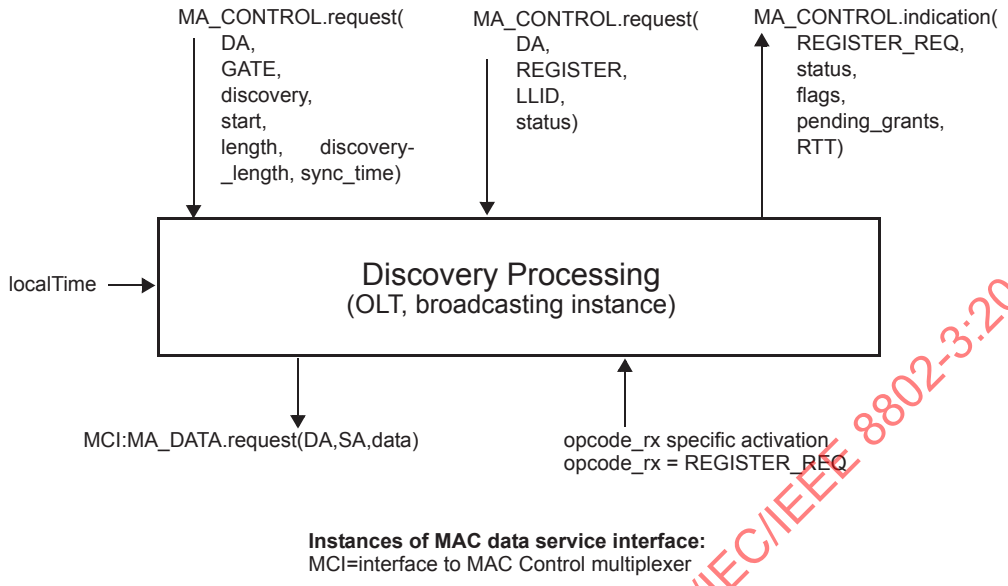

Figure 64–15—Discovery Processing service interfaces (OLT, broadcasting instance)

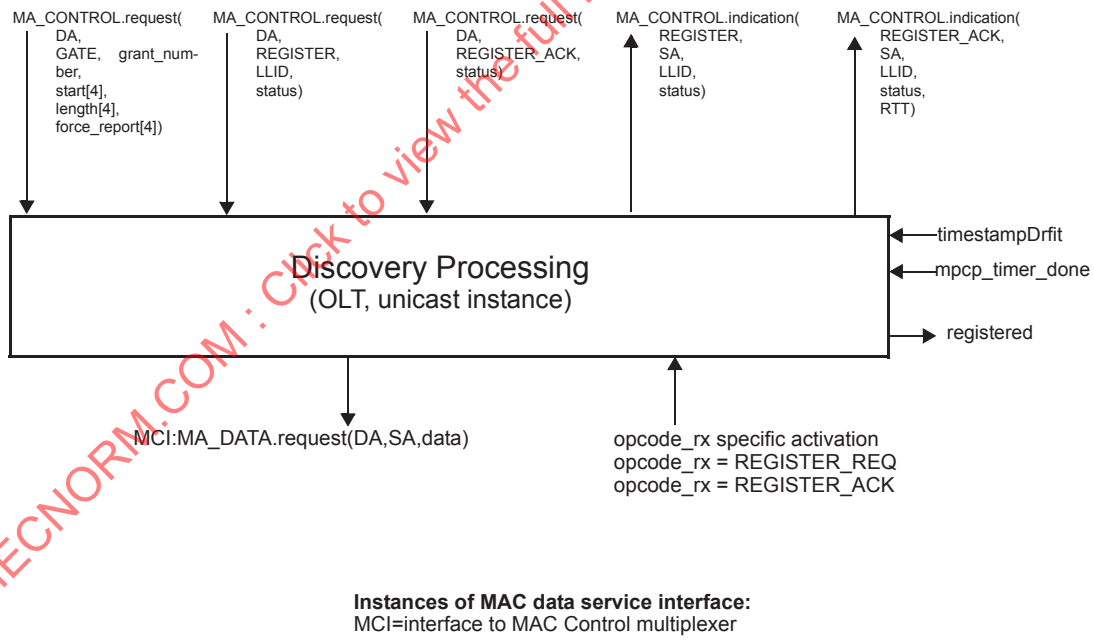

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Figure 64–16—Discovery Processing service interfaces (OLT, unicasting instance)

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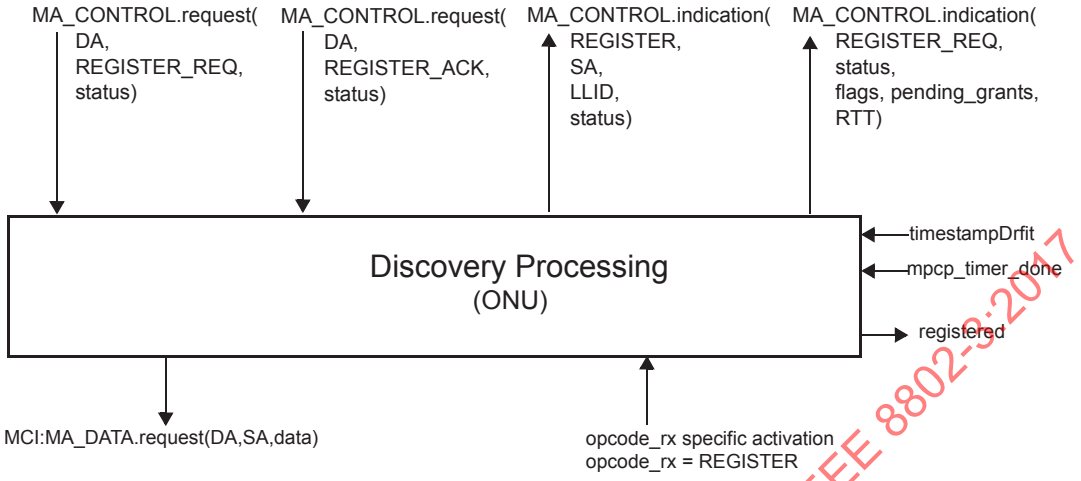

Figure 64–17—Discovery Processing service interfaces (ONU)

64.3.3.1 Constants

No constants defined.

64.3.3.2 Variables

BEGIN
: This variable is defined in 64.2.2.3.

data_rx
: This variable is defined in 64.2.2.3.

data_tx
: This variable is defined in 64.2.2.3.

grantEndTime
: This variable holds the time at which the OLT expects the ONU grant to complete. Failure of a REGISTER_ACK message from an ONU to arrive at the OLT before grantEndTime is a fatal error in the discovery process, and causes registration to fail for the specified ONU, who may then retry to register. The value of grantEndTime is measured in units of time_quantum.
: TYPE: 32-bit unsigned

insideDiscoveryWindow
: This variable holds the current status of the discovery window. It is set to true when the discovery window opens, and is set to false when the discovery window closes.
: TYPE: Boolean

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localTime
This variable is defined in 64.2.2.2.

opcode_rx
This variable is defined in 64.2.2.3.

opcode_tx
This variable is defined in 64.2.2.3.

pendingGrants
This variable holds the maximum number of pending grants that an ONU is able to queue.
TYPE: 16 bit unsigned

registered
This variable holds the current result of the Discovery Process. It is set to true once the discovery process is complete and registration is acknowledged.
TYPE: Boolean

syncTime
This variable holds the time required to stabilize the receiver at the OLT. It counts time_quanta units from the point where transmission output is stable to the point where synchronization has been achieved. The value of syncTime includes gain adjustment interval ($T_{receiver_settling}$), clock synchronization interval (T_{CDR}), and code-group alignment interval ($T_{code_group_align}$), as specified in 60.9.13.2. The OLT conveys the value of syncTime to ONUs in Discovery GATE and REGISTER messages. During the synchronization time only IDLE patterns can be transmitted by an ONU.
TYPE: 16 bit unsigned

timestampDrift
This variable is defined in 64.2.2.3.

64.3.3.3 Functions

None.

64.3.3.4 Timers

discovery_window_size_timer
This timer is used to wait for the event signaling the end of the discovery window.
VALUE: The timer value is set dynamically based on the parameters received in a DISCOVERY GATE message.

mpcp_timer
This timer is used to measure the arrival rate of MPCP frames in the link. Failure to receive frames is considered a fatal fault and leads to deregistration.

64.3.3.5 Messages

MA_DATA.indication(DA, SA, m_sdu, receiveStatus)
The service primitive is defined in 2.3.2.

MA_DATA.request (DA, SA, m_sdu)
The service primitive is defined in 2.3.2.

MA_CONTROL.request(DA, GATE, discovery, start, length, discovery_length, sync_time)
The service primitive used by the MAC Control client at the OLT to initiate the Discovery Process. This primitive takes the following parameters:

DA:	multicast or unicast MAC address.
GATE:	opcode for GATE MPCPDU as defined in Table 31A–1.
discovery:	flag specifying that the given GATE message is to be used for discovery only.

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start: start time of the discovery window.
length: length of the grant given for discovery.
discovery_length: length of the discovery window process.
sync_time: the time interval required to stabilize the receiver at the OLT.

MA_CONTROL.request(DA, GATE, grant_number, start[4], length[4], force_report[4])

This service primitive is used by the MAC Control client at the OLT to issue the GATE message to an ONU. This primitive takes the following parameters:

DA: multicast MAC Control address as defined in Annex 31B.
GATE: opcode for GATE MPCPDU as defined in Table 31A–1.
grant_number: number of grants issued with this GATE message. The number of grants ranges from 0 to 4.
start[4]: start times of the individual grants. Only the first grant_number elements of the array are used.
length[4]: lengths of the individual grants. Only the first grant_number elements of the array are used.
force_report[4]: flags indicating whether a REPORT message should be generated in the corresponding grant. Only the first grant_number elements of the array are used.

MA_CONTROL.request(DA, REGISTER_REQ, status)

The service primitive used by a client at the ONU to request the Discovery Process to perform a registration. This primitive takes the following parameters:

DA: multicast MAC Control address as defined in Annex 31B.
REGISTER_REQ: opcode for REGISTER_REQ MPCPDU as defined in Table 31A–1.
status: This parameter takes on the indication supplied by the flags field in the REGISTER_REQ MPCPDU as defined in Table 64–3.

MA_CONTROL.indication(REGISTER_REQ, status, flags, pending_grants, RTT)

The service primitive issued by the Discovery Process to notify the client and Layer Management that the registration process is in progress. This primitive takes the following parameters:

REGISTER_REQ: opcode for REGISTER_REQ MPCPDU as defined in Table 31A–1.
status: This parameter holds the values incoming or retry. Value incoming is used at the OLT to signal that a REGISTER_REQ message was received successfully. The value retry is used at the ONU to signal to the client that a registration attempt failed and will be repeated.
flags: This parameter holds the contents of the flags field in the REGISTER_REQ message. This parameter holds a valid value only when the primitive is generated by the Discovery Process is in the OLT.
pending_grants: This parameters holds the contents of the pending_grants field in the REGISTER_REQ message. This parameter holds a valid value only when the primitive is generated by the Discovery Process in the OLT.

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RTT: The measured round trip time to/from the ONU is returned in this parameter. RTT is stated in time_quanta units. This parameter holds a valid value only when the primitive is generated by the Discovery Process in the OLT.

MA_CONTROL.request(DA, REGISTER, LLID, status, pending_grants)

The service primitive used by the MAC Control client at the OLT to initiate acceptance of an ONU. This primitive takes the following parameters:

DA: Unicast MAC address or multicast MAC Control address as defined in Annex 31B.

REGISTER: opcode for REGISTER MPCPDU as defined in Table 31A–1.

LLID: This parameter holds the logical link identification number assigned by the MAC Control client.

status: This parameter takes on the indication supplied by the flags field in the REGISTER MPCPDU as defined in Table 64–4.

pending_grants: This parameters echoes back the pending_grants field that was previously received in the REGISTER_REQ message.

MA_CONTROL.indication(REGISTER, SA, LLID, status)

This service primitive is issued by the Discovery Process at the OLT or an ONU to notify the MAC Control client and Layer Management of the result of the change in registration status. This primitive takes the following parameters:

REGISTER: opcode for REGISTER MPCPDU as defined in Table 31A–1.

SA This parameter represents is the MAC address of the OLT.

LLID This parameter holds the logical link identification number assigned by the MAC Control client.

status This parameter holds the value of accepted/denied/deregistered/reregistered.

MA_CONTROL.request(DA, REGISTER_ACK, status)

This service primitive is issued by the MAC Control clients at the ONU and the OLT to acknowledge the registration. This primitive takes the following parameters:

DA: multicast MAC Control address as defined in Annex 31B.

REGISTER_ACK: opcode for REGISTER_ACK MPCPDU as defined in Table 31A–1.

status: This parameter takes on the indication supplied by the flags field in the REGISTER MPCPDU as defined in Table 64–5.

MA_CONTROL.indication(REGISTER_ACK, SA, LLID, status, RTT)

This service primitive is issued by the Discovery Process at the OLT to notify the client and Layer Management that the registration process has completed. This primitive takes the following parameters:

REGISTER_ACK: opcode for REGISTER_ACK MPCPDU as defined in Table 31A–1.

SA This parameter represents the MAC address of the reciprocating device (ONU address at the OLT, and OLT address at the ONU).

LLID This parameter holds the logical link identification number assigned by the MAC Control client.

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status	This parameter holds the value of accepted/denied/reset/ deregistered.
RTT	The measured round trip time to/from the ONU is returned in this parameter. RTT is stated in time_quanta units. This parameter holds a valid value only when the invoking Discovery Process is in the OLT

Opcode-specific function(opcode)

Functions exported from opcode specific blocks that are invoked on the arrival of a MAC Control message of the appropriate opcode.

64.3.3.6 State Diagram

Discovery process in the OLT shall implement the discovery window setup state diagram shown in Figure 64–18, request processing state diagram as shown in Figure 64–19, register processing state diagram as shown in Figure 64–20, and final registration state diagram as shown in Figure 64–21. The discovery process in the ONU shall implement registration state diagram as shown in Figure 64–22.

Instantiation of state diagrams as described in Figure 64–18, Figure 64–19, and Figure 64–20 is performed only at the Multipoint MAC Control instance attached to the broadcast LLID. Instantiation of state diagrams as described in Figure 64–21 and Figure 64–22 is performed for every Multipoint MAC Control instance, except the instance attached to the broadcast channel.

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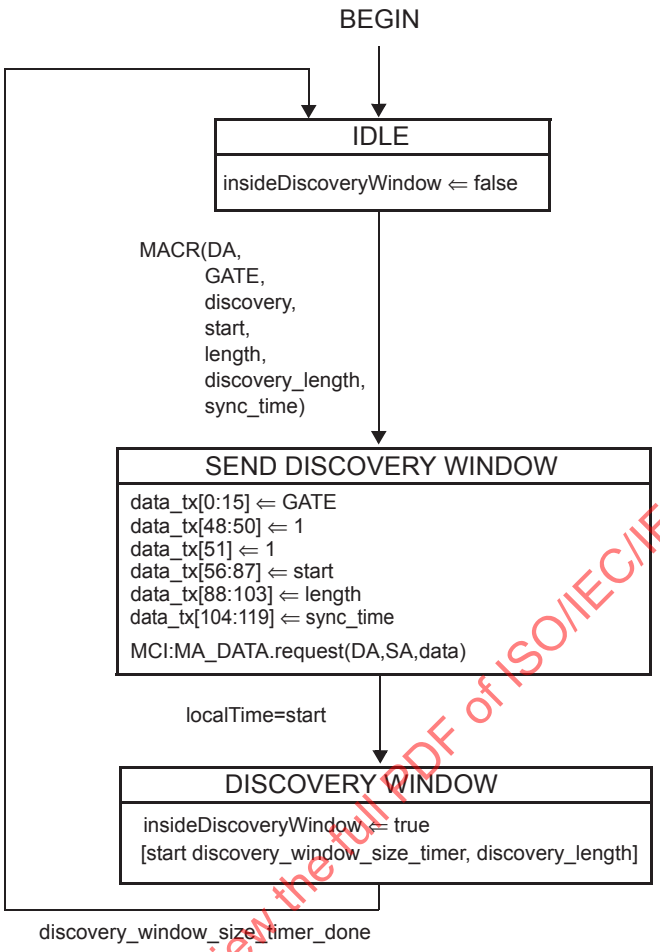

Figure 64–18—Discovery Processing OLT Window Setup state diagram

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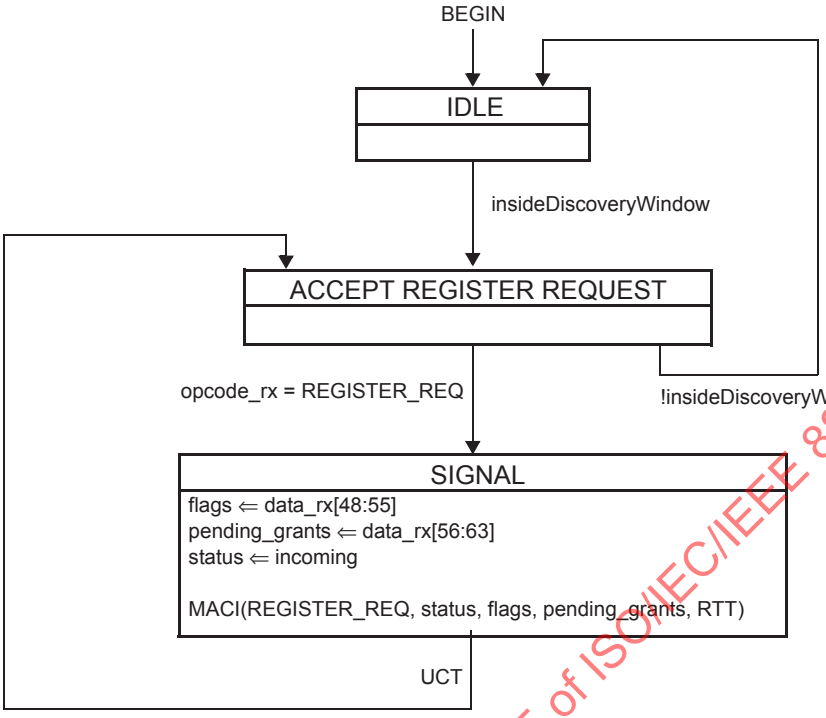

Figure 64–19—Discovery Processing OLT Process Requests State Diagram

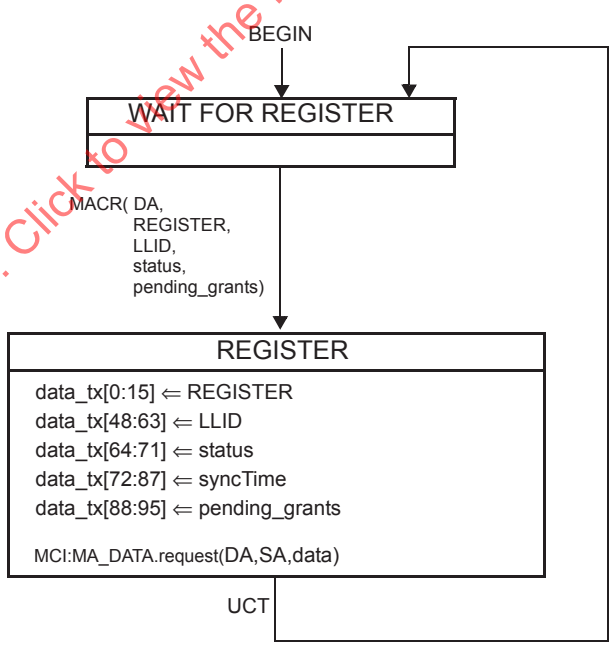

Figure 64–20—Discovery Processing OLT Register State Diagram

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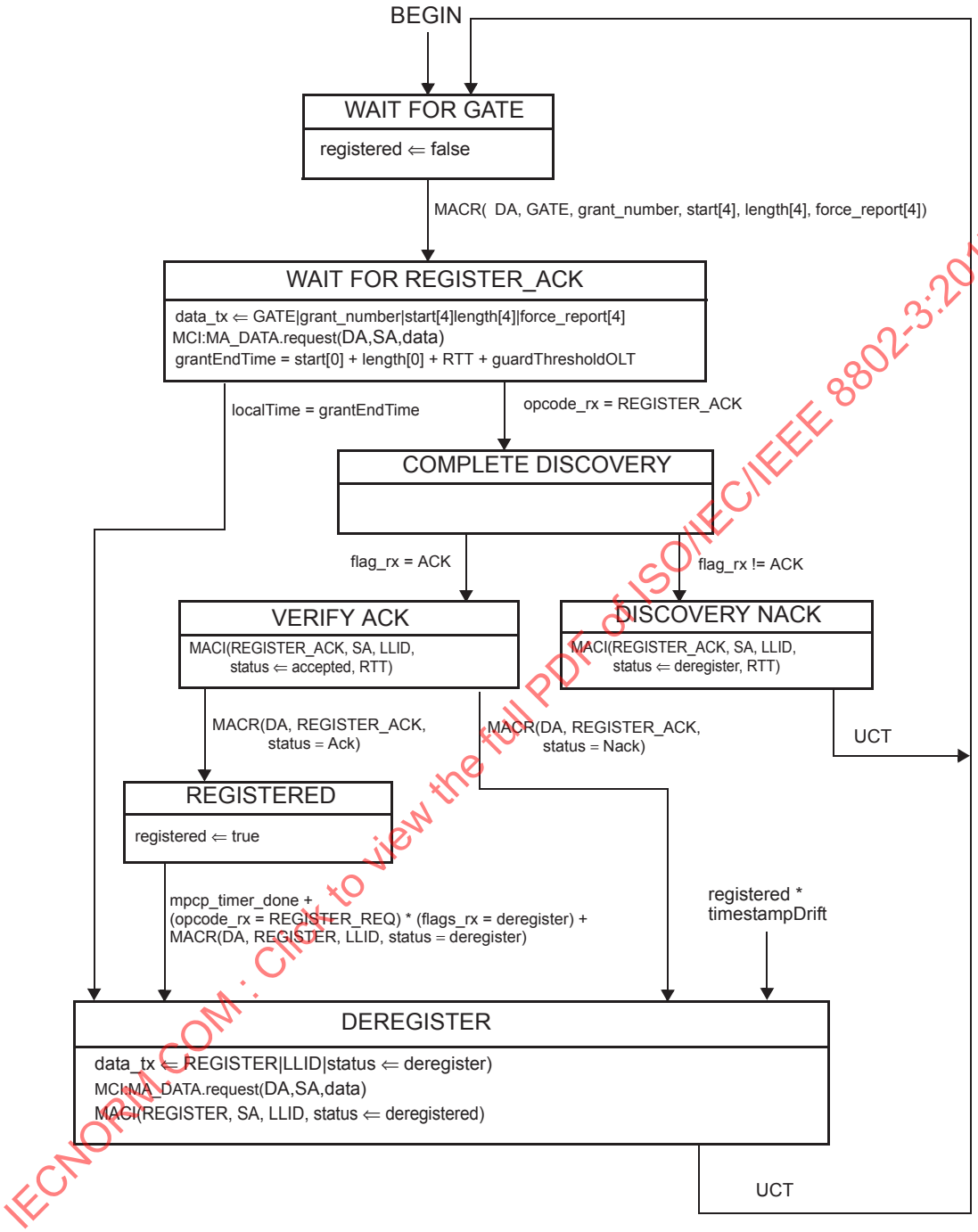

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NOTE—The MAC Control Client issues the grant following the REGISTER message, taking the ONU processing delay of REGISTER message into consideration.

Figure 64–21—Discovery Processing OLT Final Registration State Diagram

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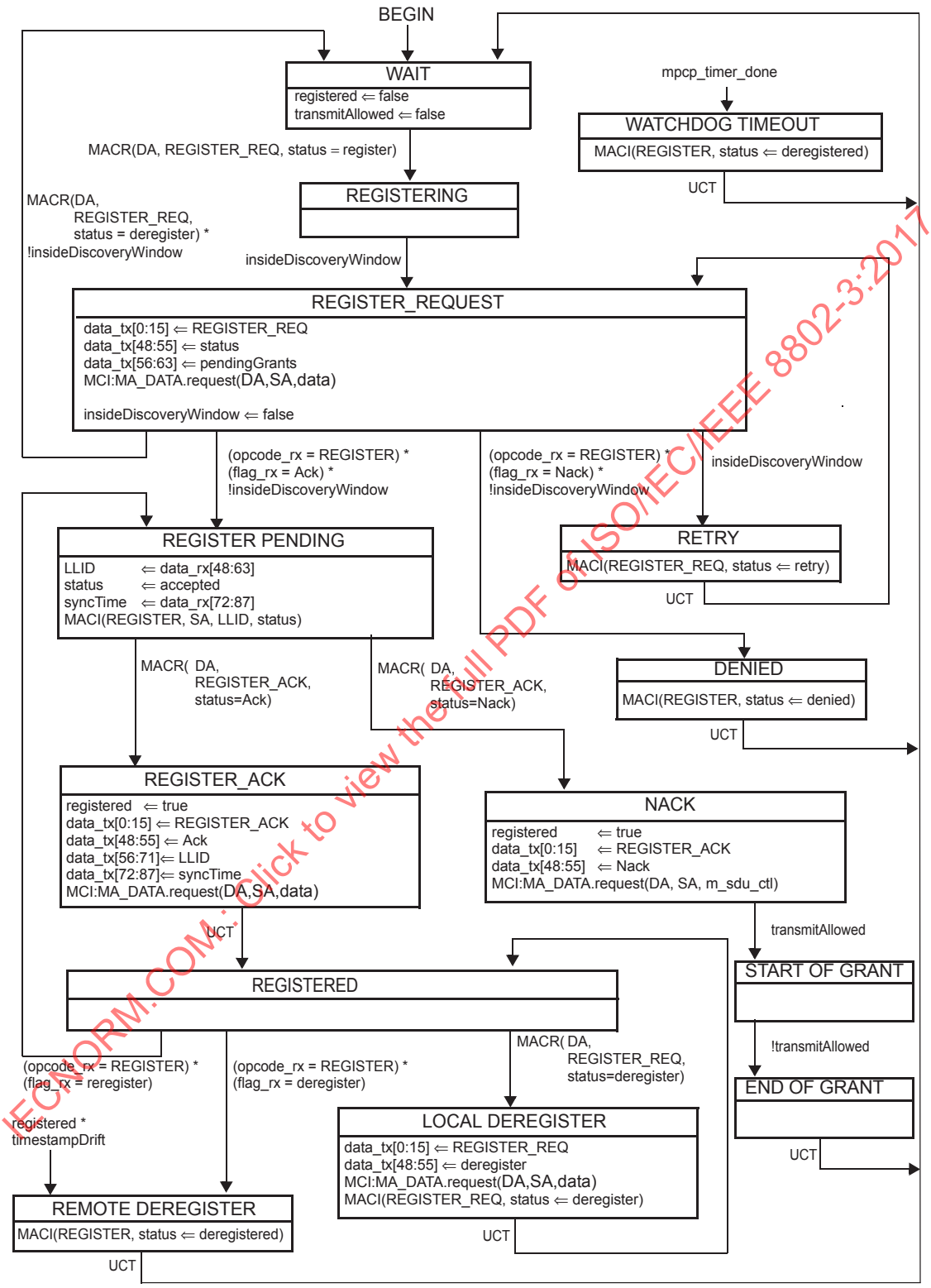

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Figure 64–22—Discovery Processing ONU Registration State Diagram

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64.3.4 Report Processing

The Report Processing functional block has the responsibility of dealing with queue report generation and termination in the network. Reports are generated by higher layers and passed to the MAC Control sublayer by the MAC Control clients. Status reports are used to signal bandwidth needs as well as for arming the OLT watchdog timer.

Reports shall be generated periodically, even when no request for bandwidth is being made. This keeps a watchdog timer in the OLT from expiring and deregistering the ONU. For proper operation of this mechanism the OLT shall grant the ONU periodically.

The Report Processing functional block, and its MPCP protocol elements are designed for use in conjunction with an IEEE 802.1P capable bridge.

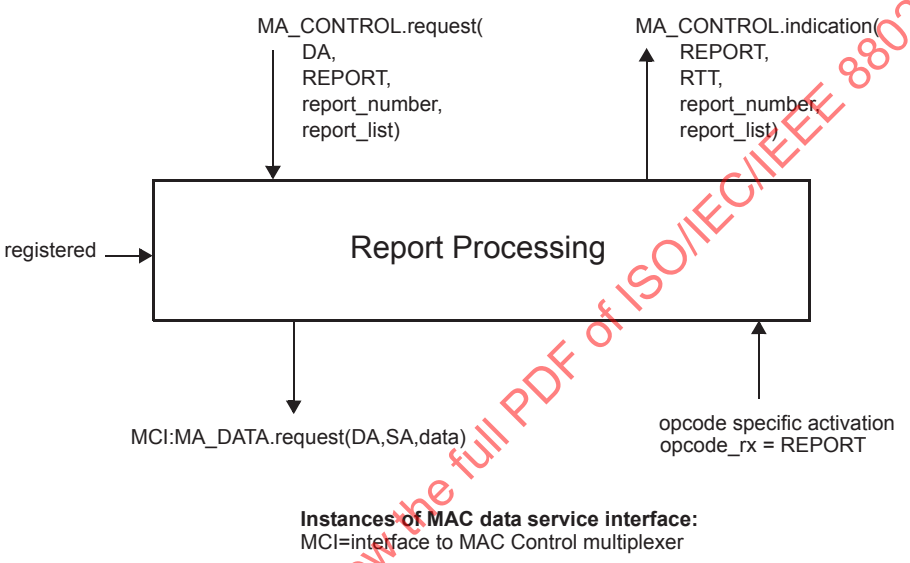

Figure 64–23—Report Processing service interfaces

64.3.4.1 Constants

None

64.3.4.2 Variables

BEGIN
: This variable is used when initiating operation of the functional block state diagram. It is set to true following initialization and every reset.
TYPE: Boolean

data_rx
: This variable is defined in 64.2.2.3.

data_tx
: This variable is defined in 64.2.2.3.

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mpcp_timeout
: This variable represents the maximum allowed interval of time between two MPCPDU messages. Failure to receive at least one frame within this interval is considered a fatal fault and leads to deregistration. This variable is expressed in units of time_quanta.
  TYPE 32-bit unsigned
  VALUE 03-B9-AC-A0 (1 s, default value)

opcode_rx
: This variable is defined in 64.2.2.3.

opcode_tx
: This variable is defined in 64.2.2.3.

registered
: This variable is defined in 64.3.3.2.

report_timeout
: This variable represents the maximum allowed interval of time between two REPORT messages generated by the ONU, expressed in units of time_quanta.
  TYPE 32-bit unsigned
  VALUE 00-2F-AF-08 (50 ms, default value)

64.3.4.3 Functions

None.

64.3.4.4 Timers

report_periodic_timer
: ONUs are required to generate REPORT MPCPDUs with a periodicity of less than report_timeout value. This timer counts down time remaining before a forced generation of a REPORT message in an ONU.

mpcp_timer
: This timer is defined in 64.3.3.4.

64.3.4.5 Messages

MA_DATA.request (DA, SA, m_sdu)
: The service primitive is defined in 2.3.2.

MA_CONTROL.request(DA, REPORT, report_number, report_list)
: This service primitive is used by a MAC Control client to request the Report Process at the ONU to transmit a queue status report. This primitive may be called at variable intervals, independently of the granting process, in order to reflect the time varying aspect of the network. This primitive uses the following parameters:

DA:	multicast MAC Control address as defined in Annex 31B.
REPORT:	opcode for REPORT MPCPDU as defined in Table 31A–1.
report_number:	the number of queue status report sets located in report list. The report_number value ranges from 0 to a maximum of 13.

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report_list: the list of queue status reports. A queue status report consists of two fields: valid and status. The parameter valid, is a Boolean array with length of 8, '0' or false indicates that the corresponding status field is not present (the length of status field is 0), while '1' or true indicates that the corresponding status field is present (the length of status field is 2 octets). The index of the array is meant to reflect the same numbered priority queue in the IEEE 802.1P nomenclature.
The parameter status is an array of 16-bit unsigned integer values. This array consists only of entries whose corresponding bit in field valid is set to true.

MA_CONTROL.indication(REPORT, RTT, report_number, report_list)

The service primitive issued by the Report Process at the OLT to notify the MAC Control client and higher layers the queue status of the MPCP link partner. This primitive may be called multiple times, in order to reflect the time-varying aspect of the network. This primitive uses the following parameters:

REPORT: opcode for REPORT MPCPDU as defined in Table 31A–1.

RTT: this parameter holds an updated round trip time value which is recalculated following each REPORT message reception.

report_number: the number of queue status report sets located in report list. The report number value ranges from 0 to a maximum of 13.

report_list: the list of queue status reports. A queue status report consists of two fields: valid and status. The parameter valid, is a Boolean array with length of 8, '0' or false indicates that the corresponding status field is not present (the length of status field is 0), while '1' or true indicates that the corresponding status field is present (the length of status field is 2 octets). The index of the array is meant to reflect the same numbered priority queue in the 802.1P nomenclature.
The parameter status is an array of 16-bit unsigned integer values. This array consists only of entries whose corresponding bit in field valid is set to true.

Opcode-specific function(opcode)

Functions exported from opcode specific blocks that are invoked on the arrival of a MAC Control message of the appropriate opcode.

64.3.4.6 State Diagram

The report process in the OLT shall implement the report processing state diagram as shown in Figure 64–24. The report process in the ONU shall implement the report processing state diagram as shown in Figure 64–25. Instantiation of state diagrams as described is performed for Multipoint MAC Control instances attached to unicast LLIDs only.

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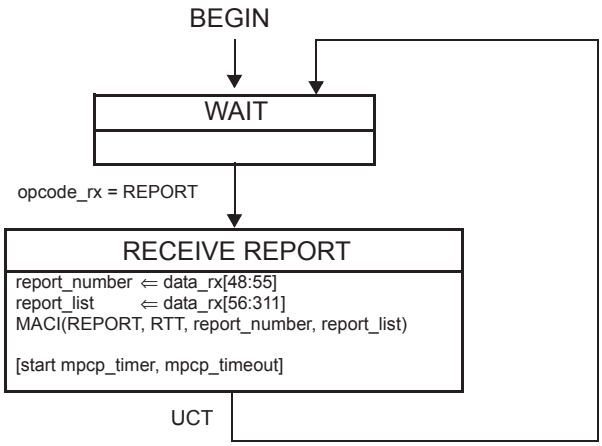
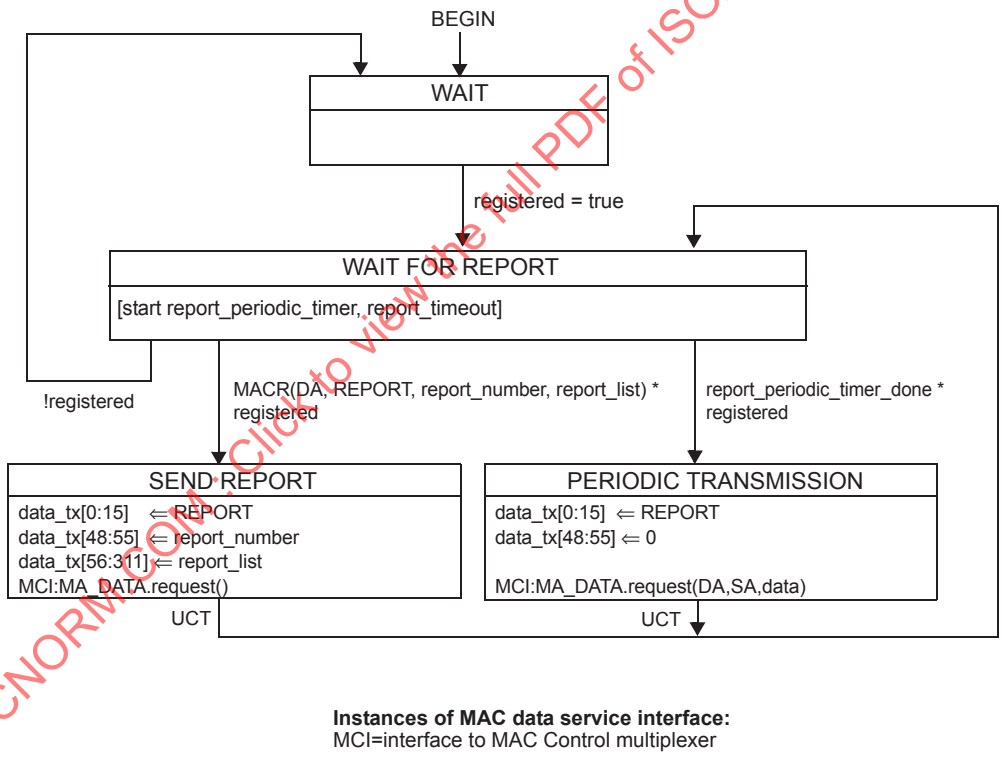


Figure 64–24—Report Processing State Diagram at OLT



Instances of MAC data service interface:
MCI=interface to MAC Control multiplexer

Figure 64–25—Report Processing state diagram at ONU

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64.3.5 Gate Processing

A key concept pervasive in Multipoint MAC Control is the ability to arbitrate a single transmitter out of a plurality of ONUs. The OLT controls an ONU's transmission by the assigning of grants.

The transmitting window of an ONU is indicated in GATE message where start time and length are specified. An ONU will begin transmission when its localTime counter matches start_time value indicated in the GATE message. An ONU will conclude its transmission with sufficient margin to ensure that the laser is turned off before the grant length interval has elapsed.

Multiple outstanding grants may be issued to each ONU. The OLT shall not issue more than the maximal supported maximal outstanding grants as advertised by the ONU during registration (see pending grants in 64.3.6.3).

In order to maintain the watchdog timer at the ONU, grants are periodically generated. For this purpose empty GATE messages may be issued periodically.

When registered, the ONU ignores all gate messages where the discovery flag is set.

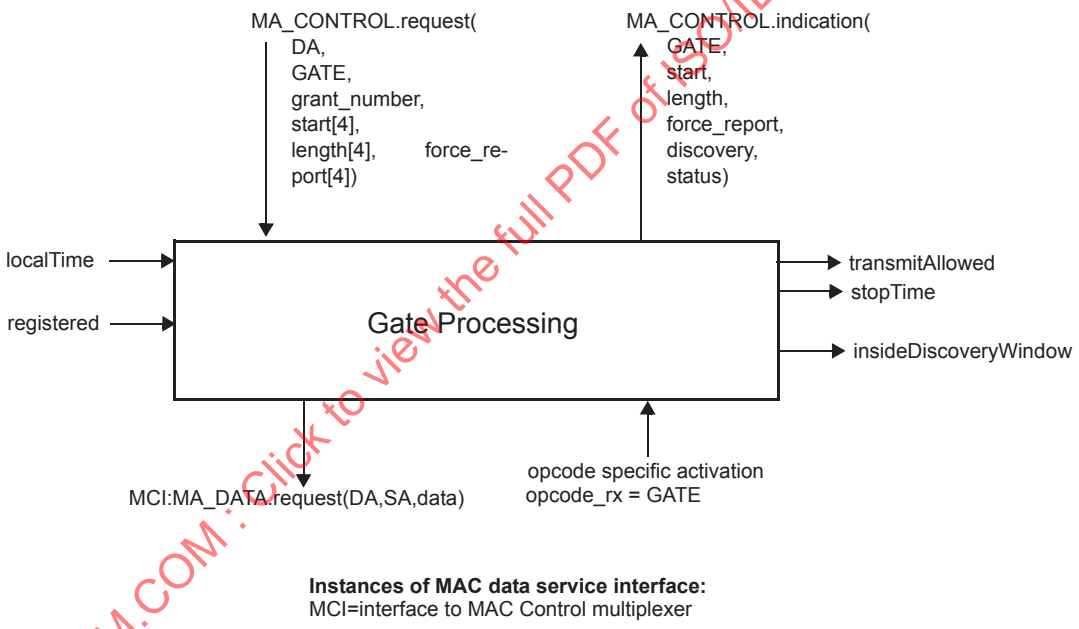

Figure 64–26—Gate Processing service interface

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64.3.5.1 Constants

discoveryGrantLength

This constant represents the duration of ONU's transmission during discovery attempt. The value of discoveryGrantLength includes MPCPDU transmission time and tailGuard as defined in 64.2.2.1. discoveryGrantLength is represented in units of time_quanta.

TYPE: 32 bit unsigned
VALUE: 00-00-00-26 (608 ns)

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laserOffTime
This constant holds the time required to terminate the laser. It counts in time_quanta units the time period required for turning off the PMD, as specified in 60.9.13.1.
TYPE: 32 bit unsigned
VALUE: 00-00-00-20 (512 ns)

laserOnTime
This constant holds the time required to initiate the PMD. It counts in time_quanta units the time period required for turning on the PMD, as specified in 60.9.13.1.
TYPE: 32 bit unsigned
VALUE: 00-00-00-20 (512 ns)

max_future_grant_time
This constant holds the time limiting the future time horizon for a valid incoming grant.
TYPE: 32 bit unsigned
VALUE: 03-B9-AC-A0 (1 s)

min_processing_time
This constant is the time required for the ONU processing time.
TYPE: 32 bit unsigned
VALUE: 00-00-04-00 (16.384 us)

tqSize
This constant is defined in 64.2.2.1.

64.3.5.2 Variables

BEGIN
This variable is used when initiating operation of the functional block state diagram. It is set to true following initialization and every reset.
TYPE: Boolean

counter
This variable is used as a loop iterator counting the number of incoming grants in a GATE message.
TYPE: integer

currentGrant
This variable is used for local storage of a pending grant state during processing. It is dynamically set by the Gate Processing functional block and is not exposed.
The state is a structure field composed of multiple subfields.
TYPE: structure {

DA	48 bit unsigned, a.k.a MAC address type
start	32 bit unsigned
length	16 bit unsigned
force_report	Boolean
discovery	Boolean}

data_rx
This variable is defined in 64.2.2.3.

data_tx
This variable is defined in 64.2.2.3.

effectiveLength
This variable is used for temporary storage of a normalized net time value. It holds the net effective length of a grant normalized for elapsed time, and compensated for the periods required to turn the laser on and off, and waiting for receiver lock.
TYPE: 32 bit unsigned

fecEnabled
This variable is defined in 64.2.2.3.

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gate_timeout

This variable represents the maximum allowed interval of time between two GATE messages generated by the OLT to the same ONU, expressed in units of time_quanta.

TYPE 32-bit unsigned
VALUE 00-2F-AF-08 (50 ms, default value)

grantList

This variable is used for storage of the list of pending grants. It is dynamically set by the Gate Processing functional block and is not exposed. Each time a grant is received it is added to the list.

The list elements are structure fields composed of multiple subfields.

The list is indexed by the start subfield in each element for quick searches.

TYPE: list of elements having the structure define in currentGrant

insideDiscoveryWindow

This variable is defined in 64.3.3.2.

maxDelay

This variable holds the maximum delay that can be applied by an ONU before sending the REGISTER MPCPDU. This delay is calculated such that the ONU would have sufficient time to transmit the REGISTER message and its associated overhead (FEC parity date, end-of-frame sequence, etc.) and terminate the laser before the end of the discovery grant.

TYPE 16 bit unsigned

nextGrant

This variable is used for local storage of a pending grant state during processing. It is dynamically set by the Gate Processing functional block and is not exposed. The content of the variable is the next grant to become active.

TYPE: element having same structure as defined in currentGrant

nextStopTime

This variable holds the value of the localTime counter corresponding to the end of the next grant.

TYPE: 32 bit unsigned

registered

This variable is defined in 64.3.3.2.

stopTime

This variable is defined in 64.2.2.3.

syncTime

This variable is defined in 64.3.3.2.

transmitAllowed

This variable is defined in 64.2.2.3.

64.3.5.3 Functions

empty(list)

This function is use to check whether the list is empty. When there are no elements queued in the list, the function returns true. Otherwise, a value of false is returned.

InsertInOrder(sorted_list, inserted_element)

This function is used to queue an element inside a sorted list. The queueing order is sorted. In the condition that the list is full the element may be discarded. The length of the list is dynamic and its maximal size equals the value advertised during registration as maximum number of pending grants.

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IsBroadcast(grant)

This function is used to check whether its argument represents a broadcast grant, i.e., grant given to multiple ONUs. This is determined by the destination MAC address of the corresponding GATE message. The function returns the value true when MAC address is a global assigned MAC Control address as defined in Annex 31B, and false otherwise.

PeekHead(sorted_list)

This function is used to check the content of a sorted list. It returns the element at the head of the list without dequeuing the element.

Random(r)

This function is used to compute a random integer number uniformly distributed between 0 and r. The randomly generated number is then returned by the function.

RemoveHead(sorted_list)

This function is used to dequeue an element from the head of a sorted list. The return value of the function is the dequeued element.

64.3.5.4 Timers

gntStTmr

This timer is used to wait for the event signaling the start of a grant window.
VALUE: The timer value is dynamically set according to the signaled grant start time.

gntWinTmr

This timer is used to wait for the event signaling the end of a grant window.
VALUE: The timer value is dynamically set according to the signaled grant length.

gate_periodic_timer

The OLT is required to generate GATE MPCPDUs with a periodicity of less than gate_timeout value. This timer counts down time remaining before a forced generation of a GATE message in the OLT.

mpcp_timer

This timer is defined in 64.3.3.4.

rndDlyTmr

This timer is used to measure a random delay inside the discovery window. The purpose of the delay is to apriori reduce the probability of transmission overlap during the registration process, and thus lowering the expectancy of registration time in the PON.
VALUE: A random value less than the net discovery window size less the REGISTER_REQ MPCPDU frame size less the idle period and laser turn on and off delays less the preamble size less the IFG size. The timer value is set dynamically based on the parameters passed from the client.

64.3.5.5 Messages

MA_DATA.request (DA, SA, m_sdu)

The service primitive is defined in 2.3.2.

MA_CONTROL.request(DA, GATE, grant_number, start[4], length[4], force_report[4])

This service primitive is defined in 64.3.3.5.

MA_CONTROL.indication(GATE, start, length, force_report, discovery, status)

This service primitive issued by the Gate Process at the ONU to notify the MAC Control client and higher layers that a grant is pending. This primitive is invoked multiple times when a single GATE message arrives with multiple grants. It is also generated at the start and end of each grant as it becomes active. This primitive uses the following parameters:

GATE: opcode for GATE MPCPDU as defined in Table 31A–1.

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start: start time of the grant. This parameter is not present when the status value is deactive.

length: length of the grant. This parameter is not present when the status value is deactive.

force_report: flags indicating whether a REPORT message should be transmitted in this grant. This parameter is not present when the status value is deactive.

discovery: This parameter holds the value true when the grant is to be used for the discovery process, and false otherwise. This parameter is not present when the status value is deactive.

status: This parameter takes the value *arrive* on grant reception, *active* when a grant becomes active, and *deactive* at the end of a grant.

Opcode-specific function(opcode)

Functions exported from opcode specific blocks that are invoked on the arrival of a MAC Control message of the appropriate opcode.

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64.3.5.6 State Diagrams

The gating process in the OLT shall implement the gate processing state diagram as shown in Figure 64–26. The gating process in the ONU shall implement the gate processing state diagram as shown in Figure 64–27. Instantiation of state diagrams as described is performed for all Multipoint MAC Control instances.

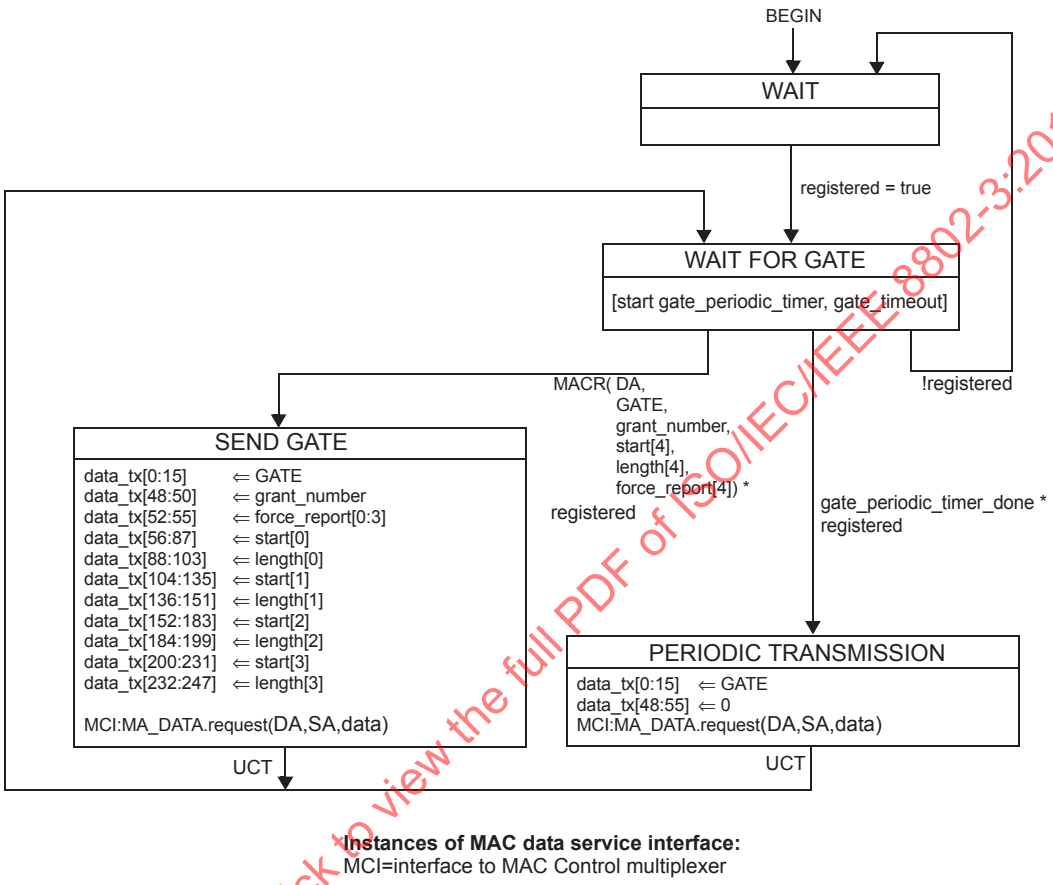

Figure 64–27—Gate Processing state diagram at OLT

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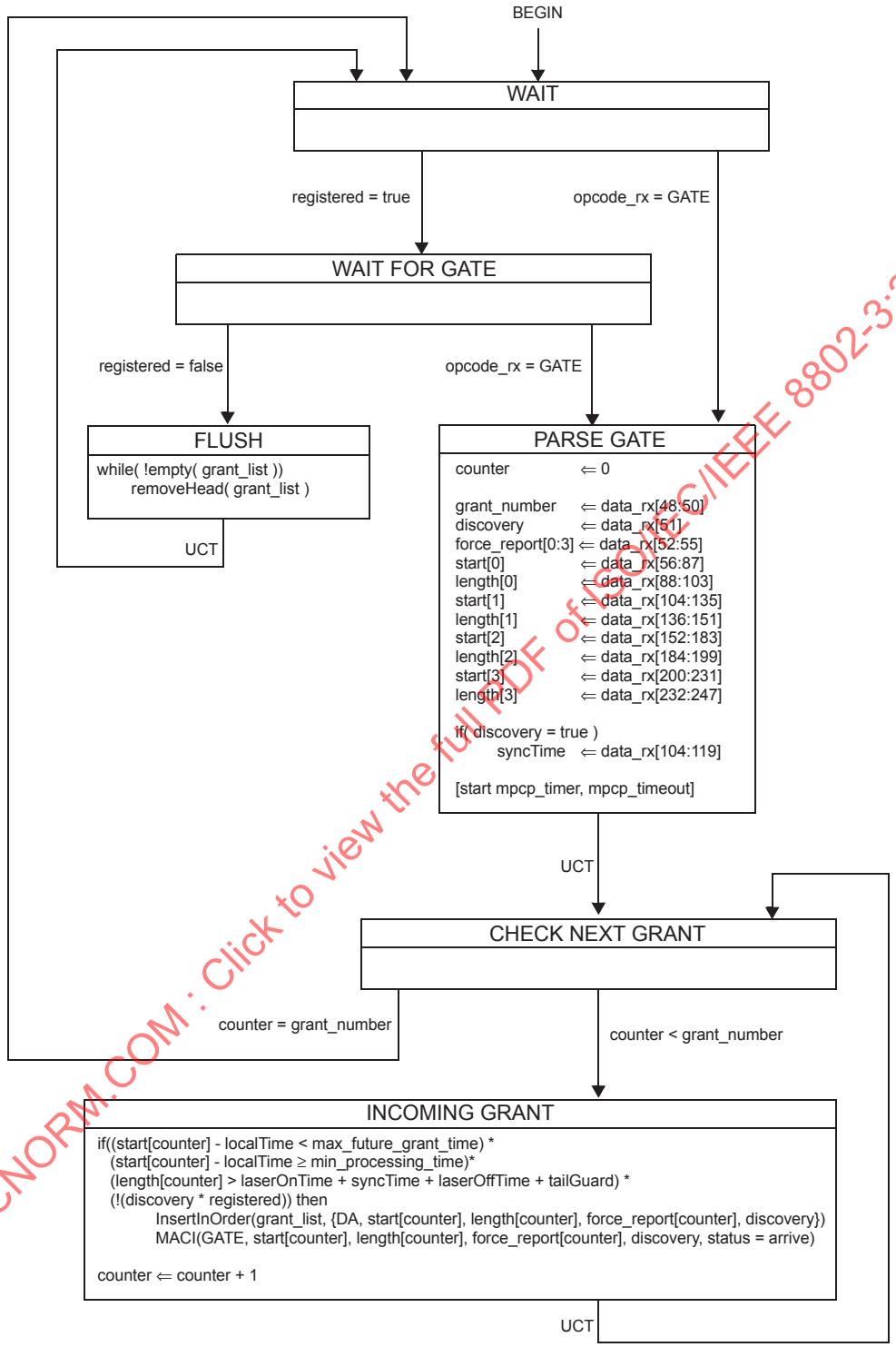

Figure 64–28—Gate Processing ONU Programing State Diagram

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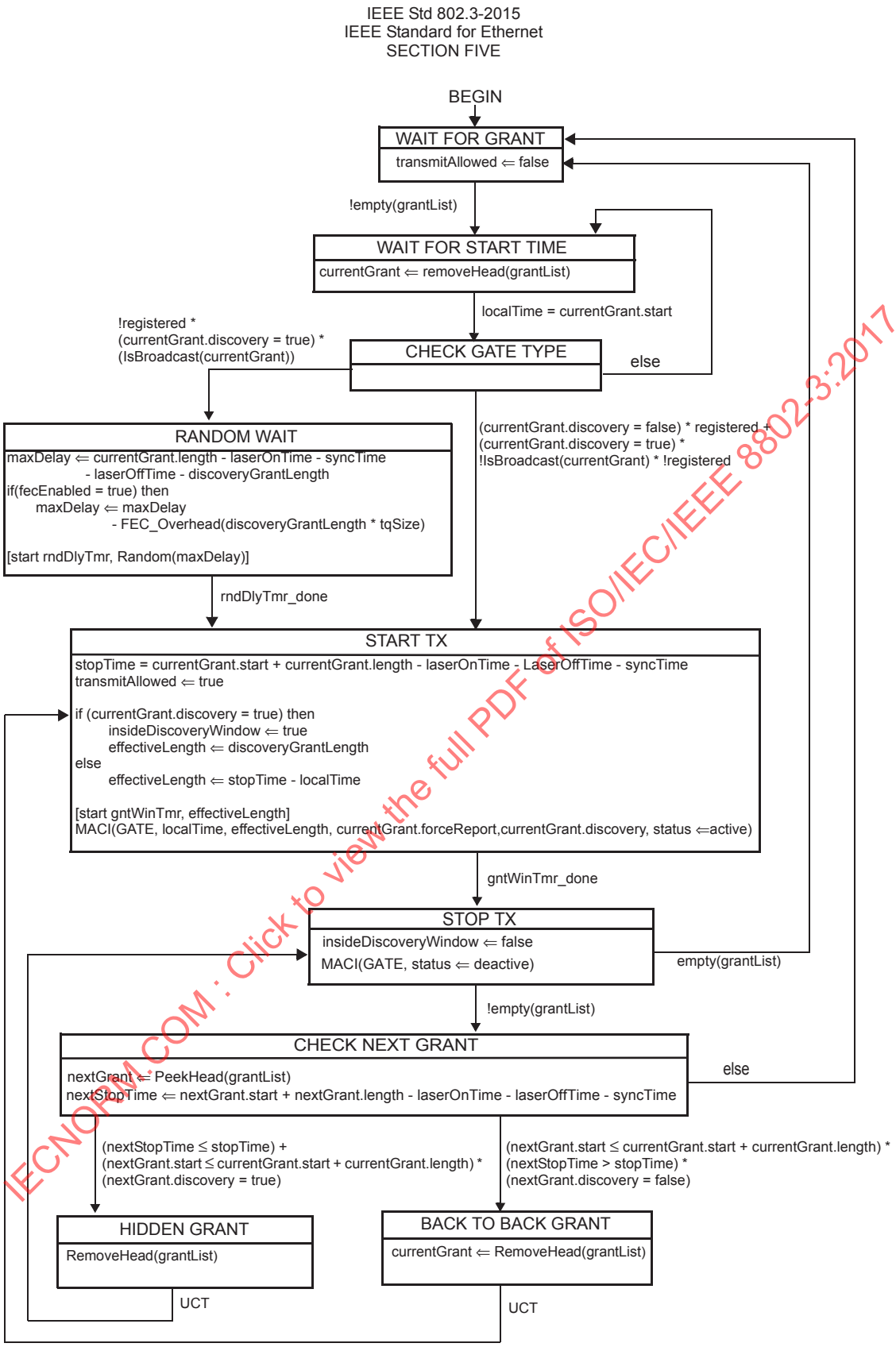

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Figure 64–29—Gate Processing ONU Activation State Diagram

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64.3.6 MPCPDU structure and encoding

The MPCPDU structure shall be as shown in Figure 64–30, and is further defined in the following definitions:

a) Destination Address (DA). The DA in MPCPDU is the MAC Control Multicast address as specified in the annexes to Clause 31, or the individual MAC address associated with the port to which the MPCPDU is destined.
b) Source Address (SA). The SA in MPCPDU is the individual MAC address associated with the port through which the MPCPDU is transmitted. For MPCPDUs originating at the OLT end, this can be the address any of the individual MACs. These MACs may all share a single unicast address, as explained in 64.1.2.
c) Length/Type. The Length/Type in MPCPDU carries the MAC_Control_Type field value as specified in 31.4.1.3.
d) Opcode. The opcode identifies the specific MPCPDU being encapsulated. Values are defined in Table 31A–1.
e) Timestamp. The timestamp field conveys the content of the localTime register at the time of transmission of the MPCPDUs. This field is 32 bits long, and counts 16 bit transmissions. The timestamp counts time in 16 bit time granularity.
f) Data/Reserved/PAD. These 40 octets are used for the payload of the MPCPDUs. When not used they would be filled with zeros on transmission, and be ignored on reception.
g) FCS. This field is the Frame Check Sequence, typically generated by the underlying MAC.

Based on the MAC instance used to generate the specific MPCPDU, the appropriate LLID shall be generated by the RS.

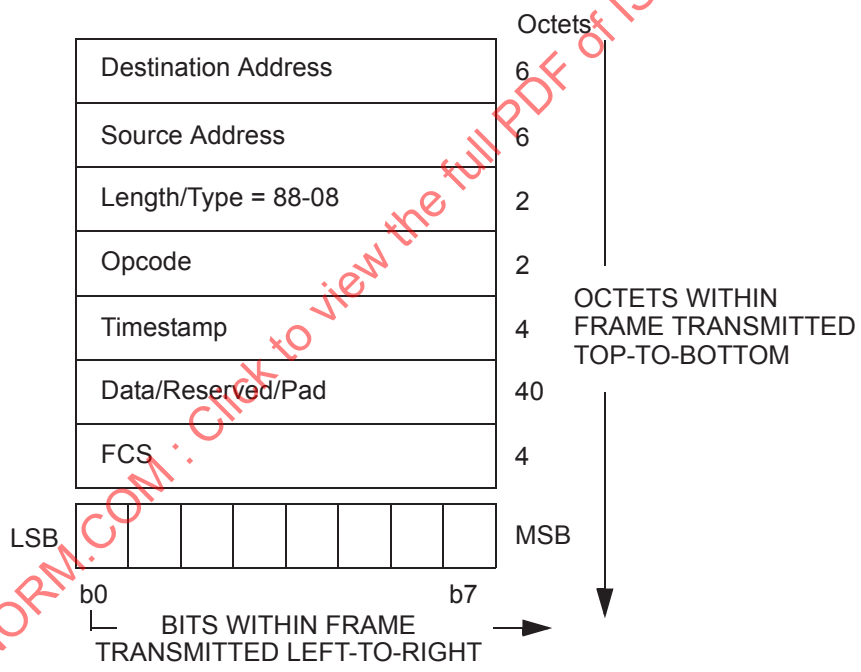

Figure 64–30—Generic MPCPDU

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64.3.6.1 GATE description

The purpose of GATE message is to grant transmission windows to ONUs for both discovery messages and normal transmission. Up to four grants can be included in a single GATE message. The number of grants can also be set to zero for using the GATE message as an MPCP keep alive from OLT to the ONU.

The GATE MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) Opcode. The opcode for the GATE MPCPDU is 0x0002.

b) Flags. This is an 8 bit flag register that holds the following flags: The Number of grants field contains the number of grants, composed of valid Length, Start Time pairs in this MPCPDU. This is a number between 0 and 4. Note: when Number of grants is set to 0, sole purpose of message is conveying of timestamp to ONU.
The Discovery flag field indicates that the signaled grants would be used for the discovery process, in which case a single grant shall be issued in the gate message.
The Force Report flag fields ask the ONU to issue a REPORT message related to the corresponding grant number at the corresponding transmission opportunity indicated in this GATE.

c) Grant #n Length. Length of the signaled grant, this is an 16 bit unsigned field. The length is counted in 16 bit time increments. There are 4 Grants that are possibly packed into the GATE MPCPDU. The laserOnTime, syncTime, and laserOffTime are included in and thus consume part of Grant #n Length.

d) Grant #n Start Time. Start time of the grant, this is an 32 bit unsigned field. The start time is compared to the local clock, to correlate the start of the grant. Transmitted values shall satisfy the condition Grant #n Start Time < Grant #n + 1 Start Time for consecutive grants within the same GATE MPCPDU.

e) Sync Time. This is an unsigned 16 bit value signifying the required synchronization time of the OLT receiver. During the synchronization time the ONU shall send IDLE code-pairs. The value is counted in 16 bit time increments. The advertised value includes synchronization requirement on all receiver elements including PMD, PMA and PCS. This field is present only when the gate is a discovery gate, as signaled by the Discovery flag and is not present otherwise.

Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored on reception when constructing a complying MPCP protocol implementation. The size of this field depends on the used Grant #n Length/Start Time entry-pairs, and varies in length from 13–39 accordingly. The GATE MPCPDU shall be generated by a MAC Control instance mapped to an active ONU, and as such shall be marked with a unicast type of LLID, except when the discovery flag is set where the MAC Control instance is mapped to all ONUs and such frame is marked by the broadcast LLID.

Table 64–1—GATE MPCPDU Number of grants/Flags Fields

Bit	Flag Field	Values
0-2	Number of grants	0–4
3	Discovery	0—Normal GATE 1—Discovery GATE
4	Force Report Grant 1	0—No action required 1—A REPORT frame should be issued at the corresponding transmission opportunity indicated in Grant 1
5	Force Report Grant 2	0—No action required 1—A REPORT frame should be issued at the corresponding transmission opportunity indicated in Grant 2
6	Force Report Grant3	0—No action required 1—A REPORT frame should be issued at the corresponding transmission opportunity indicated in Grant 3
7	Force Report Grant 4	0—No action required 1—A REPORT frame should be issued at the corresponding transmission opportunity indicated in Grant 4

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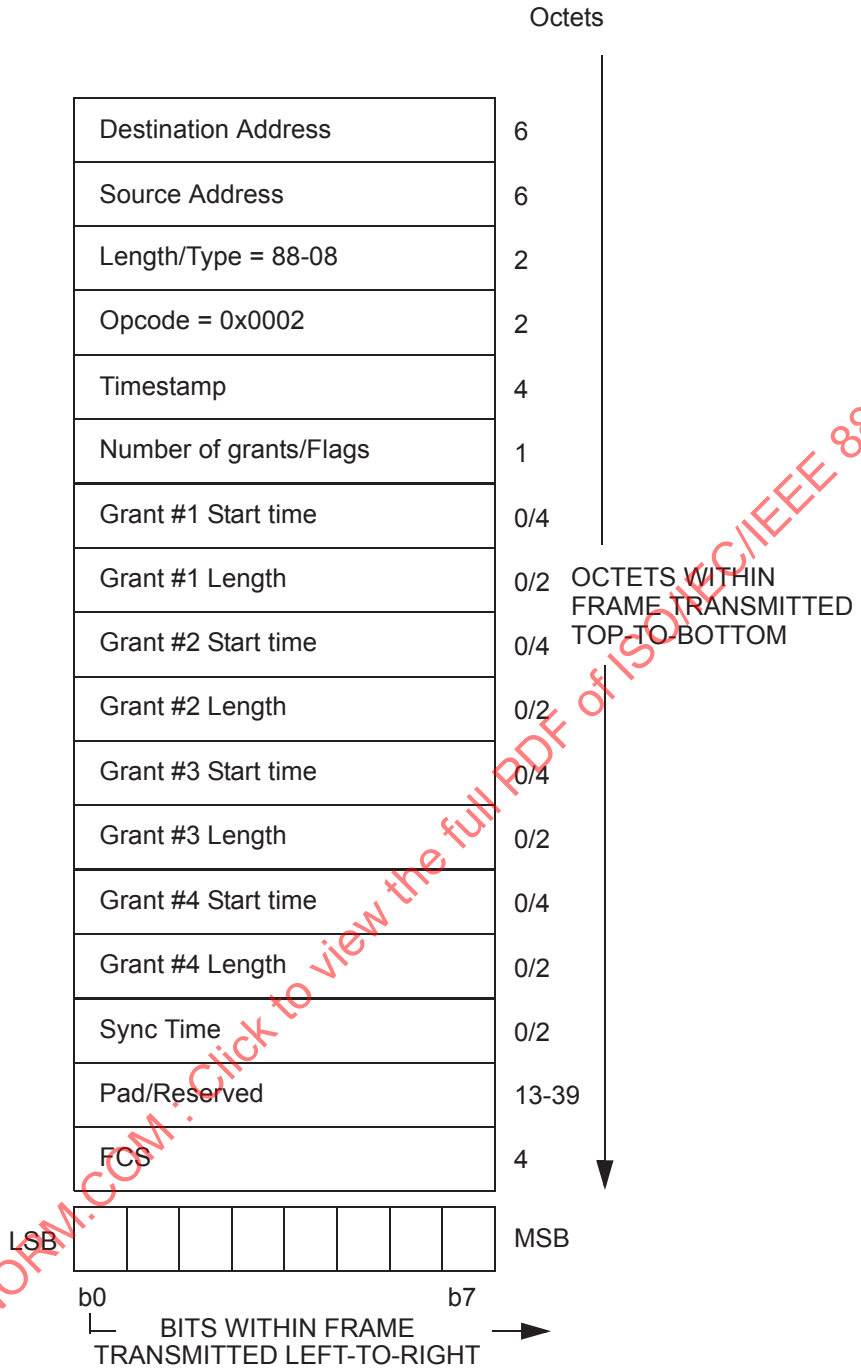

Figure 64–31—GATE MPCPDU

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64.3.6.2 REPORT description

REPORT messages have several functionalities. Time stamp in each REPORT message is used for round trip (RTT) calculation. In the REPORT messages ONUs indicate the upstream bandwidth needs they request per IEEE 802.1Q priority queue. REPORT messages are also used as keep-alives from ONU to OLT. ONUs issue REPORT messages periodically in order to maintain link health at the OLT as defined in 64.3.4. In addition, the OLT may specifically request a REPORT message.

The REPORT MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) Opcode. The opcode for the REPORT MPCPDU is 0x0003.
b) Number of Queue Sets. This field specifies the number of requests in the REPORT message. A REPORT frame may hold multiple sets of Report bitmap and Queue #n as specified in the Number of Queue Sets field
c) Report bitmap. This is an 8 bit flag register that indicates which queues are represented in this REPORT MPCPDU.

Table 64–2—REPORT MPCPDU Report bitmap fields

Bit	Flag Field	Values
0	Queue 0	0—queue 0 report is not present 1—queue 0 report is present
1	Queue 1	0—queue 1 report is not present 1—queue 1 report is present
2	Queue 2	0—queue 2 report is not present 1—queue 2 report is present
3	Queue 3	0—queue 3 report is not present 1—queue 3 report is present
4	Queue 4	0—queue 4 report is not present 1—queue 4 report is present
5	Queue 5	0—queue 5 report is not present 1—queue 5 report is present
6	Queue 6	0—queue 6 report is not present 1—queue 6 report is present
7	Queue 7	0—queue 7 report is not present 1—queue 7 report is present

d) Queue #n Report. This value represents the length of queue# n at time of REPORT message generation. The reported length shall be adjusted to account for the necessary inter-frame spacing and FEC parity data overhead, if FEC is enabled. The Queue #n Report field is an unsigned 16 bit integer representing transmission request in units of time quanta. This field is present only when the corresponding flag in the Report bitmap is set.
e) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored on reception when constructing a complying MPCP protocol implementation. The size of this field depends on the used Queue Report entries, and accordingly varies in length from 0 to 39.

The REPORT MPCPDU shall be generated by a MAC Control instance mapped to an active ONU, and as such shall be marked with a unicast type of LLID.

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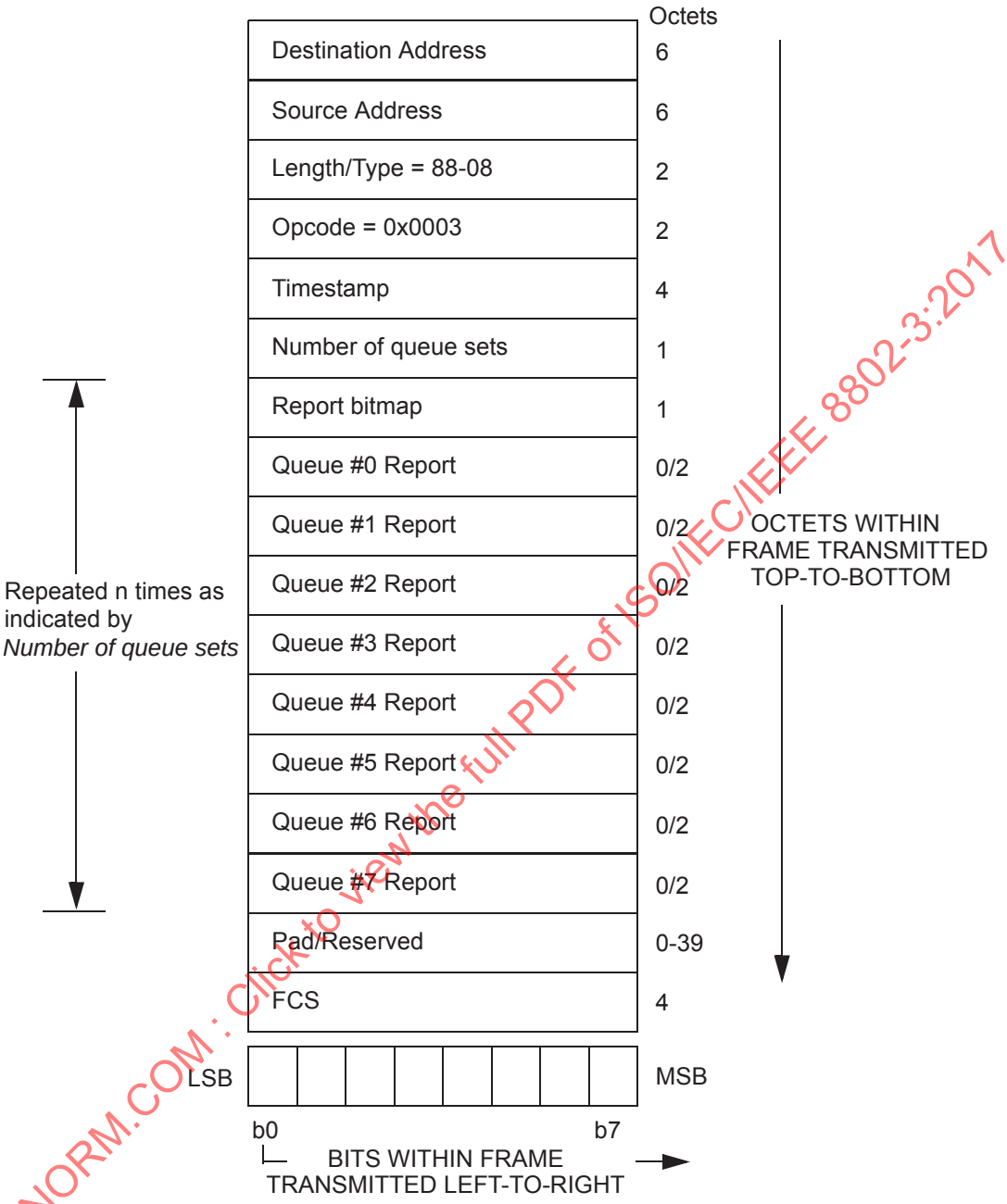

Figure 64–32—REPORT MPCPDU

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64.3.6.3 REGISTER_REQ description

The REGISTER_REQ MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) Opcode. The opcode for the REGISTER_REQ MPCPDU is 0x0004.
b) Flags. This is an 8 bit flag register that indicates special requirements for the registration.

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Table 64–3—REGISTER_REQ MPCPDU Flags fields

Value	Indication	Comment
0	Reserved	Ignored on reception.
1	Register	Registration attempt for ONU.
2	reserved	Ignored on reception.
3	Deregister	This is a request to deregister the ONU. Subsequently, the MAC is deallocated and the LLID may be reused.
4–255	Reserved	Ignored on reception.

c) Pending grants. This is an unsigned 8 bit value signifying the maximum number of future grants the ONU is configured to buffer. The OLT should not grant the ONU more than this maximum number of Pending grants vectors comprised of {start, length, force_report, discovery} into the future.

d) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored on reception when constructing a complying MPCP protocol implementation.

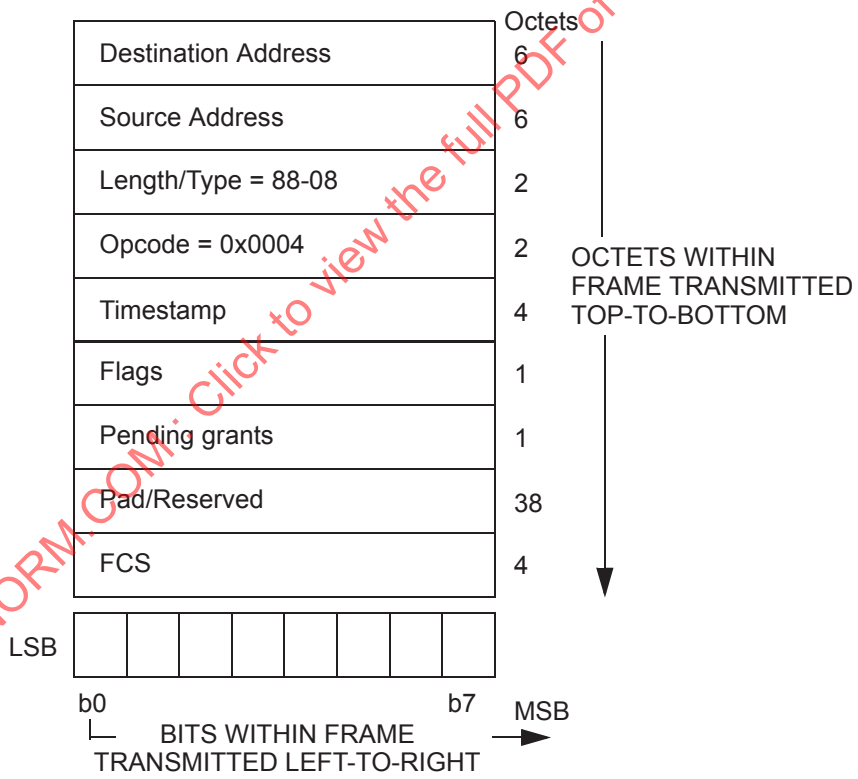

Figure 64–33—REGISTER_REQ MPCPDU

The REGISTER_REQ MPCPDU shall be generated by a MAC Control instance mapped to an undiscovered ONU, and as such shall be marked with a broadcast type of LLID.

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64.3.6.4 REGISTER description

The REGISTER MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) DA. The destination address used shall be an individual MAC address.
b) Opcode. The opcode for the REGISTER MPCPDU is 0x0005.
c) Assigned Port. This field holds a 16 bit unsigned value reflecting the LLID of the port assigned following registration.
d) Flags. this is an 8 bit flag register that indicates special requirements for the registration.

Table 64–4—REGISTER MPCPDU Flags field

Value	Indication	Comment
0	Reserved	Ignored on reception.
1	Reregister	The ONU is explicitly asked to re-register.
2	Deregister	This is a request to deallocate the port and free the LLID. Subsequently, the MAC is deallocated.
3	Ack	The requested registration is successful.
4	Nack	The requested registration attempt is denied by the higher-layer-entity.
5–255	Reserved	Ignored on reception.

e) Sync Time. This is an unsigned 16 bit value signifying the required synchronization time of the OLT receiver. During the synchronization time the ONU transmits only IDLE code-pairs. The value is counted in 16 bit time increments. The advertised value includes synchronization requirement on all receiver elements including PMD, PMA and PCS.
f) Echoed pending grants. This is an unsigned 8 bit value signifying the number of future grants the ONU may buffer before activating. The OLT should not grant the ONU more than this number of grants into the future.
g) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored on reception when constructing a complying MPCP protocol implementation.

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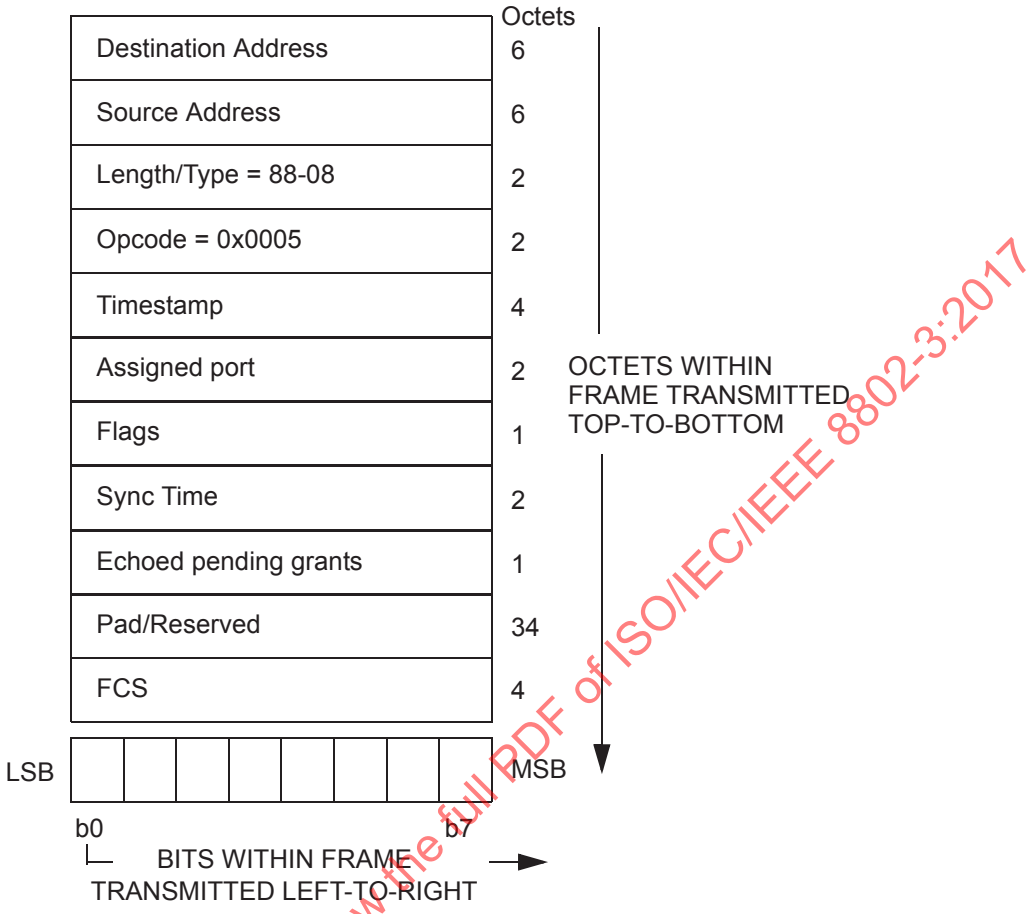

Figure 64–34—REGISTER MPCPDU

The REGISTER MPCPDU shall be generated by a MAC Control instance mapped to all ONUs and such frame is marked by the broadcast LLID.

64.3.6.5 REGISTER_ACK description

The REGISTER_ACK MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) Opcode. The opcode for the REGISTER_ACK MPCPDU is 0x0006.
b) Flags. This is an 8-bit flag register that indicates special requirements for the registration.Echoed assigned port. This field holds a 16 bit unsigned value reflecting the LLID of the port assigned following registration.
c) Echoed Sync Time. This is an unsigned 16 bit value echoing the required synchronization time of the OLT receiver as previously advertised (see 64.3.6.4).
d) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored at reception when constructing a complying MPCP protocol implementation.

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Table 64–5—REGISTER_ACK MPCPDU Flags fields

Value	Indication	Comment
0	Nack	The requested registration attempt is denied by the higher-layer-entity.
1	Ack	The registration process is successfully acknowledged.
2–255	Reserved	Ignored on reception.

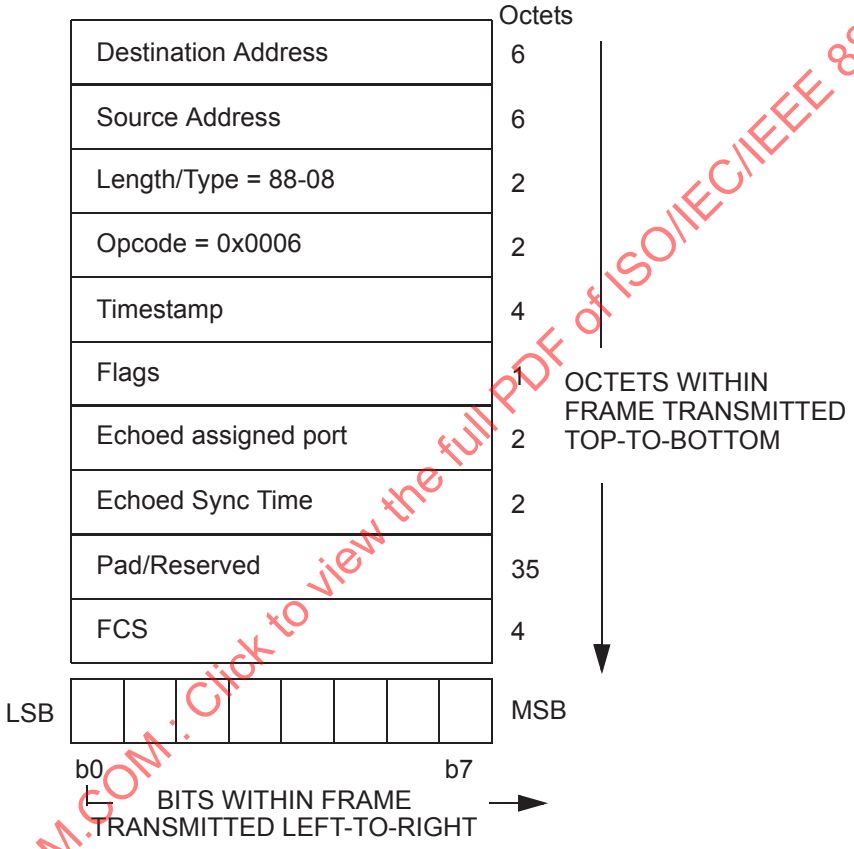

Figure 64–35—REGISTER_ACK MPCPDU

The REGISTER_ACK MPCPDU shall be generated by a MAC Control instance mapped to an active ONU, and as such shall be marked with a unicast type of LLID.

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64.4 Protocol implementation conformance statement (PICS) proforma for Clause 64, Multipoint MAC Control[20]

64.4.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 64 Multipoint MAC Control, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

64.4.2 Identification

64.4.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

64.4.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 64, Multipoint MAC Control
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	
Date of Statement	

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[20] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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64.4.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*OLT	OLT functionality	64.1	Device supports functionality required for OLT	O/1	Yes [ ] No [ ]
*ONU	ONU functionality	64.1	Device supports functionality required for ONU	O/1	Yes [ ] No [ ]

64.4.4 PICS proforma tables for Multipoint MAC Control

64.4.4.1 Compatibility Considerations

Item	Feature	Subclause	Value/Comment	Status	Support
CC1	Delay through MAC and PHY	64.3.2.4	Maximum delay variation of 16 ns (1 time_quantum)	M	Yes [ ]
CC2	OLT grant time delays	64.3.2.4	Not grant nearer than 1024 time_quanta into the future	OLT:M	Yes [ ]
CC3	ONU processing delays	64.3.2.4	Must process all messages in less than 1024 time_quanta	ONU:M	Yes [ ]
CC4	OLT grant issuance	64.3.2.4	Not grant more than one message every 1024 time_quanta	OLT:M	Yes [ ]

64.4.4.2 Multipoint MAC Control

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	OLT localTime	64.2.2.2	Track transmit clock	OLT:M	Yes [ ]
OM2	ONU localTime	64.2.2.2	Track receive clock	ONU:M	Yes [ ]
OM3	Random wait for transmitting REGISTER_REQ messages	64.3.3	Shorter than length of discovery time window	ONU:M	Yes [ ]
OM4	Periodic report generation	64.3.4	Reports are generated periodically	ONU:M	Yes [ ]
OM5	Periodic granting	64.3.4	Grants are issued periodically	OLT:M	Yes [ ]
OM6	Issuing of grants	64.3.5	Not issue more than maximal supported grants	OLT:M	Yes [ ]

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64.4.4.3 State diagrams

Item	Feature	Subclause	Value/Comment	Status	Support
SM1	Multipoint Transmission Control	64.2.2.7	Meets the requirements of Figure 64–9	M	Yes [ ]
SM2	OLT Control Parser	64.2.2.7	Meets the requirements of Figure 64–10	M	Yes [ ]
SM3	ONU Control Parser	64.2.2.7	Meets the requirements of Figure 64–11	M	Yes [ ]
SM4	OLT Control Multiplexer	64.2.2.7	Meets the requirements of Figure 64–12	OLT:M	Yes [ ]
SM5	ONU Control Multiplexer	64.2.2.7	Meets the requirements of Figure 64–13	OLT:M	Yes [ ]
SM6	Discovery Processing OLT Window Setup	64.3.3.6	Meets the requirements of Figure 64–18	OLT:M	Yes [ ]
SM7	Discovery Processing OLT Process Requests	64.3.3.6	Meets the requirements of Figure 64–19	OLT:M	Yes [ ]
SM8	Discovery Processing OLT Register	64.3.3.6	Meets the requirements of Figure 64–20	ONU:M	Yes [ ]
SM9	Discovery Processing OLT Final Registration	64.3.3.6	Meets the requirements of Figure 64–21	OLT:M	Yes [ ]
SM10	Discovery Processing ONU Registration	64.3.3.6	Meets the requirements of Figure 64–22	ONU:M	Yes [ ]
SM11	Report Processing at OLT	64.3.4.6	Meets the requirements of Figure 64–24	OLT:M	Yes [ ]
SM12	Report Processing at ONU	64.3.4.6	Meets the requirements of Figure 64–25	ONU:M	Yes [ ]
SM13	Gate Processing at OLT	64.3.5.6	Meets the requirements of Figure 64–27	OLT:M	Yes [ ]
SM14	Gate Processing at ONU	64.3.5.6	Meets the requirements of Figure 64–28	ONU:M	Yes [ ]
SM15	Gate Processing ONU Activation	64.3.5.6	Meets the requirements of Figure 64–29	ONU:M	Yes [ ]

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64.4.4.4 MPCP

Item	Feature	Subclause	Value/Comment	Status	Support
MP1	MPCPDU structure	64.3.6	As in Figure 64–30	M	Yes [ ]
MP2	LLID for MPCPDU	64.3.6	RS generates LLID for MPCPDU	M	Yes [ ]
MP3	Grants during discovery	64.3.6.1	Single grant in GATE message during discovery	OLT:M	Yes [ ]
MP4	Grant start time	64.3.6.1	Grants within one GATE MPCPDU are sorted by their Start time values	OLT:M	Yes [ ]
MP5	TX during synchronization	64.3.6.1	Transmit IDLE code groups	ONU:M	Yes [ ]
MP6	GATE generation	64.3.6.1	GATE generated for active ONU except during discovery	OLT:M	Yes [ ]
MP7	GATE LLID	64.3.6.1	Unicast LLID except for discovery	OLT:M	Yes [ ]
MP8	REPORT issuing	64.3.6.2	Issues REPORT periodically	ONU:M	Yes [ ]
MP9	REPORT generation	64.3.6.2	Generated by active ONU	ONU:M	Yes [ ]
MP10	REPORT LLID	64.3.6.2	REPORT has unicast LLID	ONU:M	Yes [ ]
MP11	REGISTER_REQ generation	64.3.6.3	Generated by undiscovered ONU	ONU:M	Yes [ ]
MP12	REGISTER_REQ LLID	64.3.6.3	Use broadcast LLID	ONU:M	Yes [ ]
MP13	REGISTER DA address	64.3.6.4	Use individual MAC address	OLT:M	Yes [ ]
MP14	REGISTER generation	64.3.6.4	Generated for all ONUs	OLT:M	Yes [ ]
MP15	REGISTER_ACK generation	64.3.6.5	Generated by active ONU	ONU:M	Yes [ ]
MP16	REGISTER_ACK LLID	64.3.6.5	Use unicast LLID	ONU:M	Yes [ ]

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65. Extensions of the Reconciliation Sublayer (RS) and Physical Coding Sublayer (PCS) / Physical Media Attachment (PMA) for 1000BASE-X for multipoint links and forward error correction

This clause describes functions for use in a 1000BASE-PX point-to-multipoint (P2MP) networks. This is an optical multipoint network that connects multiple DTEs using a single shared fiber. The architecture is asymmetrical, based on a tree and branch topology utilizing passive optical splitters. This type of network requires that the Multipoint MAC Control sublayer exists above the MACs, as described in Clause 64.

65.1 Extensions of the Reconciliation Sublayer (RS) for point-to-point emulation

65.1.1 Overview

This subclause extends Clause 35 to enable multiple data link layers to interface with a single Physical Layer. The number of MACs supported is limited only by the implementation. It is acceptable for only one MAC to be connected to this Reconciliation Sublayer. Figure 65–1 shows the relationship of this RS to the ISO/IEC OSI reference model. The mapping of GMII signals to PLS service primitives is described in 35.2.1.

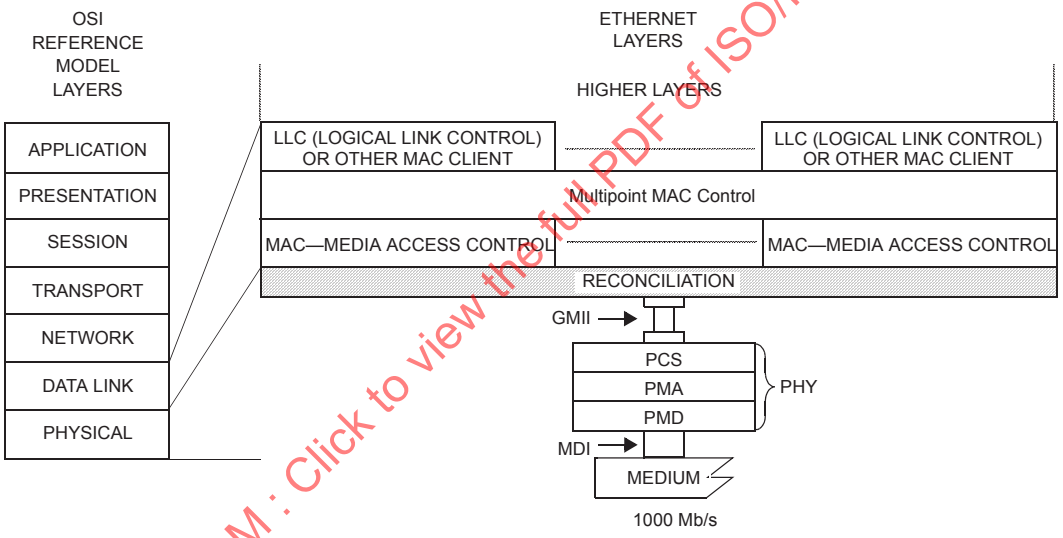

Figure 65–1—RS location in the OSI protocol stack

65.1.2 Principle of operation

A successful registration process, described in 64.3.3, results in the assignment of values to the MODE and LLID variables associated with a MAC. This may be one of many MACs in an Optical Line Terminal (OLT) or a single MAC in an Optical Network Unit (ONU). The MODE and LLID variables are used to identify a packet transmitted from that MAC and how received packets are directed to that MAC. The PCS of OLT shall operate in unidirectional mode as defined in 66.2.2.

As described in 64.1.2, multiple MACs within an OLT are bound to a single GMII, while at the ONU a single MAC is bound to the GMII. The multipoint control protocol (MPCP) ensures that only one MAC is transmitting at any one time. Correspondingly, only one PLS_DATA.request primitive is active at any time. The active PLS_DATA.request is mapped to the GMII signals, TXD<7:0>, TX_EN, TX_ER, and

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GTX_CLK. The RS replaces octets of preamble with the values of the transmitting MAC's MODE and LLID variables.

In the receive direction, these MODE and LLID values, embedded within the preamble, identify the MAC to which this frame should be directed. The RS establishes a temporal mapping of the GMII signals, RXD<7:0>, RX_ER, RX_CLK, and RX_DV, to the correct PLS_DATA.indication and PLS_DATA_VALID.indication primitives.

65.1.3 Functional specifications

The variables below provide a mapping between MODE and LLID variables and multiple MACs. While the usage of this mapping is less interesting in the ONU, it is critical in the OLT. This mapping is used to replace transmitted preambles with MODE and LLID fields as well as to steer received packets to the appropriate MAC.

65.1.3.1 Variables

enable
: Value: Boolean
: This variable shall be TRUE for an ONU MAC. For an OLT MAC, this variable is defined as below:
: TRUE when management has assigned a value to mode and logical_link_id. Indicates the MAC is enabled to receive frames.
: FALSE when the MAC is not in use.

mode
: Value: 1 bit
: This variable shall be 0 for an ONU MAC and may be 0 or 1 for an OLT MAC.
: When the LLID is used to emulate a single copy broadcast or multicast channel, this variable will be set to 1. When emulating a unicast channel, this variable will be set to 0.

logical_link_id
: Value: 15 bits
: This variable shall be set to the broadcast value of 0x7FFF for the unregistered ONU MAC.
: Enabled OLT MACs may use any value for this variable. If the optional multicast LLID feature is supported, the OLT may use a multicast_link_id along with the mode bit 0.
: Registered ONU MACs may use any value other than 0x7FFF or a multicast_link_id for this variable.

multicast_link_id
: Value: 15 bits
: Enabled OLT MACs that support the optional multicast LLID feature may use any value for this variable. This variable is used, along with a mode bit reset to 0, to derive the multicast LLID.

65.1.3.2 Transmit

The transmit function of this extended RS replaces some of the octets of the preamble as transmitted by the MAC with several fields: SLD (start of LLID delimiter), LLID and CRC8. The SLD field is used by the receiver function to locate the LLID and CRC8 fields. The LLID field identifies the source or destination MAC. The CRC8 field provides a level of integrity on the LLID field. Table 65–1 shows the replacement mapping.

Table 65–1—Preamble/SFD replacement mapping

Offset	Field	Preamble/SFD	Modified preamble/SFD
1	—	0x55	same
2	—	0x55	same
3	SLD	0x55	0xd5
4	—	0x55	same
5	—	0x55	same
6	LLID[15:8]	0x55	<mode, logical_link_id[14:8]>[a]

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Table 65–1—Preamble/SFD replacement mapping *(continued)*

Offset	Field	Preamble/SFD	Modified preamble/SFD
7	LLID[7:0]	0x55	<logical_link_id[7:0]>[b]
8	CRC8	0xd5	The 8-bit CRC calculated over offsets 3 through 7

[a]mode maps to TXD[7], logical_link_id[14] maps to TXD[6], logical_link_id[8] maps to TXD[0]
[b]logical_link_id[7] maps to TXD[7], logical_link_id[0] maps to TXD[0]

65.1.3.2.1 SLD

The SLD field is one octet in length and replaces the third octet of the preamble.

NOTE—The 1000BASE-X PCS transmit function replaces the first octet of preamble with the /S/ code-group or it discards the first octet and replaces the second octet of preamble with the /S/ code-group. This decision is based upon the even or odd alignment of the PCS's transmit state diagram (see Figure 36–5). The 1000BASE-X PCS receive function replaces the /S/ code-group with an octet of preamble. The third octet of preamble is the first octet passed through the 1000BASE-X PHY without modification.

65.1.3.2.2 LLID

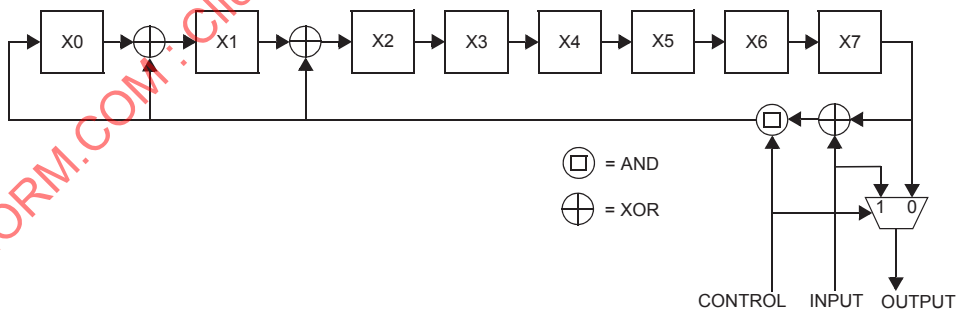
The LLID field is two octets in length and replaces the last two octets of preamble. The LLID field is a concatenation of the mode and logical_link_id variables for the associated MAC.

65.1.3.2.3 CRC-8

The CRC8 field contains an 8-bit cyclic redundancy check value. This value is computed as a function of the contents of the modified preamble beginning with the SLD field (offset 3) through the LLID field (offset 7). The encoding is defined by the generating polynomial shown in Equation (65–1):

$$G(x) = x^8 + x^2 + x + 1 \qquad (65–1)$$

This CRC calculation shall produce the same result as the serial implementation shown in Figure 65–2. Before calculation begins, the shift register shall be initialized to the value 0x00. The content of the shift register is transmitted without inversion.



CONTROL = 1 when shifting the modified preamble and calculating the CRC
CONTROL = 0 when transmitting the CRC8 field

Figure 65–2—CRC8 field generation

65.1.3.3 Receive function

The receive function of this extended RS is responsible for the following functions:

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a) Locate the SLD field.
b) Use the location of the SLD field to locate the CRC8 field and verify that the received value matches the CRC calculated using the received data.
c) Use the location of the SLD field to locate the LLID field and parse it to determine the destination MAC.
d) If the packet is not discarded due to incorrect CRC or unknown LLID, then replace the SLD and LLID fields with normal preamble and the CRC8 field with the SFD and transfer the packet to the appropriate MAC.
e) Otherwise, discard the entire packet, replacing it with normal inter-frame.

Table 65–2 shows the mapping of the modified preamble/SFD to RXD.

Table 65–2—Preamble/SFD replacement mapping

Signal	Bit values of octets received through GMII[a]									
RXD0	X	1[b]	1	1[c]	1	1	logical_link_id[8][d]	logical_link_id[0][e]	X7[f]	D0[g]
RXD1	X	0	0	0	0	0	logical_link_id[9]	logical_link_id[1]	X6	D1
RXD2	X	1	1	1	1	1	logical_link_id[10]	logical_link_id[2]	X5	D2
RXD3	X	0	0	0	0	0	logical_link_id[11]	logical_link_id[3]	X4	D3
RXD4	X	1	1	1	1	1	logical_link_id[12]	logical_link_id[4]	X3	D4
RXD5	X	0	0	0	0	0	logical_link_id[13]	logical_link_id[5]	X2	D5
RXD6	X	1	1	1	1	1	logical_link_id[14]	logical_link_id[6]	X1	D6
RXD7	X	0	0	1	0	0	mode	logical_link_id[7]	X0	D7
RX_DV	0	1	1	1	1	1	1	1	1	1

[a]Leftmost octet is the first received
[b]This octet may be missing per 1000BASE-X PCS transmit state diagram (see Figure 36–5)
[c]SLD field
[d]First octet of LLID field
[e]Second octet of LLID field
[f]CRC8 field
[g]D0 through D7 is the first octet of the PDU (first octet of the Destination Address)

65.1.3.3.1 SLD

Recall that the 1000BASE-X transmit function must maintain an even alignment for its Start_of_Packet delimiters. It may replace the first octet of preamble with the /S/ code-group and pass the second octet unchanged or it may discard the first octet of preamble and replace the second octet of preamble with the /S/ code-group. The SLD is transmitted in the third octet. These are the only two possibilities considered when parsing the incoming octet stream for the SLD. If the SLD field is not found then the packet shall be discarded. If the packet is transferred, the SLD shall be replaced with a normal preamble octet and the one or two octets preceding the SLD and the two octets following the SLD are passed without modification.

65.1.3.3.2 LLID

The third and fourth octets following the SLD contain the mode and logical_link_id values. These values are acted upon differently for OLTs and ONUs.

If the device is an OLT then the following comparison is made:

a) The received mode bit is ignored.
b) If the received logical_link_id value matches 0x7FFF and an enabled MAC exists with a logical_link_id variable with the same value then the comparison is considered a match to that MAC.

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c) If the received logical_link_id value is any value other than 0x7FFF and an enabled MAC exists with a mode variable with a value of 0 and a logical_link_id variable with a value matching the received logical_link_id value then the comparison is considered a match to that MAC.

If the device is an ONU then the following comparison is made:

d) If the received mode bit is 0 and the received logical_link_id value matches the logical_link_id variable then the comparison is considered a match.
e) If the received mode bit is 1 and the received logical_link_id value does not match the logical_link_id variable, or the received logical_link_id matches 0x7FFF, then the comparison is considered a match.
f) If the device supports the multicast LLID feature, the received mode bit is 0 and the received logical_link_id value matches an assigned multicast_link_id, then the comparison is considered a match.

If no match is found, then the packet shall be discarded within the RS. If a match is found, then the packet is intended to be transferred. If the packet is transferred, then both octets of the LLID field shall be replaced with normal preamble octets.

65.1.3.3.3 CRC-8

The octet following the LLID field contains the CRC8 field. The value of this field is compared against the calculated CRC of the received octets, beginning with the SLD field and ending with the last octet of the LLID field. If the received and calculated CRC values do not match, then the packet shall be discarded. If the values match then the packet is transferred. If the packet is transferred, then the CRC8 field shall be replaced with the SFD.

65.2 Extensions of the physical coding sublayer for data detection and forward error correction

65.2.1 Overview

This subclause extends the physical coding sublayer Clause 36 to support burst mode operation of the point-to-multipoint physical medium. This subclause also specifies an optional forward error correction (FEC) mechanism to increase the optical link budget or the fiber distance. Figure 65–3 shows the relationship between the extended PCS sublayer and the ISO/IEC OSI reference model. Auto-Negotiation, as defined in Clause 37, establishes a point-to-point handshaking mechanism for allowing 1000BASE-X devices to achieve a highest common denominator link. The P2MP aspect of a 1000BASE-PX network prohibits the use of the auto-negotiation protocol.

NOTE—Many implementations of the transmit and receive buffers might be dependent on the maximum length of frame supported. It is recommended that these frame buffers should be sized to accommodate maximum length envelope frames (see 3.2.7). It is also recommended that the FEC function should accommodate maximum length envelope frames requiring up to 9 FEC code blocks per frame.

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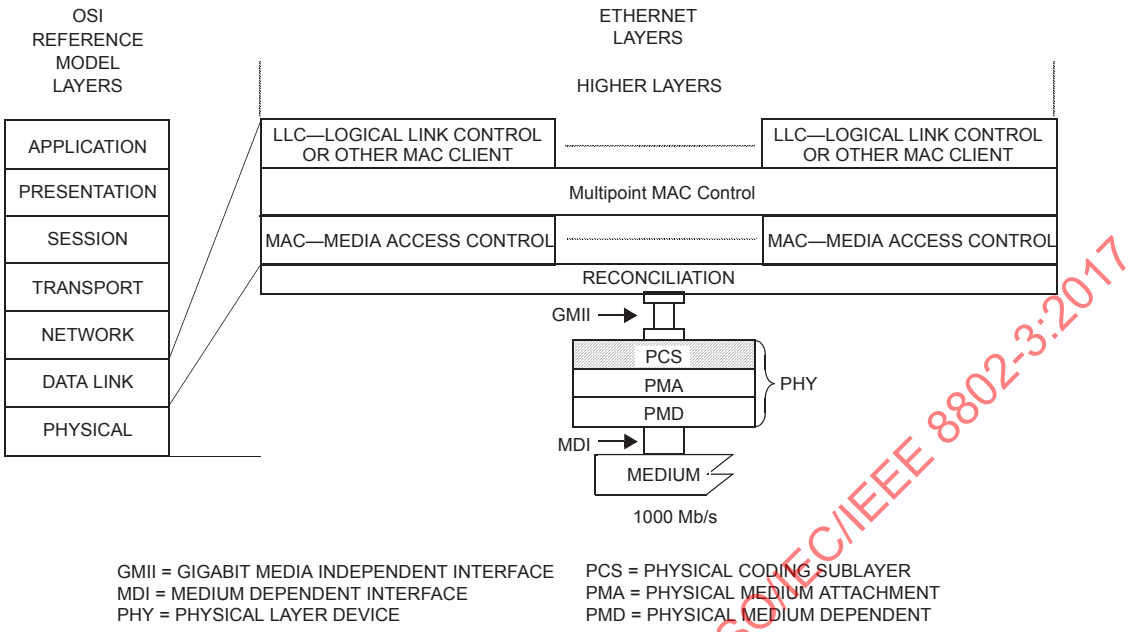

Figure 65–3—PCS location in the OSI protocol stack

65.2.2 Burst-mode operation

To avoid spontaneous emission noise from near ONUs obscuring signal from a distant ONU, the ONUs' lasers should be turned off between their transmissions. To control the laser, the PCS is extended to detect the presence of transmitted data and generate the PMD_SIGNAL.request(tx_enable) primitive to turn the laser on and off at the correct times. This function is performed by the Data Detector shown in the functional block diagram in Figure 65–4.

65.2.2.1 Principle of operation

The Data Detector contains a delay line (FIFO buffer) storing code-groups to be transmitted. The length of the FIFO buffer shall be chosen such that the delay introduced by the buffer together with any delay introduced by the PMA sublayer is long enough to turn the laser on and to allow a predefined number of idle characters to be transmitted. This number of idle characters is needed by the receiver to adjust its gain ($T_{receiver_settling}$), synchronize its receiving clock (T_{CDR}), and complete the synchronization process (T_{sync}).

Upon initialization, the FIFO buffer is filled with /I/ ordered sets and the laser is turned off. When the first code-group that is not /I/ arrives at the buffer, the Data Detector sets the PMD_SIGNAL.request(tx_enable) primitive to the value ON, instructing the PMD sublayer to start the process of turning the laser on (see Figure 65–4).

When the buffer empties of data (i.e., contains only /I/ ordered sets), the Data Detector sets the PMD_SIGNAL.request(tx_enable) primitive to the value OFF, instructing the PMD sublayer to start the process of turning the laser off. Between packets, /I/ or /R/ ordered sets will arrive at the buffer. If the number of these /I/ or /R/ ordered sets is insufficient to fill the buffer then the laser is not turned off.

Figure 65–5 shows the relationship of filling the buffer and the generation of laser_control. In the OLT, the laser always remains turned on. Correspondingly, therefore the OLT's Data Detector does not need a delay line or buffer in the data path for this purpose.

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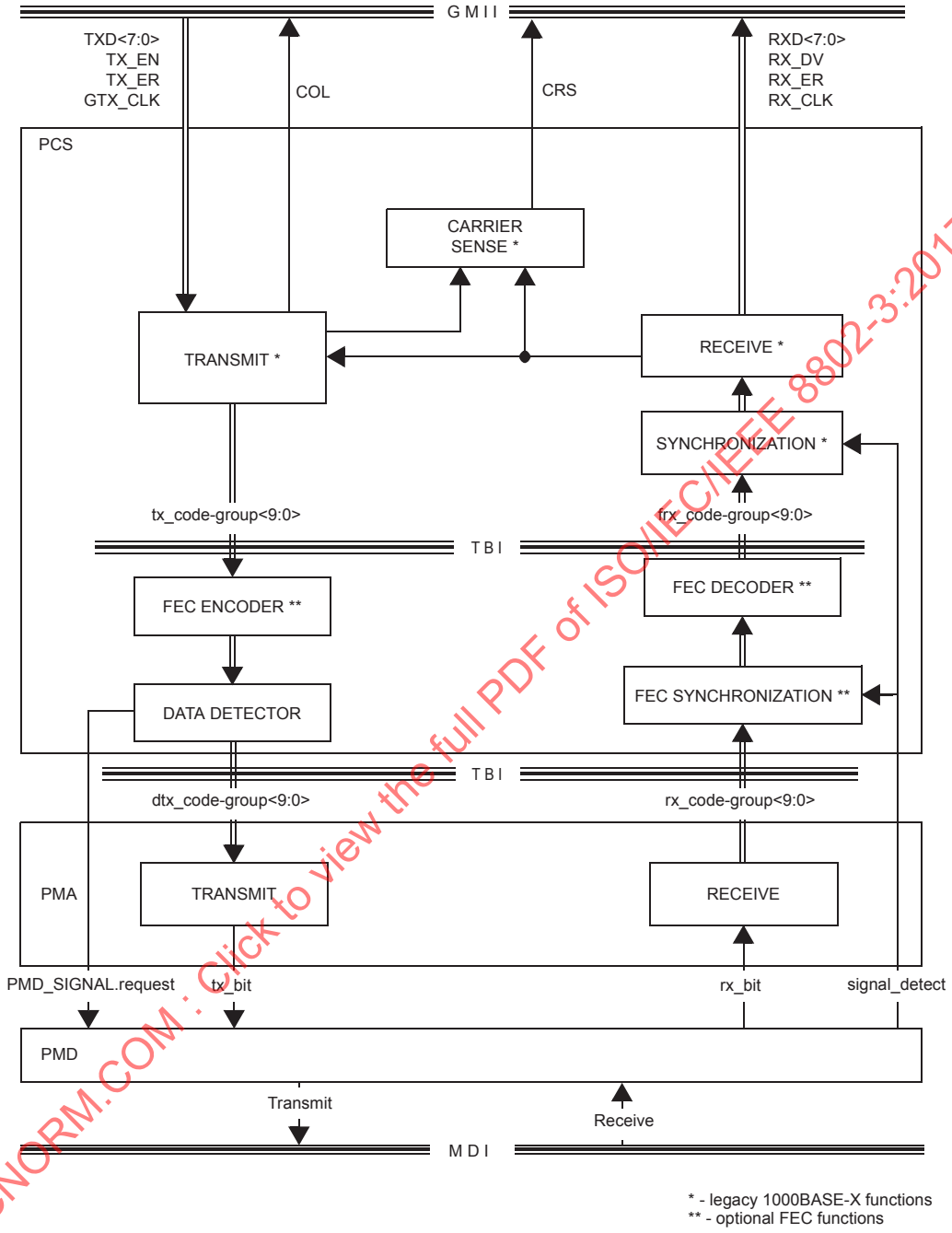

Figure 65–4—PCS Extension functional block diagram

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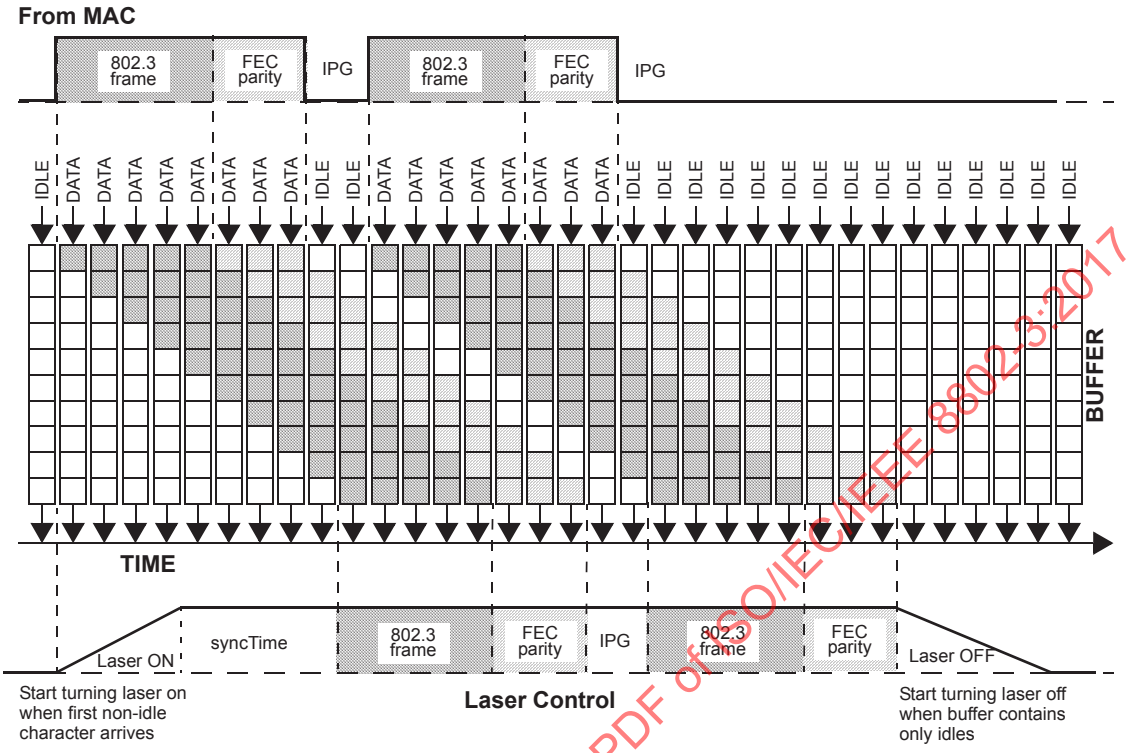

Figure 65–5—Laser control as a function of buffer fill

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65.2.2.2 Detailed functions and state diagrams

The body of this clause comprises state diagrams, including the associated definitions of variables, constants, and functions. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails. The notation used in the state diagrams in this clause follows the conventions in 21.5. State diagram variables follow the conventions of 21.5.2 except when the variable has a default value. Variables in a state diagram with default values evaluate to the variable default in each state where the variable value is not explicitly set.

65.2.2.2.1 Variables

BEGIN

TYPE: Boolean

This variable is used when initiating operation of the state diagram. It is set to true following initialization and every reset.

DelayBound

TYPE: 16-bit unsigned

DEFAULT VALUE: 00-6A (106 code-groups = 848 ns)

This represents the delay sufficient to initiate the laser and to stabilize the receiver at the OLT. The default value of DelayBound is based on default values of laserOnTime (64.3.5.1) and SyncTime (64.3.3.2). This variable is only used by the ONU.

dtx_code-group

A 10-bit vector representing one code-group, as specified in Tables 36–1a through 36–2, which has been prepared for transmission by the Data Detector process. This vector is conveyed to

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the PMA as the parameter of a PMA_UNITDATA.request(dtx_code-group) service primitive. The element dtx_code-group<0> is the first bit transmitted and dtx_code-group<9> is the last bit transmitted.

laser_control

This variable represents the status of the laser. The value on corresponds to the laser being turned on, and the value off corresponds to laser being off.

TYPE: Boolean.

tx_code-group

A 10-bit vector of bits representing one code-group, as specified in Table 36–1a or Table 36–2, which has been prepared for transmission by the PCS Transmit process. The element tx_code-group<0> is the first tx_bit transmitted; tx_code-group<9> is the last tx_bit transmitted.

65.2.2.2.2 Functions

IsIdle(tx_code-group)

This function is used to determine whether tx_code-group is a code-group in /I/, the IDLE ordered set, or /C/, the Configuration ordered set. This function returns true if tx_code-group is /K28.5/ or any code-group that follows a /K28.5/ or any two consecutive /D/ code-groups that follow /K28.5/D21.5/ or /K28.5/D2.2/. Otherwise, the IsIdle function returns false.

FIFO.RemoveHead()

This function removes the first code-group from the FIFO buffer and advances all remaining code-groups one position ahead. This function returns the 10-bit vector representing the removed code-group.

FIFO.Append(tx_code-group)

This function appends a new 10-bit vector to the end of the FIFO buffer.

65.2.2.2.3 Messages

PMD_SIGNAL.request(tx_enable)

This primitive is used to turn the laser on and off at the PMD sublayer. In the OLT, this primitive shall always take the value ON. In the ONU, the value of this variable is controlled by the Data detector state diagram (see Figure 65–6).

PUDR

Alias for PMA_UNITDATA.request(tx_code-group<9:0>).

65.2.2.2.4 Counters

IdleLength

This counter represents the length of the consecutive interval of idles ending with the most recent tx_code-group. If the most recent tx_code-group represents a non-idle character, the IdleLength is reset to 0.

TYPE: 32-bit unsigned

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65.2.2.3 State Diagrams

The Data Detector shall be implemented for an ONU as depicted in Figure 65–6, including compliance with the associated state variables as specified in 65.2.2.2.

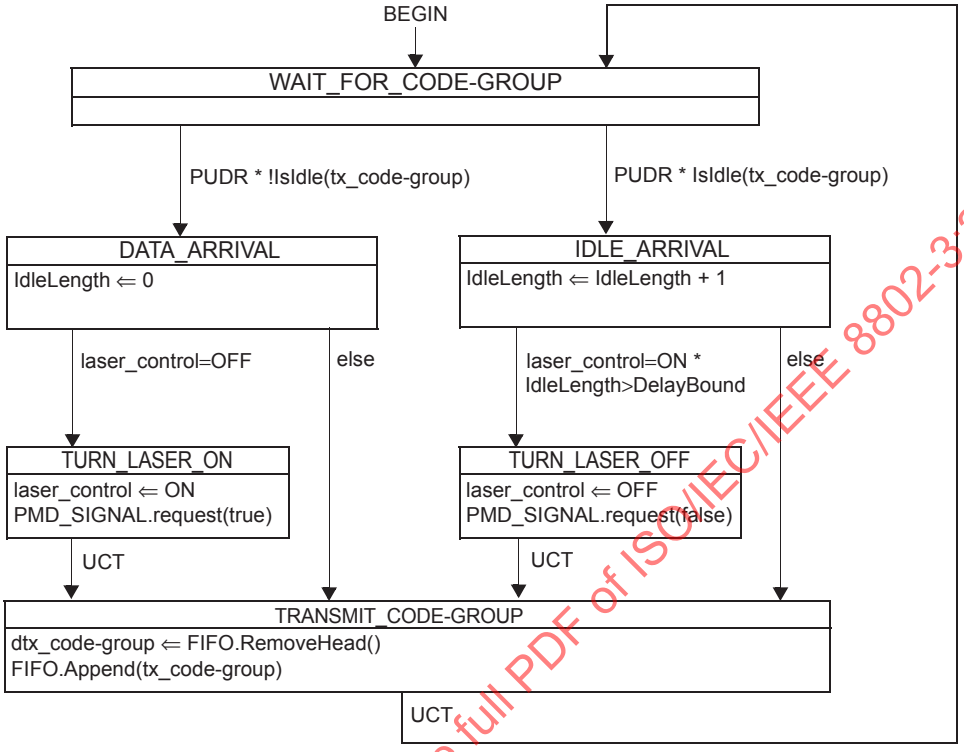

Figure 65–6—ONU data decoder state diagram

65.2.3 Forward error correction

This subclause specifies an optional forward error correction (FEC) mechanism to increase the optical link budget or the fiber distance. The FEC appends to the Ethernet frame additional data that is a result of a set of non-binary arithmetic functions (known as Galois arithmetic) performed on the data of the Ethernet frame. This additional data (known as the FEC parity octets) is used to correct errors at the receiving end of the link that may occur when the data is transferred through the link.

The FEC function comprises three functional blocks: FEC Encoder, FEC Decoder, and FEC Synchronization, as shown in Figure 65–4. These blocks have ten-bit interfaces (TBIs) to both sides and can be omitted for implementations not requiring FEC. Though the FEC functionality is optional, if implemented for operation over a multipoint optical link, it shall behave as specified in 65.2.3.

The following are the objectives of FEC:

a) Keep frame format compliant to 1000BASE-X PCS.
b) Support optional functionality.
c) Allow backwards compatibility with legacy 1000BASE-X devices.
d) Support BER objective of 10^{-12} at PCS.
e) Support BER objective of 10^{-4} at FEC sublayer.

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65.2.3.1 FEC code

The FEC code specification, properties and performance analysis are specified in ITU-T G.975.

The FEC code used is a linear cyclic block code - the Reed-Solomon code (255,239,8) over the Galois Field of GF(2^8) - a non-binary code operating on 8-bit symbols. The code encodes 239 information symbols and adds 16 parity symbols. The code is systematic—meaning that the information symbols are not disturbed in any way in the encoder and the parity symbols are added separately to each block.

The code is the systematic form of the RS code based on the generating polynomial $G(x) = \prod_{i=0}^{15}(x-\alpha^i)$

where α is equal to 0x02 and is a root of the binary primitive polynomial $x^8+x^4+x^3+x^2+1$.

A codeword of the systematic code is presented by $D(x) + P(x) = G(x) * L(x)$ where:

$D(x)$ is the data vector – $D(x)=D_{238}X^{254} + ... + D_0X^{16}$. D_{238} is the first data octet and D_0 is the last.

$P(x)$ is the parity vector – $P(x)=P_{15}X^{15} + ... + P_0$. P_{15} is the first parity octet and P_0 is the last.

A data octet (d_7, d_6, ..., d_1, d_0) is identified with the element: $d_7*\alpha^7 + d_6*\alpha^6 + ... d_1*\alpha^1 + d_0$ in GF(2^8), the finite field with 2^8 elements. The code has a correction capability of up to eight symbols.

NOTE—For the (255,239,8) Reed-Solomon code, the symbol size equals one octet. d_0 is identified as the LSB and d_7 is identified as the MSB bit in accordance with the conventions of 3.1.1.

The FEC decoder shall replace all octets in an uncorrectable block with /V/ to clearly propagate the error condition to the PCS.

65.2.3.2 FEC frame format

The frame format of an FEC coded Ethernet frame is herein described.

65.2.3.2.1 Placing parity octets

Ethernet packets are received from the PCS. The data is partitioned into 239-symbol frames (blocks), with the first block beginning with the first symbol after the /S/ code-group and the last block ending with the last symbol before the /T/ code-group. Each block is encoded using the (255,239,8) Reed-Solomon encoder, which results in an additional 16 parity symbols for each block. The block plus the associated 16 parity symbols form the 255 symbol Reed-Solomon codeword. The additional 16 parity symbols, which are generated from this encoding process for each block, are gathered and added at the end of the packet.

65.2.3.2.2 Shortened last block

When dividing the data into blocks there might be a case where the last block is shorter than 239 symbols. This block is noted as a shortened block. A shortened block of length r octets results in the data vector assignment of D_{238} to D_r as zeros and D_{r-1} to D_0 as valid data, where D_{r-1} is the first octet of the shortened block and D_0 is the last. This full size block is then encoded and the 16 parity symbols are generated. The data is then sent without the zero symbols. At the receiver, the decoder completes the block again into the full block (by adding back the zeros) for decoding.

65.2.3.2.3 Special frame markers

The Ethernet frame consists of a number of blocks plus special frame start and stop markers. In order to decode the FEC code, the receiver must first synchronize on the Ethernet frame. The Ethernet frame markers

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are not protected by the FEC code and are exposed to higher BER. Therefore, special start and stop marker symbols are added at the beginning and the end of the FEC coded frame that are capable of being correctly detected in a high noise environment. The special symbol noise immunity is made possible by the implementation of a simple correlator. The marker framing sequences used are at least 5 octets long, long enough to be detected with very high probability. The start FEC framing sequence is denoted by /S_FEC/ and the end FEC framing sequence is denoted by /T_FEC/.

In order to determine that an FEC coded frame has started, the input symbol stream is scanned for a match with the /S_FEC/ ordered set with fewer than d/2 errors. In order to determine that an FEC coded frame has ended, the input symbol stream is scanned for a match with the /T_FEC_O/ or /T_FEC_E/ ordered sets with fewer than d/2 errors.

The value chosen for d is 10, the number of bits that are different between these ordered sets and any other regularly occurring five consecutive code-groups when considered in the 10-bit domain.

The sequence can flow through non-FEC PCS transparently (in a False_Carrier_Sense mode).

The start and end symbols are constructed from 8B/10B code-groups:

— /S_FEC/ - start of FEC coded packet - /K28.5/D6.4/K28.5/D6.4/S/
— /T_FEC_E/ - end of FEC coded packet with even alignment. If the starting running disparity is positive, the /T_FEC_E/ has the following pattern: /T/R/K28.5/D10.1/T/R/. If the starting running disparity is negative, the T_FEC_E has the following pattern: /T/R/K28.5/D29.5/T/R/.
— /T_FEC_O/ - end of FEC coded packet with odd alignment - /T/R/R/I/T/R/

/S/, /T/, /R/ and /I/ are described in Table 36–3. The /I/ in both the /T_FEC_E/ and the /T_FEC_O/ ordered sets can be either an /I1/ (a disparity correcting IDLE) or an /I2/ (a disparity preserving IDLE).

Figure 65–7 describes the FEC coded Ethernet frame. Between the FCS and PARITY fields, the T_FEC can be either the /T_FEC_E/ or the /T_FEC_O/ ordered set. After the PARITY field, the T_FEC can only be a /T_FEC_E/ ordered set.

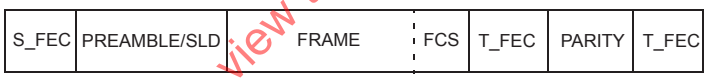

Figure 65–7—FEC coded Ethernet frame

65.2.3.3 FEC sublayer operation

This section describes the functionality and operation of the FEC sublayer.

65.2.3.3.1 Principles of operation

At transmission, the FEC sublayer receives the packets from the PCS, performs the FEC coding, appends the parity octets in place of the stretched IPG and sends the data to the PMA. At reception, the FEC sublayer receives the data from the PMA, performs the octet alignment, detects the Start FEC Framing Sequence, decodes the FEC code, correcting data where necessary and possible, replaces the parity octets with IDLE and sends the data to the PCS.

NOTE—To ensure correct MPCP operation, FEC function must maintain constant and equal delay for all code-groups and all signals transmitted from PMA to PCS. Timing effects of adding FEC function should be indistinguishable from an increased propagation delay.

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65.2.3.3.2 Functional block diagram

As depicted in Figure 65–4, the FEC sublayer comprises a transmit side and a receive side. The following sections define the functionality of each block in the sublayer. See 36.3.3 for a complete description of the TBI.

65.2.3.3.3 Transmission

Figure 65–8 describes a block diagram of the FEC sublayer transmit data path. The packet delimiters of the packets from the PCS are detected. The /I/I/S/ is replaced with the /S_FEC/ ordered set. The data in the frame is then 8B/10B decoded so that the FEC coding can take place and the parity octets buffered. The /T/R/I/I/ or /T/R/R/I/I/ is detected and replaced with the /T_FEC_E/ or /T_FEC_O/, respectively. Then the parity octets and another /T_FEC_E/ is appended, replacing the stretched interframe spacing.

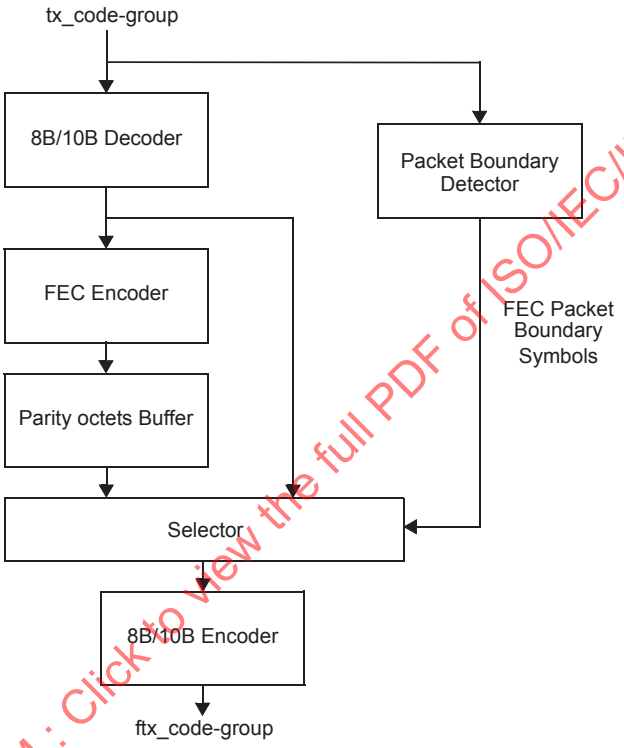

Figure 65–8—Transmit block diagram

The FEC Transmit process continually generates code-groups based upon information provided in the PMA_UNITDATA.request primitive with the tx_code-group<9:0> parameter, sending them immediately to the PMA Service Interface via the same primitive with the ftx_code-group<9:0> parameter.

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65.2.3.3.4 Reception

Figure 65–9 describes the receive synchronization block diagram of the FEC sublayer receive data path. The FEC Synchronization process continually accepts code-groups via the PMA_UNITDATA.indication service primitive and conveys received code-groups to the FEC Receive process via the SYNC_UNITDATA.indicate service primitive. The FEC Synchronization process sets the sync_status flag to indicate whether the PMA is functioning dependably (as well as can be determined without exhaustive error-ratio analysis).

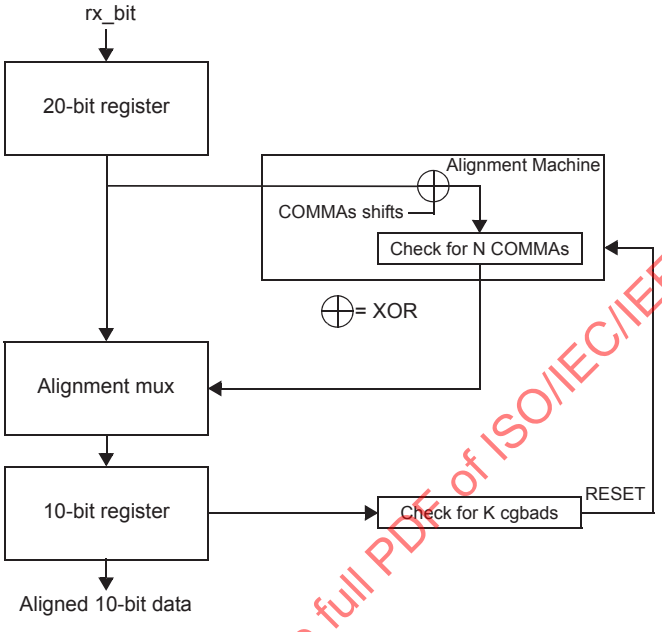

Figure 65–9—Receive synchronization block diagram

Figure 65–10 describes a block diagram of the FEC sublayer receive data path. The FEC Receive process continuously accepts code-groups via the SYNC_UNITDATA.indicate service primitive. It fills a buffer with these code-groups, converting an /S_FEC/ with fewer than d/2 errors to /I/I/S/ and converting all /T_FEC/ with fewer than d/2 errors to a clean /T_FEC/. This buffer exists in order to store all necessary data until the parity octets are available for performing data correction. Data correction is performed within the buffer. While emptying the buffer, the parity octets, along with the latter /T/R/ of the first /T_FEC/ and the entire second /T_FEC/ are converted to /I/.

NOTE—Under specific conditions, the PCS may generate a large number of FALSE_CARRIER events. FEC encryption only protects Ethernet frames. The IDLEs are not FEC-protected. During idle periods, excessive bit errors may results in FALSE_CARRIER events. Additionally, when FEC and non-FEC devices are combined in the same EPON, a non-FEC device will treat FEC parity data as FALSE_CARRIER events.

65.2.3.4 Detailed functions and state diagrams

The body of this clause comprises state diagrams, including the associated definitions of variables, constants, and functions. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails. The notation used in the state diagrams in this clause follows the conventions in 21.5. State diagram variables follow the conventions of 21.5.2 except when the variable has a default value. Variables in a state diagram with default values evaluate to the variable default in each state where the variable value is not explicitly set.

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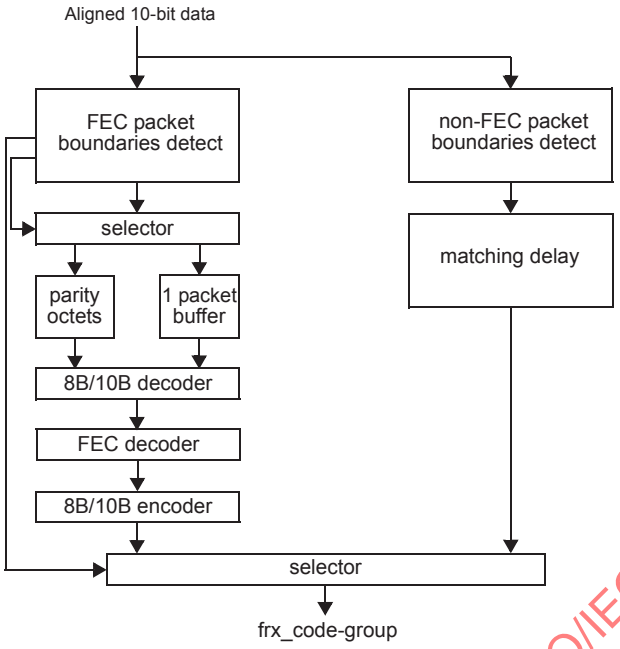

Figure 65–10—Receive data block diagram

65.2.3.4.1 State variables

65.2.3.4.2 Notation conventions

/x/

Denotes the constant code-group specified in 36.2.5.1.2 (valid code-groups must follow the rules of running disparity as per 36.2.4.5 and 36.2.4.6).

[/x/]

Denotes the latched received value of the constant code-group (/x/) specified in 36.2.5.1.2 and conveyed by the SYNC_UNITDATA.indicate message described in 36.2.5.1.6.

65.2.3.4.3 Constants

/COMMA/

The set of special code-groups that include a comma as specified in 36.2.4.9 and listed in Table 36–2.

/D/

The set of 256 code-groups corresponding to valid data, as specified in 36.2.4.11.

/Dx.y/

One of the set of 256 code-groups corresponding to valid data, as specified in 36.2.4.11.

/I/

The IDLE ordered set group, comprising either the /I1/ or /I2/ ordered sets, as specified in 36.2.4.12.

/INVALID/

The set of invalid data or special code-groups, as specified in 36.2.4.6.

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/Kx.y/
One of the set of 12 code-groups corresponding to valid special code-groups, as specified in Table 36–2.

/R/
The code-group used as either: End_of_Packet delimiter part 2; End_of_Packet delimiter part 3; Carrier_Extend; and /I/ alignment.

/S/
The code-group corresponding to the Start_of_Packet delimiter (SPD) as specified in 36.2.4.14.

/T/
The code-group used for the End_of_Packet delimiter part 1.

/V/
The Error_Propagation code-group, as specified in 36.2.4.17.

65.2.3.4.4 Variables

buffer
The Receive process buffer of undefined length containing code-groups.

buffer_head
The code-group at the head of the Receive process buffer.

cgbad
Alias for the following terms: ((rx_code-group∈ /INVALID/) + (rx_code-group=/COMMA/ *rx_even=TRUE)) * PMA_UNITDATA.indication

cggood
Alias for the following terms: !((rx_code-group∈ /INVALID/) + (rx_code-group=/COMMA/ *rx_even=TRUE)) * PMA_UNITDATA.indication

fec_encode
A Boolean set by the FEC Transmit process to indicate the status of the RS_Encode(Data) function.

Values: TRUE; data is acted upon by the RS_Encode(Data) function.
FALSE; data is not being acted upon by the RS_Encode(Data) function.

ftx_bit
A binary parameter used to convey data from the PMA to the PMD via the PMD_UNITDATA.request service primitive as specified in 60.1.5.1.

Values: ZERO; Data bit is a logical zero.
ONE; Data bit is a logical one.

ftx_code-group<9:0>
A vector of bits representing one code-group, as specified in Table 36–1a through Table 36–2, which has been prepared for transmission by the FEC Transmit process. This vector is conveyed to the PMA as the parameter of a PMA_UNITDATA.request(ftx_code-group) service primitive. The element ftx_code-group<0> is the first ftx_bit transmitted; ftx_code-group<9> is the last ftx_bit transmitted.

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parity<D7:D0>

An 8-bit array that contains the current parity bits to be encoded in the FEC Transmit Process. The elements within the array are updated with the next 8-bits to be encoded upon each entry into the XMIT_PARITY state.

Values for each element in the array: ZERO; Data bit is a logical zero.
ONE; Data bit is a logical one.

parity_buffer_empty

A Boolean set by the FEC Transmit process to indicate if more parity octets need to be encoded.

Values: TRUE; No more parity octets need to be encoded.
FALSE; More parity octets need to be encoded.

rx_disparity

A Boolean set by the FEC Receive process to indicate the running disparity at the end of code-group reception as a binary value. Running disparity is described in 36.2.4.3.

Values: POSITIVE
NEGATIVE

rx_even

A Boolean set by the FEC Synchronization process to designate received code-groups as either even- or odd-numbered code-groups as specified in 36.2.4.2.

Values: TRUE; Even-numbered code-group being received.
FALSE; Odd-numbered code-group being received.

rx_code-group<9:0>

A 10-bit vector represented by the most recently received code-group from the PMA. The element rx_code-group<0> is the least recently received (oldest) rx_bit; rx_code-group<9> is the most recently received rx_bit (newest). When code-group alignment has been achieved, this vector contains precisely one code-group.

signal_detect

A Boolean set by the PMD continuously via the PMD_SIGNAL.indication(signal_detect) message to indicate the status of the incoming link signal.

Values: FAIL; A signal is not present on the link.
OK; A signal is present on the link.

sync_status

A parameter set by the FEC Synchronization process to reflect the status of the link as viewed by the receiver.

Values: FAIL; The receiver is not synchronized to code-group boundaries.
OK; The receiver is synchronized to code-group boundaries.

tx_bit

A binary parameter used to convey data from the PMA to the PMD via the PMD_UNITDATA.request service primitive as specified in 60.1.5.1.

Values: ZERO; Data bit is a logical zero.
ONE; Data bit is a logical one.

tx_code-group<9:0>

A vector of bits representing one code-group, as specified in Table 36–1a or Table 36–2, which has been prepared for transmission by the PCS Transmit process. This vector is conveyed to the PMA as the parameter of a PMD_UNITDATA.request(tx_bit) service

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primitive. The element tx_code-group<0> is the first tx_bit transmitted; tx_code-group<9> is the last tx_bit transmitted.

tx_disparity
A Boolean set by the FEC Transmit process to indicate the running disparity at the end of code-group transmission as a binary value. Running disparity is described in 36.2.4.3.

Values: POSITIVE
NEGATIVE

65.2.3.4.5 Functions

check_ahead_tx
Prescient function used by the FEC Transmit process to find the Start_of_Packet in order to replace the Start_of_Packet and its two preceding IDLE ordered sets with /S_FEC/.

check_ahead_rx
Prescient function used by the FEC Receive process to find the /S_FEC/ and /T_FEC/, with fewer than d/2 errors.

DECODE ([/x/])
In the PCS Receive process, this function takes as its argument the latched value of rx_code-group<9:0> ([/x/]) and the current running disparity, and returns the corresponding GMII RXD<7:0>, rx_Config_Reg<D7:D0>, or rx_Config_Reg<D15:D8> octet, per Table 36–1a–e. DECODE also updates the current running disparity per the running disparity rules outlined in 36.2.4.4.

ENCODE(x)
In the PCS Transmit process, this function takes as its argument (x), where x is a GMII TXD<7:0>, tx_Config_Reg<D7:D0>, or tx_Config_Reg<D15:D8> octet, and the current running disparity, and returns the corresponding ten-bit code-group per Table 36–1a. ENCODE also updates the current running disparity per Table 36–1a–e.

POP_BUFFER
Removes the octet at the head of the Receive process buffer, making the next octet available.

RS_Encode(Data)
This function is used to encode the Reed-Solomon (255,239,8) code. The encoder encodes the 239 octets data frame and generates 16 parity octets for each data frame. Before being passed to the Reed-Solomon encoder, this function passes the data through DECODE([/x/]).

RS_Decode(Data)
This function is used to decode the Reed-Solomon (255,239,8) code. The decoder decodes the 255 symbols data frame and generates 239 corrected data octets for each frame and an error signal.

signal_detectCHANGE
In the PCS Synchronization process, this function monitors the signal_detect variable for a state change. The function is set upon state change detection.

Values: TRUE; A signal_detect variable state change has been detected.
FALSE; A signal_detect variable state change has not been detected (default).

65.2.3.4.6 Counters

good_cgs
Count of consecutive valid code-groups received.

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loop_count
: A 3-bit counter used to keep track of the number of loops in the receive synchronization process.

65.2.3.4.7 Messages

FEC_UNITDATA.indicate(frx_code-group<9:0>)
: A signal sent by the FEC Receive process conveying the next code-group received over the medium.

FUDI
: Alias for FEC_UNITDATA.indicate(frx_code-group<9:0>).

PMA_UNITDATA.indication(rx_code-group<9:0>)
: A signal sent by the PMA Receive process conveying the next code-group received over the medium (see 36.3.1.2).

PMA_UNITDATA.request(tx_code-group<9:0>)
: A signal sent to the PMA or FEC Transmit process conveying the next code-group ready for transmission over the medium (see 36.3.1.1).

PUDI
: Alias for PMA_UNITDATA.indication(rx_code-group<9:0>).

PUDR
: Alias for PMA_UNITDATA.request(tx_code-group<9:0>).

SUDI
: Alias for SYNC_UNITDATA.indicate(parameters).

SYNC_UNITDATA.indicate(parameters)
: A signal sent by the FEC Synchronization process to the FEC Receive process conveying the following parameters:

  Parameters: [/x/]; the latched value of the indicated code-group (/x/);
  EVEN/ODD; The latched state of the rx_even variable;

  Value: EVEN; Passed when the latched state of rx_even=TRUE.
  ODD; Passed when the latched state of rx_even=FALSE.

65.2.3.5 State diagrams

65.2.3.5.1 Transmit state diagram

The FEC shall implement its transmit process as depicted in Figure 65–11, including compliance with the associated state variables as specified in 65.2.3.4.1.

65.2.3.5.2 Receive synchronization state diagram

The FEC shall implement its synchronization process as depicted in Figure 65–12, including compliance with the associated state variables in 65.2.3.4.1.

65.2.3.5.3 Receive state diagram

The FEC shall implement its receive process as depicted in Figure 65–13 and Figure 65–14, including compliance with the associated state variables in 65.2.3.4.1.

It is expected that the FEC decoding is performed while the data is in the buffer.

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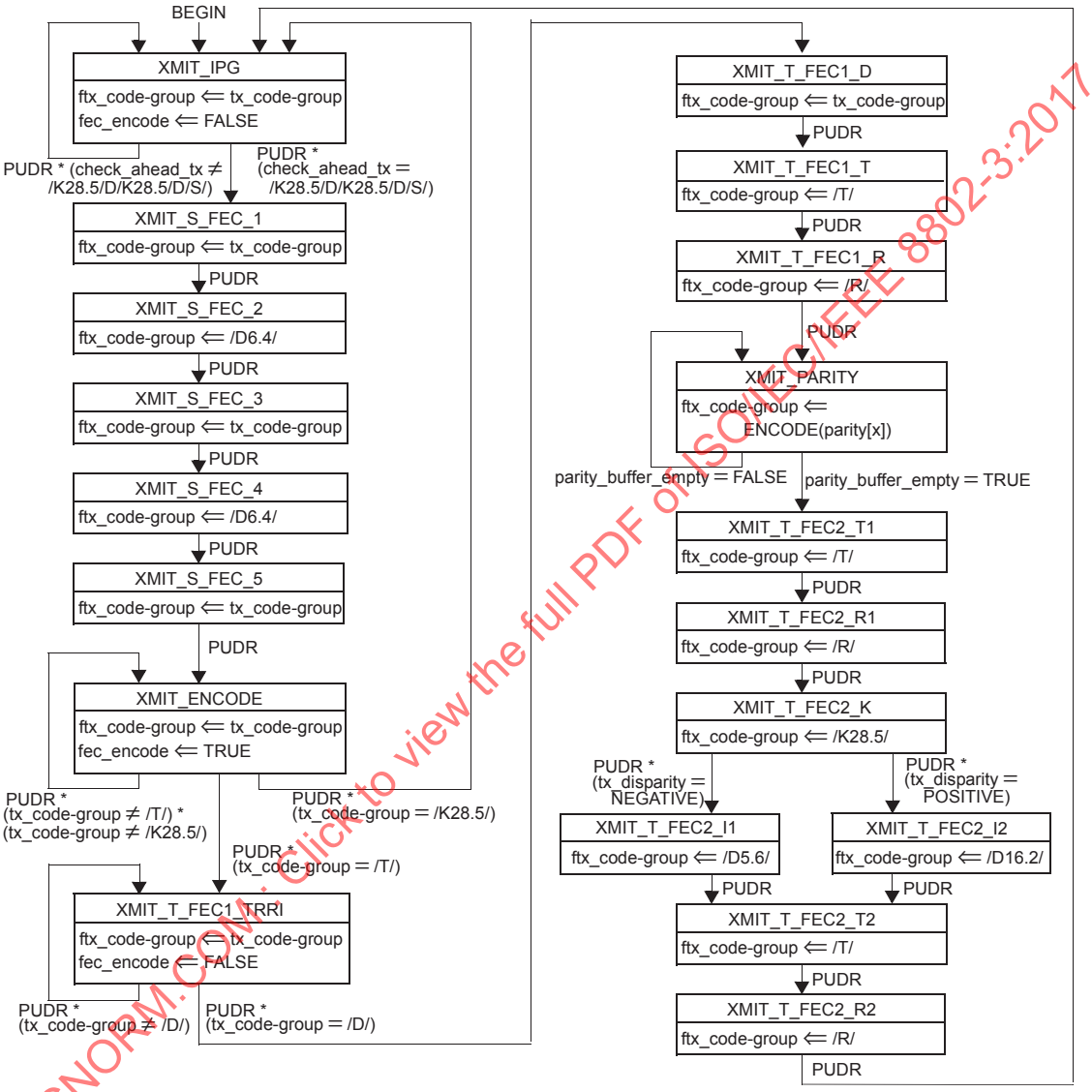

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Figure 65–11—Transmit state diagram

65.2.3.6 Error monitoring capability

The following counters apply to FEC sublayer management and error monitoring. If an MDIO interface is provided (see Clause 22), it is accessed via that interface. If not, it is recommended that an equivalent access be provided. These counters are reset to zero upon read or upon reset of the FEC sublayer. When a counter reaches all ones, it stops counting. The counters' purpose is to help monitor the quality of the link.

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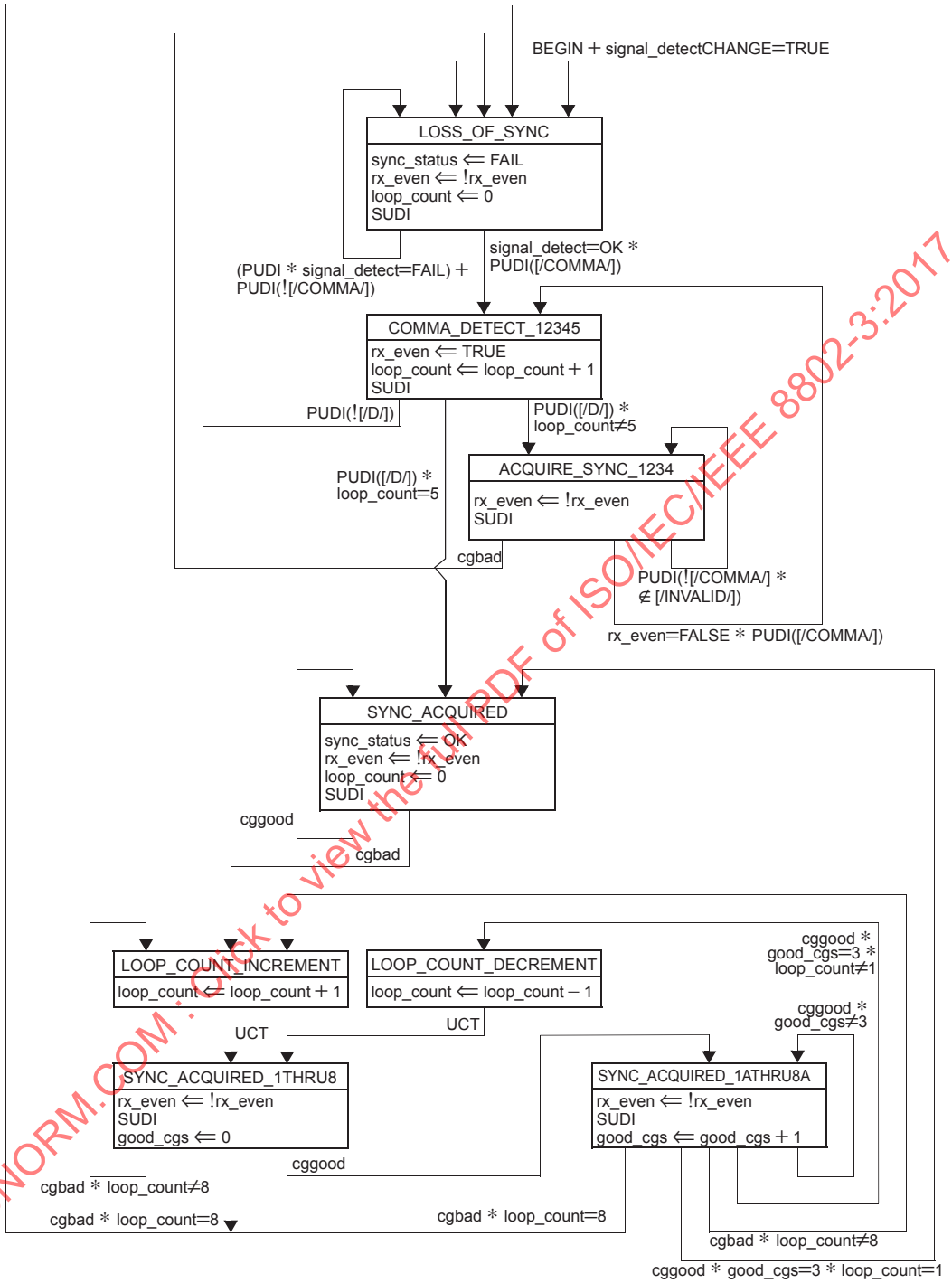

Figure 65–12—Receive synchronization state diagram

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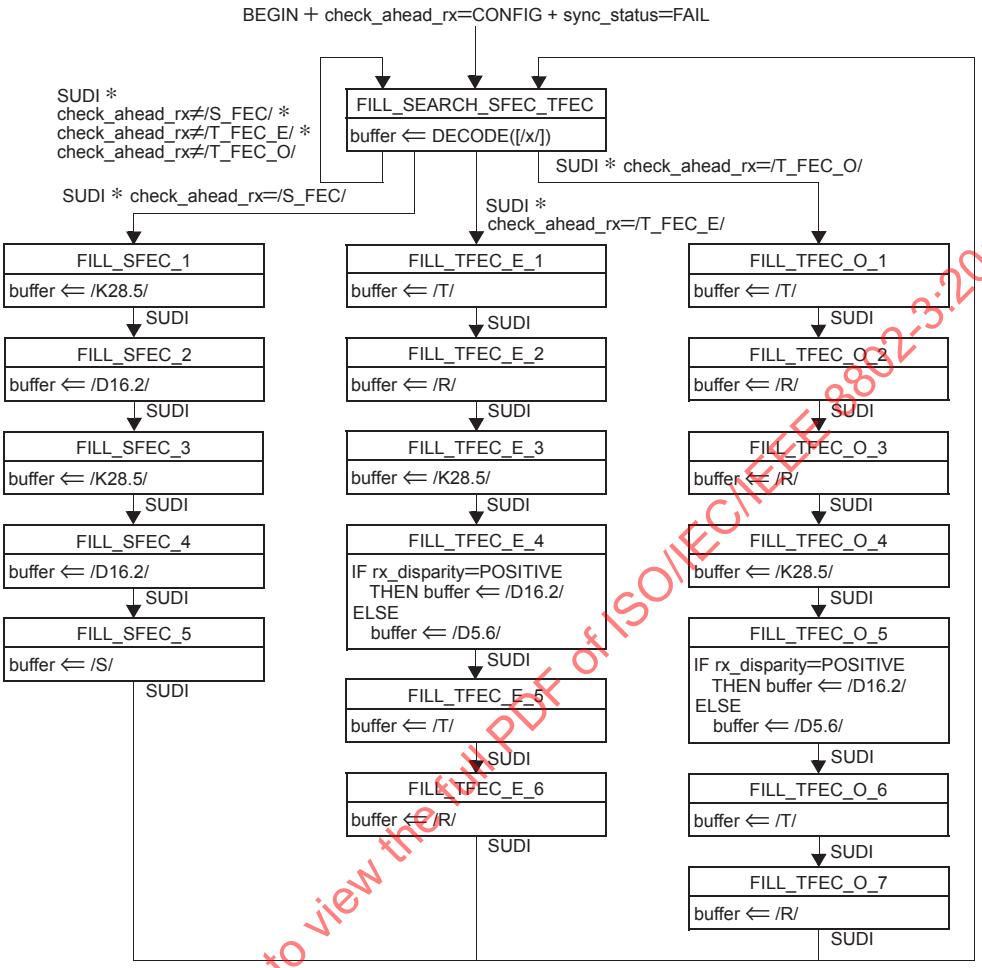

Figure 65–13—Receive buffer-fill state diagram

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65.2.3.6.1 buffer_head_coding_violation_counter

32-bit counter. buffer_head_coding_violation_counter counts once for each invalid code-group received directly from the link. This variable is provided by a management interface that may be mapped to the 45.2.8.4 register (29.9.15:0).

65.2.3.6.2 FEC_corrected_blocks_counter

32-bit counter. FEC_corrected_blocks_counter counts once for each corrected FEC blocks in the decoding. This variables is provided by a management interface that may be mapped to the 45.2.8.5 register (29.10.15:0).

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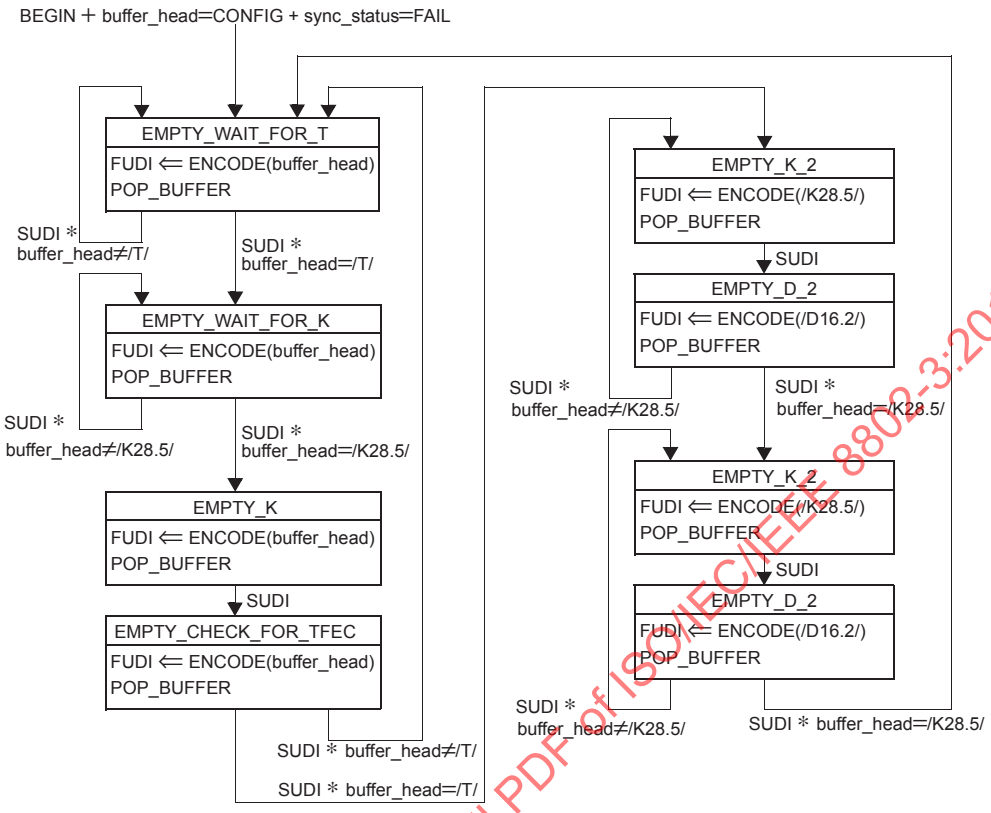

Figure 65–14—Receive buffer-empty state diagram

65.2.3.6.3 FEC_uncorrected_Blocks_counter

32-bit counter. FEC_uncorrected_blocks_counter counts once for each uncorrected FEC blocks in the decoding. This variables is provided by a management interface that may be mapped to the 45.2.8.6 register (29.11.15:0).

65.3 Extensions to PMA for 1000BASE-PX

In addition to the requirements defined in Clause 36, P2MP operation imposes the following requirement on the PMA sublayer of the OLT and ONU.

65.3.1 Extensions for 1000BASE-PX-U

65.3.1.1 Physical Medium Attachment (PMA) sublayer interfaces

In addition to the primitives of Clause 36, the following primitive is defined:

PMD_SIGNAL.request(tx_enable)

This primitive controls PMD emission of light. It is generated by the PCS's data detector (see 65.2.2.2.3) and the effect of its receipt is defined in 60.1.5.3. This primitive is received from the PCS and passed in timely fashion and without modification to the PMD. It takes the following parameter:

tx_enable The tx_enable parameter can take one of two values, ON or OFF.

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65.3.1.2 Loop-timing specifications for ONUs

ONUs shall operate at the same time basis as the OLT, i.e., the ONU TX clock tracks the ONU RX clock. Jitter transfer masks are defined in 60.8.

65.3.2 Extensions for 1000BASE-PX-D

65.3.2.1 CDR lock timing measurement

A PMA instantiated in an OLT becomes synchronized at the bit level within 400 ns (T_{CDR}) and code-group level within an additional 32 ns ($T_{code_group_alignment}$) of the appearance of a valid 1000BASE-X IDLE pattern at TP4 when the PMA_TX_CLK frequency is equal to twice the PMA_RX_CLK frequency.

65.3.2.1.1 Definitions

CDR Lock Time (denoted T_{CDR}) is defined as a time interval required by the receiver to acquire phase and frequency lock on the incoming data stream. T_{CDR} is measured as the time elapsed from the moment when electrical signal after the PMD at TP4 reaches the conditions specified in 60.9.13.2.1 for receiver settling time to the moment when the phase and frequency are recovered and jitter is maintained for a network with BER of no more than 10^{-12} for non-FEC systems, or no more than 10^{-4} for FEC enabled systems.

The combined value of measured T_{CDR} and $T_{code_group_alignment}$ shall not exceed 432 ns.

65.3.2.1.2 Test specification

Figure 60–2 illustrates the tests setup for the OLT PMA receiver (upstream) T_{CDR} time. The test assumes that there is an optical PMD transmitter at the ONU with well known parameters, having a fixed known T_{on} time as defined in 60.9.13.1, and an optical PMD receiver at the OLT with well-known parameters, having a fixed known $T_{receiver_settling}$ time as defined in 60.9.13.2. After T_{on} + $T_{receiver_settling}$ time the parameters at TP4 reach within 15% of their steady state values.

Measure T_{CDR} as the time from the TX_ENABLE assertion, minus the known T_{on} + $T_{receiver_settling}$ time, to the time the electrical signal at the output of the PMA reaches up to phase difference from the input signal of the transmitting PMA, assuring BER of 10^{-12} for non-FEC systems, or BER of 10^{-4} for FEC enabled systems, and maintaining its jitter specifications. The signal throughout this test, is the 1000BASE-X IDLE pattern.

A non-rigorous way to describe this test setup would be (using a transmitter PMD at the ONU, with a known T_{on} time and a receiver PMD at the OLT, with a known $T_{receiver_settling}$ time):

For a tested PMA receiver with a declared T_{CDR} time, measure the phase and jitter of the recovered PMA receiver signal after T_{CDR} time from the TX_ENABLE trigger minus the reference T_{on} + $T_{receiver_settling}$ time, reassuring synchronization to the ONU PMA input signal and conformance to the specified steady state phase, frequency, and jitter values for BER of 10^{-12} for non-FEC systems, or BER of 10^{-4} for FEC enabled systems.

65.3.3 Delay variation requirements

The MPCP relies on strict timing based on the distribution of timestamps. The actual delay is implementation dependent but an implementation shall maintain a combined delay variation through RS, PCS, and PMA sublayers of no more than 16 bit times so as to comply with this mechanism.

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65.4 Protocol implementation conformance statement (PICS) proforma for Clause 65, Extensions of the Reconciliation Sublayer (RS) and Physical Coding Sublayer (PCS) / Physical Media Attachment (PMA) for 1000BASE-X for multipoint links and forward error correction[21]

65.4.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 65, Extensions of the Reconciliation Sublayer (RS) and Physical Coding Sublayer (PCS) / Physical Media Attachment (PMA) for 1000BASE-X for multipoint links and forward error correction, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

65.4.2 Identification

65.4.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

65.4.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 65, Extensions of the Reconciliation Sublayer (RS) and Physical Coding Sublayer (PCS) / Physical Media Attachment (PMA) for 1000BASE-X for multipoint links and forward error correction
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	
Date of Statement	

[21] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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65.4.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*OLT	OLT functionality	65.1.1	Device supports functionality required for OLT	O.1	Yes [ ] No [ ]
*ONU	ONU functionality	65.1.1	Device supports functionailty required for ONU	O.1	Yes [ ] No [ ]
*FEC	Forward error correction for multipoint optical links	65.2.3	Device supports FEC for multipoint optical links	O	Yes [ ] No [ ]

65.4.4 PICS proforma tables for Extensions of Reconciliation Sublayer (RS) and Physical Coding Sublayer (PCS) / Physical Media Attachment (PMA) for 1000BASE-X for multipoint links and forward error correction

65.4.4.1 Operating modes of OLT MACs

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	Unidirectional mode	65.1.2	Device operates in unidirectional transmission mode	OLT:M	Yes [ ]

65.4.4.2 ONU and OLT variables

Item	Feature	Subclause	Value/Comment	Status	Support
FS1	enable variable	65.1.3.1	True for ONU MAC, TRUE for OLT MAC if enabled, FALSE for OLT MAC if not enabled	M	Yes [ ]
FS2	mode variable	65.1.3.1	0 for ONU MAC, 0 or 1 for enabled OLT MAC	M	Yes [ ]
FS3	logical_link_id variable	65.1.3.1	Set to 0x7FFF until ONU MAC is registered Set to any value for enabled OLT MAC. Set to any value other then 0x7FFF for registered ONU MAC	M	Yes [ ]
FS4	multicast LLID support	65.1.3.1	Supports multicast LLID, multicast_link_id variable	O	Yes [ ] No [ ]

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65.4.4.3 Preamble mapping and replacement

Item	Feature	Subclause	Value/Comment	Status	Support
PM1	CRC-8 generation	65.1.3.2.3	CRC calculation produces same result as serial implementation	M	Yes [ ] No [ ]
PM2	CRC-8 initial value	65.1.3.2.3	CRC shift register initialized to 0x00 before each new calculations	M	Yes [ ] No [ ]
PM3	SLD parsing	65.1.3.3.1	If SLD is not found then discard packet	M	Yes [ ] No [ ]
PM4	SLD replacement	65.1.3.3.1	Replace SLD with preamble	M	Yes [ ] No [ ]
PM5	LLID matching	65.1.3.3.2	If LLID does not match then discard packet	M	Yes [ ] No [ ]
PM6	multicast LLID matching	65.1.3.3.2	If multicast LLID matches accept the packet	*FS4:M	Yes [ ] No [ ]
PM7	LLID Replacement	65.1.3.3.2	Replace LLID with preamble	M	Yes [ ] No [ ]
PM8	CRC-8 checking	65.1.3.3.3	If CRC does not match then discard packet	M	Yes [ ] No [ ]
PM9	CRC-8 replacement	65.1.3.3.3	Replace CRC with preamble	M	Yes [ ] No [ ]

65.4.4.4 Data detection

Item	Feature	Subclause	Value/Comment	Status	Support
DD1	Buffer depth	65.2.2.1	Depth sufficient to turn on laser and settle receiver	ONU:M	Yes [ ] No [ ]
DD2	OLT laser control	65.2.2.2.3	Always takes the value ON	OLT:M	Yes [ ] No [ ]
DD3	State diagrams	65.2.2.3	Meets the requirements of Figure 65–6	ONU:M	Yes [ ] No[ ]

65.4.4.5 FEC requirements

Item	Feature	Subclause	Value/Comment	Status	Support
FE1	FEC Coding Choice	65.2.3	If FEC is used, it is this one	FEC:M	Yes [ ] No [ ]
FE2	Uncorrectable block replacement	65.2.3.1	Replace all code-groups in an uncorrectable block with /V/	FEC:M	Yes [ ] No [ ]

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65.4.4.6 FEC State diagrams

Item	Feature	Subclause	Value/Comment	Status	Support
SM1	Transmit	65.2.3.5.1	Meets the requirements of Figure 65–11	FEC:M	Yes [ ]
SM2	Receive synchronization	65.2.3.5.2	Meets the requirements of Figure 65–12	FEC:M	Yes [ ]
SM3	Receive	65.2.3.5.3	Meets the requirements of Figure 65–13 for buffer fill and Figure 65–14 for buffer empty	FEC:M	Yes [ ]

65.4.4.7 PMA

Item	Feature	Subclause	Value/Comment	Status	Support
BMC1	Loop Timing	65.3.1.2	ONU RX clock tracks OLT TX clock	ONU:M	Yes [ ] No [ ]

65.4.4.8 OLT Receiver

Item	Feature	Subclause	Value/Comment	Status	Support
OR1	Code-group synchronization delay	65.3.2.1.1	$T_{CDR} + T_{code_group_alignment} \leq 432$ ns	M	Yes [ ] No [ ]

65.4.4.9 Delay variation

Item	Feature	Subclause	Value/Comment	Status	Support
DV1	Delay variation	65.3.3	Combined delay variation through RS, PCS, and PMA sublayers is limited to 16 bit times	M	Yes [ ] No [ ]

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66. Extensions of the 10 Gb/s Reconciliation Sublayer (RS), 100BASE-X PHY, and 1000BASE-X PHY for unidirectional transport

In the absence of unidirectional operation, the sublayers in this clause are precisely the same as their equivalents in Clause 24, Clause 36, and Clause 46. Otherwise, this clause describes additions and modifications to the 100BASE-X, 1000BASE-X, 10GBASE-R, 10GBASE-W, and 10GBASE-X Physical Layers, making them capable of unidirectional operation, which is required to initialize a 1000BASE-PX network, and allows the transmission of Operations, Administration and Management (OAM) frames regardless of whether the PHY has determined that a valid link has been established.

However, unidirectional operation may only be enabled under very limited circumstances. Before enabling this mode, the MAC shall be operating in full-duplex mode and Auto-Negotiation, if applicable, shall be disabled. In addition, the OAM sublayer above the MAC (see Clause 57) shall be present and enabled or (for 1000BASE-X), the PCS shall be part of a 1000BASE-PX-D PHY (see Clause 60 and Clause 64). Unidirectional operation shall not be invoked for a PCS that is part of a 1000BASE-PX-U PHY (except for out-of-service test purposes or where the PON contains just one ONU). Failure to follow these restrictions results in an incompatibility with the assumptions of IEEE 802.1 protocols, a PON that cannot initialize, or collisions, which are unacceptable in the P2MP protocol.

66.1 Modifications to the physical coding sublayer (PCS) and physical medium attachment (PMA) sublayer, type 100BASE-X

66.1.1 Overview

This subclause specifies the 100BASE-X PCS and PMA for support of subscriber access networks.

66.1.2 Functional specifications

The 100BASE-X PCS and PMA for subscriber access networks shall conform to the requirements of the 100BASE-X PCS specified in 24.2 and the 100BASE-X PMA specified in 24.3 with the following exception: The 100BASE-X PCS for subscriber access networks may have the ability to transmit data regardless of whether the PHY has determined that a valid link has been established. The following are the detailed changes to Clause 24 in order to support this additional ability.

66.1.2.1 Variables

Insert a new variable among those already described in 24.2.3.2:

mr_unidirectional_enable

A control variable that enables the unidirectional mode of operation. This variables is provided by a management interface that may be mapped to the Clause 22 Control register Unidirectional enable bit (0.5).

Values: FALSE; Unidirectional capability is not enabled
TRUE; Unidirectional capability is enabled

66.1.2.2 Transmit state diagram

The description of the transmit state diagram is changed to include the contribution of the new mr_unidirectional_enable variable. The third paragraph of 24.2.4.2 is changed to read (~~strikethroughs~~ show deleted text and underscores show inserted text):

> The indication of link_status ≠ OK by the ~~PMA at any time~~ PMA, when mr_unidirectional_enable = FALSE, causes an immediate transition to the IDLE state and supersedes any other Transmit process operations. When mr_unidirectional_enable = TRUE, the Transmit process ignores the value of link_status. This enables the ability to transmit data from the MII when link_status ≠ OK.

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Additionally, the functionality of Figure 24–13 shall be changed as represented by Figure 66–1.

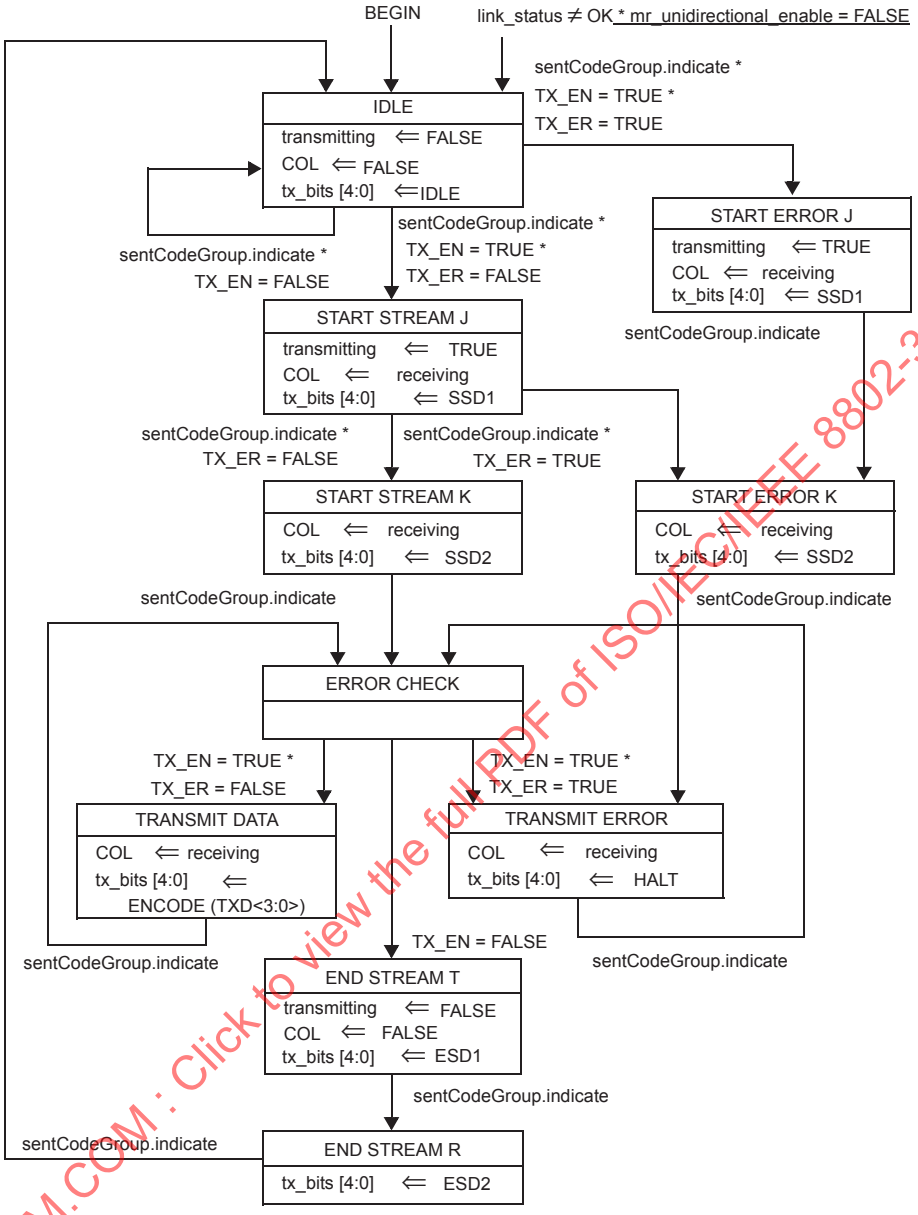

Figure 66–1—Transmit state diagram

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66.1.2.3 Far-end fault generate

The description of the far-end fault generate state diagram is also changed to include the contribution of the new mr_unidirectional_enable variable. The first paragraph of 24.3.4.5 is changed to read (~~strikethroughs~~ show deleted text and underscores show inserted text):

> Far-End Fault Generate simply passes tx_code-bits to the TX process when signal_status=ON or when mr_unidirectional_enable=TRUE. When signal_status=OFF and mr_unidirectional_enable=FALSE, it repetitively generates each cycle of the Far-End Fault Indication until signal_status is reasserted or mr_unidirectional_enable is set to TRUE.

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Additionally, the functionality of Figure 24–16 shall be changed as represented by Figure 66–2.

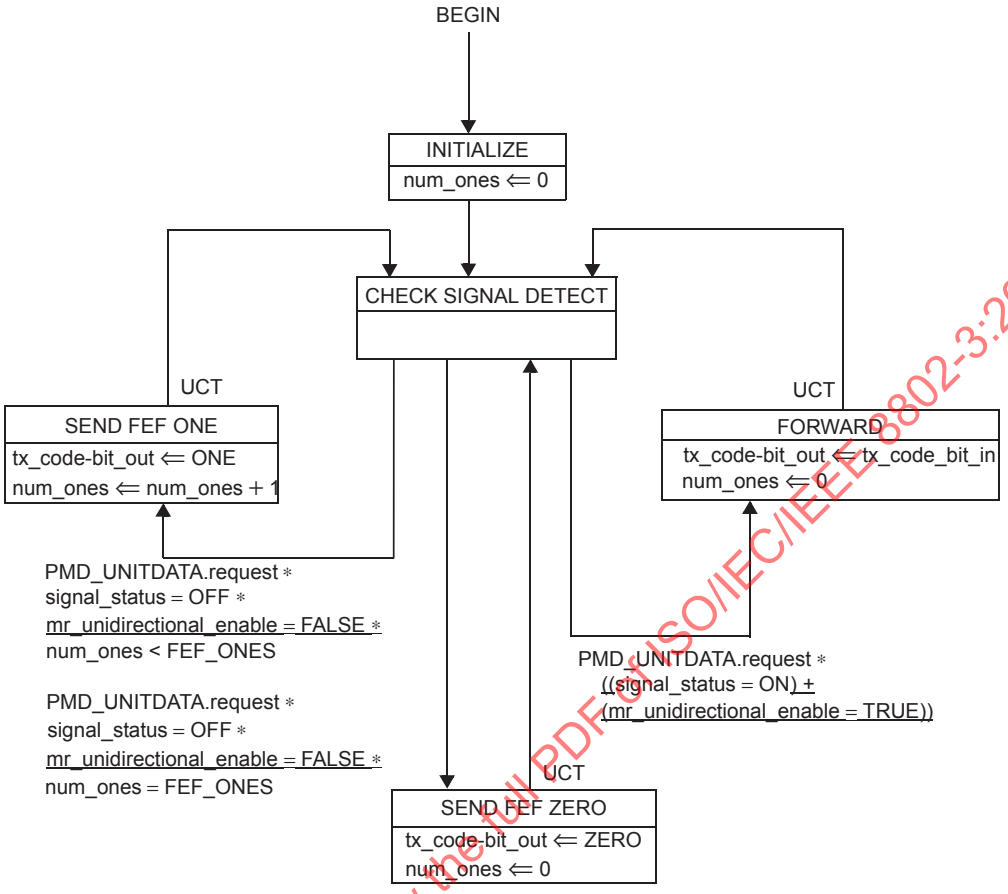

Figure 66–2—Far-End Fault Generate state diagram

66.2 Modifications to the physical coding sublayer (PCS) and physical medium attachment (PMA) sublayer, type 1000BASE-X

66.2.1 Overview

This subclause specifies the 1000BASE-X PCS and PMA for support of subscriber access networks.

66.2.2 Functional specifications

The 1000BASE-X PCS for subscriber access networks shall conform to the requirements of the 1000BASE-X PCS specified in 36.2 with the following exception: The 1000BASE-X PCS for subscriber access networks may have the ability to transmit data regardless of whether the PHY has determined that a valid link has been established. The 1000BASE-X PMA for subscriber access networks shall conform to the requirements of the 1000BASE-X PMA specified in 36.3 with no changes. The following are the detailed changes to Clause 36 in order to support this additional ability.

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66.2.2.1 Variables

Insert a new variable among those already described in 36.2.5.1.3:

mr_unidirectional_enable

A control variable that enables the unidirectional mode of operation. This variable is provided by a management interface that may be mapped to the Clause 22 Control register Unidirectional enable bit (0.5).

Values: FALSE; Unidirectional capability is not enabled
TRUE; Unidirectional capability is enabled

Additionally, modify the existing xmit variable from 36.2.5.1.3 as follows (~~strikethroughs~~ show deleted text and underscores show inserted text):

xmit

When mr_unidirectional_enable=FALSE, xmit is d~~D~~efined in 37.3.1.1. When mr_unidirectional_enable=TRUE, xmit always takes the value DATA.

66.2.2.2 Transmit

The description of the transmit state diagram is changed to include the contribution of the new mr_unidirectional_enable variable. The second paragraph of 36.2.5.2.1 is changed to read (~~strikethroughs~~ show deleted text and underscores show inserted text):

> The Transmit ordered set process continuously sources ordered sets to the Transmit code-group process. When mr_unidirectional_enable = TRUE, the Auto-Negotiation process xmit flag always takes the value DATA and the Auto-Negotiation process is never invoked. Otherwise, when initially invoked, and when the Auto-Negotiation process xmit flag indicates CONFIGURATION, the Auto-Negotiation process is invoked. When the Auto-Negotiation process xmit flag indicates IDLE, and between packets (as delimited by the GMII), /I/ is sourced. Upon the assertion of TX_EN by the GMII when the Auto-Negotiation process xmit flag indicates DATA, the SPD ordered set is sourced. Following the SPD, /D/ code-groups are sourced until TX_EN is deasserted. Following the de-assertion of TX_EN, EPD ordered sets are sourced. If TX_ER is asserted when TX_EN is deasserted and carrier extend error is not indicated by TXD, /R/ ordered sets are sourced for as many GTX_CLK periods as TX_ER is asserted with a delay of two GTX_CLK periods to first source the /T/ and /R/ ordered sets. If carrier extend error is indicated by TXD during carrier extend, /V/ ordered sets are sourced. If TX_EN and TX_ER are both de-asserted, the /R/ ordered set may be sourced, after which the sourcing of /I/ is resumed. If, while TX_EN is asserted, the TX_ER signal is asserted, the /V/ ordered set is sourced except when the SPD ordered set is selected for sourcing.

66.2.2.3 Transmit state diagram

The 1000BASE-X PCS for subscriber access networks shall implement the transmit process as depicted in Figure 36–5 and Figure 36–6, including compliance with the associated state variables as specified in 36.2.5.1 and as modified in 66.2.2.1.

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66.3 Modifications to the reconciliation sublayer (RS) for P2P 10 Gb/s operation

66.3.1 Overview

This subclause specifies the 10 Gb/s RS for support of P2P subscriber access networks.

66.3.2 Functional specifications

The 10 Gb/s RS for subscriber access networks shall conform to the requirements of the 10 Gb/s RS specified in Clause 46 with the following exception: The 10 Gb/s RS for subscriber access networks may have the ability to transmit data regardless of whether the PHY has determined that a valid link has been established. The following are the detailed changes to Clause 46 in order to support this additional ability.

66.3.2.1 Link fault signaling

The description of the link fault signaling functional specification is changed to include the contribution of the new mr_unidirectional_enable variable. The second paragraph of 46.3.4 is changed to read (~~strikethroughs~~ show deleted text and underscores show inserted text):

> Sublayers within the PHY are capable of detecting faults that render a link unreliable for communication. Upon recognition of a fault condition a PHY sublayer indicates Local Fault status on the data path. When this Local Fault status reaches an RS, the RS tests the unidirectional_enable variable. If this variable is FALSE, the RS stops sending MAC data, and continuously generates a Remote Fault status on the transmit data path (possibly truncating a MAC frame being transmitted). If this variable is TRUE, the RS continues to allow the transmission of MAC data but replaces IPG with a Remote Fault status. When Remote Fault status is received by an RS, the RS tests the unidirectional_enable variable. If this variable is FALSE, the RS stops sending MAC data, and continuously generates Idle control characters. If this variable is TRUE, the RS continues to allow the transmission of MAC data. When the RS no longer receives fault status messages, it returns to normal operation, sending MAC data.

66.3.2.2 Variables

Insert a new variable among those already described in 46.3.4.2:

unidirectional_enable

A control variable that enables the unidirectional mode of operation.

Values: FALSE; Unidirectional capability is not enabled
TRUE; Unidirectional capability is enabled

66.3.2.3 State diagram

The description of what the RS outputs onto TXC<3:0> and TXD<31:0> is changed to include the contribution of the new mr_unidirectional_enable variable. The lettered list of 46.3.4.3 is changed to read (~~strikethroughs~~ show deleted text and underscores show inserted text):

a) link_fault = OK
The RS shall send MAC frames as requested through the PLS service interface. In the absence of MAC frames, the RS shall generate Idle control characters.

b) link_fault = Local Fault
If unidirectional_enable=FALSE, t~~T~~he RS shall continuously generate Remote Fault Sequence ordered sets.
If unidirectional_enable=TRUE, the RS shall send MAC frames as requested through the PLS service interface. After a MAC frame and before transition to generation of Remote Fault Sequence

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the RS shall ensure a column of idles has been sent. In the absence of MAC frames, the RS shall generate Remote Fault Sequence ordered sets.

c) link_fault = Remote Fault
If unidirectional_enable=FALSE, t~~T~~he RS shall continuously generate Idle control characters.
If unidirectional_enable=TRUE, the RS shall send MAC frames as requested through the PLS service interface. In the absence of MAC frames, the RS shall generate Idle control characters.

66.4 Modifications to the RS for P2MP 10 Gb/s operation

66.4.1 Overview

This subclause specifies the 10 Gb/s RS for support of P2MP subscriber access networks.

66.4.2 Functional specifications

The 10 Gb/s RS for P2MP subscriber access networks shall conform to the requirements of the 10 Gb/s RS specified in Clause 46 with the following exception: The 10 Gb/s RS for P2MP subscriber access networks may have the ability to transmit data regardless of whether the PHY has determined that a valid link has been established. The following are the detailed changes to Clause 46 in order to support this additional ability.

66.4.2.1 Link fault signaling

The description of the link fault signaling functional specification is changed to include the contribution of the new unidirectional_enable variable. The second paragraph of 46.3.4 is changed to read (~~strikethroughs~~ show deleted text and underscores show inserted text):

Sublayers within the PHY are capable of detecting faults that render a link unreliable for communication. The nature of the P2MP link allows for some of these fault conditions to be ignored. Upon recognition of a fault condition a PHY sublayer indicates Local Fault status on the data path. When this Local Fault status reaches an RS, the RS tests the unidirectional_enable variable. If this variable is FALSE, the RS stops sending MAC data, and continuously generates ~~a Remote Fault status~~ Idle control characters on the transmit data path (possibly truncating a MAC frame being transmitted). If this variable is TRUE, the RS continues to allow the transmissions of MAC data. When Remote Fault status is received by an RS, the RS tests the unidirectional_enable variable. If this variable is FALSE, the RS stops sending MAC data, and continuously generates Idle control characters. If this variable is TRUE, the RS continues to allow the transmission of MAC data. When the RS no longer receives fault status messages, it returns to normal operation, sending MAC data.

66.4.2.2 Variables

Insert a new variable among those already described in 46.3.4.2:

unidirectional_enable
A control variable that enables the unidirectional mode of operation.
Values:FALSE; Unidirectional capability is not enabled
TRUE; Unidirectional capability is enabled

66.4.2.3 State diagram

The description of what the RS outputs onto TXC<3:0> and TXD<31:0> is changed to include the contribution of the new unidirectional_enable variable. The lettered list of 46.3.4.3 is changed to read (~~strikethroughs~~ show deleted text and underscores show inserted text):

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a) link_fault = OK
The RS shall send MAC frames as requested through the PLS service interface. In the absence of MAC frames, the RS shall generate Idle control characters.

b) link_fault = Local Fault
If unidirectional_enable = FALSE, t~~T~~he RS shall continuously generate Idle control characters~~Remote Fault Sequence ordered sets~~.
If unidirectional_enable = TRUE, the RS shall send MAC frames as requested through the PLS service interface. In the absence of MAC frames, the RS shall generate Idle control characters.

c) link_fault = Remote Fault
If unidirectional_enable = FALSE, t~~T~~he RS shall continuously generate Idle control characters.
If unidirectional_enable = TRUE, the RS shall send MAC frames as requested through the PLS service interface. In the absence of MAC frames, the RS shall generate Idle control characters.

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66.5 Protocol implementation conformance statement (PICS) proforma for Clause 66, Extensions of the 10 Gb/s Reconciliation Sublayer (RS), 100BASE-X PHY, and 1000BASE-X PHY for unidirectional transport[22]

66.5.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 66, Extensions of the 10 Gb/s Reconciliation Sublayer (RS), 100BASE-X PHY, and 1000BASE-X PHY for unidirectional transport, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

66.5.2 Identification

66.5.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

66.5.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 66, Extensions of the 10 Gb/s Reconciliation Sublayer (RS), 100BASE-X PHY, and 1000BASE-X PHY for unidirectional transport
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	
Date of Statement	

[22]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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66.5.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*PUNI	Unidirectional operation	66	Device supports unidirectional operation	O	Yes [ ] No [ ]
*HUN	100BASE-X functionality	66.1	Device supports functionality required for 100BASE-X PHY for subscriber access networks	O	Yes [ ] No [ ]
*GIG	1000BASE-X functionality	66.2	Device supports functionality required for 1000BASE-X PCS for subscriber access networks	O	Yes [ ] No [ ]
*XG	10 Gb/s functionality	66.3	Device supports functionality required for 10 Gb/s RS for subscriber access networks	O	Yes [ ] No [ ]
*XP2MP	10 Gb/s P2MP operation	66.4	Device supports 10 Gb/s P2MP operation	O	Yes [ ] No [ ]

66.5.4 PICS proforma tables for Extensions of the 10 Gb/s Reconciliation Sublayer (RS), 100BASE-X PHY, and 1000BASE-X PHY for unidirectional transport

66.5.4.1 Maintaining compatibility with IEEE 802.1 protocols

Item	Feature	Subclause	Value/Comment	Status	Support
MC1	Unidirectional mode enabled	66	Full duplex and disable AutoNeg and [(OAM present and enabled) or 1000BASE-PX-D] and not 1000BASE-PX-U	M	Yes [ ] No [ ]

66.5.4.2 Extensions of the 100BASE-X PHY

Item	Feature	Subclause	Value/Comment	Status	Support
H1	Integrates 100BASE-X PCS and PMA	66.1.2	See Clause 24	HUN:M	Yes [ ]
H2	Transmit state diagram	66.1.2.2	Replaces Figure 24–8	PUNI* HUN:M	Yes [ ]
H3	Far-End Fault Generate state diagram	66.1.2.3	Replaces Figure 24–16	PUNI* HUN:M	Yes [ ]

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66.5.4.3 Extensions of the 1000BASE-X PHY

Item	Feature	Subclause	Value/Comment	Status	Support
G1	Integrates 1000BASE-X PCS and PMA	66.2.2	See Clause 36	GIG:M	Yes [ ]
G2	Transmit state diagram	66.2.2.3	As modified by the new variables	PUNI* GIG:M	Yes [ ]

66.5.4.4 Extensions of the 10 Gb/s P2P RS

Item	Feature	Subclause	Value/Comment	Status	Support
LF1	Integrates 10 Gb/s RS	66.3.2	See Clause 46	XG:M	Yes [ ]
LF2	link_fault = OK and MAC frames	66.3.2.3	RS services MAC frame transmission requests	PUNI* XG:M	Yes [ ] No [ ]
LF3	link_fault = OK and no MAC frames	66.3.2.3	In absence of MAC frames, RS transmits Idle control characters	PUNI* XG:M	Yes [ ] No [ ]
LF4	link_fault = Local Fault and unidirectional_enable = FALSE	66.3.2.3	RS transmits continuous Remote Fault Sequence ordered sets	PUNI* XG:M	Yes [ ] No[ ]
LF5	link_fault = Local Fault and unidirectional_enable = TRUE and MAC frames	66.3.2.3	RS services MAC frame transmission requests	PUNI* XG:M	Yes [ ] No[ ]
LF6	link_fault = Local Fault and unidirectional_enable = TRUE and MAC frame ends	66.3.2.3	RS transmits one full column of IDLE after frame	PUNI* XG:M	Yes [ ] No[ ]
LF7	link_fault = Local Fault and unidirectional_enable = TRUE and no MAC frames	66.3.2.3	RS transmits continuous Remote Fault Sequence ordered sets	PUNI* XG:M	Yes [ ] No[ ]
LF8	link_fault = Remote Fault and unidirectional_enable = FALSE	66.3.2.3	RS transmits continuous Idle control characters	PUNI* XG:M	Yes [ ] No [ ]
LF9	link_fault = Remote Fault and unidirectional_enable = TRUE and MAC frames	66.3.2.3	RS services MAC frame transmission requests	PUNI* XG:M	Yes [ ] No [ ]
LF10	link_fault = Remote Fault and unidirectional_enable = TRUE and no MAC frames	66.3.2.3	RS transmits continuous Idle control characters	PUNI* XG:M	Yes [ ] No[ ]

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66.5.4.5 Extensions of the 10 Gb/s P2MP RS

Item	Feature	Subclause	Value/Comment	Status	Support
PF1	Integrates 10 Gb/s P2MP RS	66.4.2	See Clause 76	PUNI * XP2MP:M	Yes [ ]
PF2	link_fault = OK and MAC frames	66.4.2.3	RS services MAC frame transmission requests	PUNI * XP2MP:M	Yes [ ] No [ ]
PF3	link_fault = OK and no MAC frames	66.4.2.3	In absence of MAC frames, RS transmits Idle control characters	PUNI * XP2MP:M	Yes [ ] No [ ]
PF4	link_fault = Local Fault and unidirectional_enable = FALSE	66.4.2.3	RS transmits continuous Idle control characters	PUNI * XP2MP:M	Yes [ ] No [ ]
PF5	link_fault = Local Fault and unidirectional_enable = TRUE and MAC frames	66.4.2.3	RS services MAC frame transmission requests	PUNI * XP2MP:M	Yes [ ] No [ ]
PF6	link_fault = Local Fault and unidirectional_enable = TRUE and no MAC frames	66.4.2.3	In absence of MAC frames, RS transmits Idle control characters	PUNI * XP2MP:M	Yes [ ] No [ ]
PF7	link_fault = Remote Fault and unidirectional_enable = FALSE	66.4.2.3	RS transmits continuous Idle control characters	PUNI * XP2MP:M	Yes [ ] No [ ]
PF8	link_fault = Remote Fault and unidirectional_enable = TRUE and no MAC frames	66.4.2.3	RS services MAC frame transmission requests	PUNI * XP2MP:M	Yes [ ] No [ ]
PF9	link_fault = Remote Fault and unidirectional_enable = TRUE and no MAC frames	66.4.2.3	In absence of MAC frames, RS transmits Idle control characters	PUNI * XP2MP:M	Yes [ ] No [ ]

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67. System considerations for Ethernet subscriber access networks

67.1 Overview

This clause provides information on building Ethernet subscriber access networks, also referred to as "Ethernet in the First Mile" or EFM networks.

EFM encompasses a family of technologies that vary in media type and signaling speed. EFM is designed to be deployed in networks of one or multiple EFM media type(s) as well as interact with mixed 10/100/1000/10000 Mb/s Ethernet networks. Any network topology defined in IEEE Std 802.3 can be used within the subscriber premises and then connected to an Ethernet subscriber access network via an IEEE Std 802.1D compliant bridge, or a router.

Further, within a given EFM domain, the specific EFM technologies allow for a variety of topologies affording the subscriber access network maximum flexibility. For example, a 1000BASE-PX-10 P2MP system with 16 ONUs can be built with a 1:16 splitter or as a tree-and-branch network utilizing more than one splitter.

The design of multiple-domain networks is governed by the rules defining each of the transmission systems incorporated into the design. The physical size of a network is limited by the characteristics of individual network components. These characteristics include the media lengths and type.

Table 67–1 summarizes the various EFM media characteristics.

67.2 Discussion and examples of EFM P2MP topologies

This subclause discusses EFM P2MP topologies. It details flexibility of trading off split ratio for link span. This subclause also shows some examples of different P2MP topologies.

67.2.1 Trade off between link span and split ratio

While the P2MP PMDs are nominally described in terms of a link span of either 10 km or 20 km with a 1:16 split ratio, other link spans and split ratios can be implemented provided that the requirements of Table 60–1 are met.

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Table 67–1—Characteristics of the various EFM network media segments

Media type	Rate (Mb/s)	Number of PHYs per segment	Nominal reach (km)
Optical 100 Mb/s fiber segment (100BASE-LX10, 100BASE-BX10)	100	2	10
Optical 1000 Mb/s fiber segment (1000BASE-LX10, 1000BASE-BX10)	1000	2	10
Optical 1000 Mb/s P2MP segment (1000BASE-PX10)	1000[a]	17[b,c]	10
Optical 1000 Mb/s P2MP segment (1000BASE-PX20)		17[b,c]	20
Optical 1000 Mb/s P2MP segment (1000BASE-PX30)		33[b,c]	20
Optical 1000 Mb/s P2MP segment (1000BASE-PX40)		65[b,c]	20
Optical 10/1 Gb/s P2MP segment (10/1GBASE-PRX10)	10 000 / 1000[d]	17[b,c]	10
Optical 10/1 Gb/s P2MP segment (10/1GBASE-PRX20)		17[b,c]	20
Optical 10/1 Gb/s P2MP segment (10/1GBASE-PRX30)		33[b,c]	20
Optical 10/1 Gb/s P2MP segment (10/1GBASE-PRX40)		65[b,c]	20
Optical 10 Gb/s P2MP segment (10GBASE-PR10)	10 000[e]	17[b,c]	10
Optical 10 Gb/s P2MP segment (10GBASE-PR20)		17[b,c]	20
Optical 10 Gb/s P2MP segment (10/1GBASE-PR30)		33[b,c]	20
Optical 10 Gb/s P2MP segment (10GBASE-PR40)		65[b,c]	20
Copper high-speed segment (10PASS-TS)	10[f]	2	0.75
Copper long reach segment (2BASE-TL)	2[c]	2	2.7

[a]1000 Mb/s in downstream direction, 1000 Mb/s in upstream direction.
[b]P2MP segments may be implemented with a trade off between link span and split ratio listed. Refer to 67.2.1.
[c]The number of PHYs in the P2MP segment includes the OLT PHY.
[d]10 000 Mb/s in downstream direction, 1000 Mb/s in upstream direction (asymmetric data rate in 10/1G-EPON).
[e]10 000 Mb/s in downstream direction, 10 000 Mb/s in upstream direction (symmetric data rate in 10/10G-EPON).
[f]Nominal rate stated at the nominal reach in this table. Rate and reach can vary depending on the plant. For 2BASE-TL please refer to Annex 63B for more information. For 10PASS-TS, please refer to Annex 62A for more information.

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67.2.2 Single splitter topology

A P2MP topology implemented with a single optical splitter is shown in Figure 67–1.

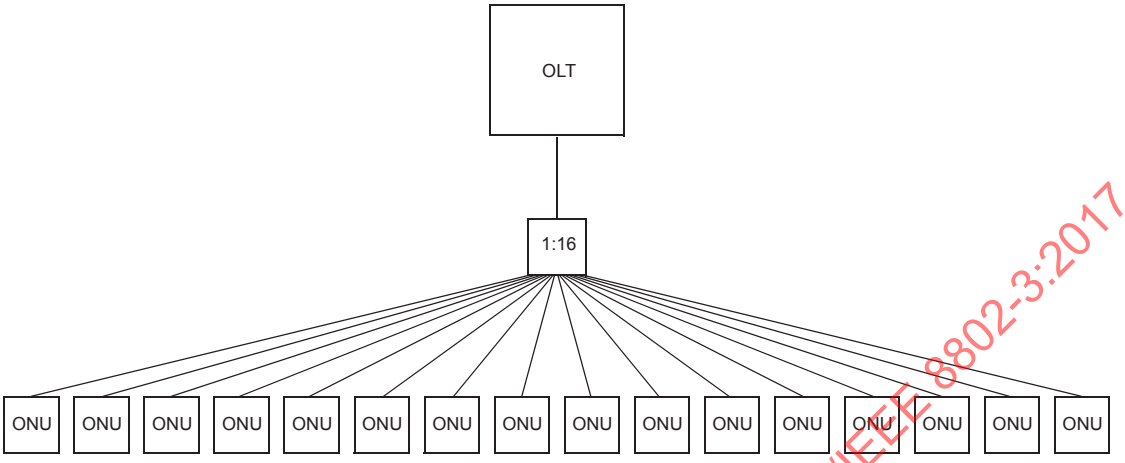

Figure 67–1—Single splitter topology

67.2.3 Tree-and-branch topology

A P2MP topology implemented with a tree-and-branches of optical splitters is shown in Figure 67–2.

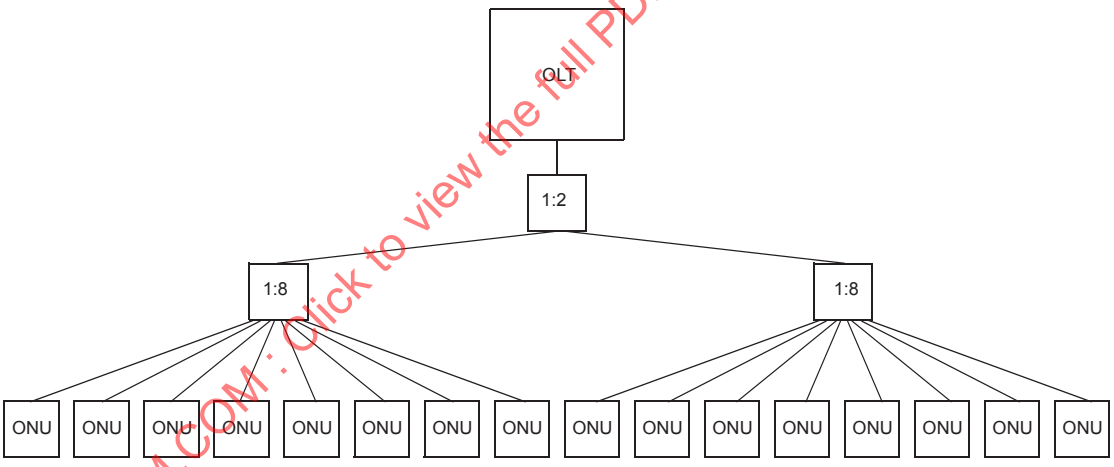

Figure 67–2—Tree-and-branch topology

67.2.4 Interoperability between certain 1000BASE-PX10 and 1000BASE-PX20

1000BASE-PX20-D PMD is interoperable with a 1000BASE-PX10-U PMD, this allows certain upgrade possibilities from 10 km to 20 km P2MP networks.

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67.3 Hybrid media topologies

Hybrid media topologies, such as those shown in Figure 67–3, can be implemented using a combination of P2P or P2MP optical links and copper links.

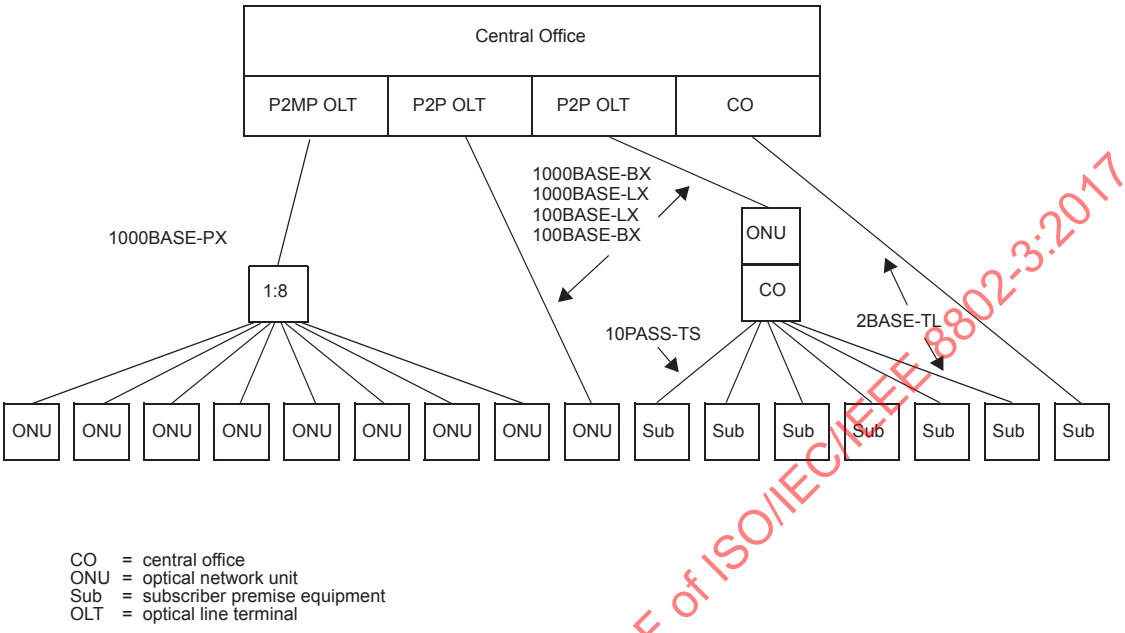

Figure 67–3—Hybrid media topologies

67.4 Topology limitations

The physical size of EFM networks is not limited by the round-trip collision propagation delay. Instead, the maximum link length between DTEs is limited by the signal transmission characteristics of the specific link.

67.5 Deployment restrictions for subscriber access copper

10PASS-TS and 2BASE-TL PHYs have been specified to allow deployment on public access networks. Non-loaded cable is a requirement of the signaling methods employed. The 10PASS-TS do not preclude coexistence with POTS. However, it is important that systems are designed and configured to comply with all appropriate regulatory, governmental and regional requirements. Refer to Annex 62A (10PASS-TS) and Annex 63A (2PASS-TL) for further information regarding configuration profiles.

67.6 Operations, Administration, and Maintenance

All P2P and emulated P2P links, including all of the EFM network media segments, support the optional OAM sublayer as defined in Clause 57. 2BASE-TL and 10PASS-TS PHYs do not support unidirectional links as defined in 57.2.6 (see 61.1).

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67.6.1 Unidirectional links

Some Physical Layer devices have the optional ability to encode and transmit data while one direction of the link is non-operational.

This ability should be used only when the OAM sublayer is present and enabled or for a 1000BASE-PX-D, 10/1GBASE-PRX, or 10GBASE-PR PHY. Otherwise, MAC Client frames will be sent across a unidirectional link potentially causing havoc with bridge and other higher layer protocols. The feature should not be enabled for 1000BASE-PX-U, 10/1GBASE-PRX-U, or 10GBASE-PR-U PHYs in service, to avoid simultaneous transmission by more than one ONU.

67.6.2 Active and Passive modes

A device may be configured to be in either Active or Passive OAM mode. At least one end of a given link is required to be in Active mode.

In an access network, customer premises devices will commonly be configured as Passive devices. All other devices in an access network will commonly be configured as Active devices. For a detailed description of Active and Passive mode, refer to 57.2.6.

67.6.3 Link status signaling in P2MP networks

In P2MP networks the local_link_status parameter should reflect the status of a logical link associated with the underlying instance of Multipoint MAC Control. This is achieved by mapping the local_link_status parameter to variable 'registered' defined in 64.3.3.2 for 1 Gb/s P2MP links and in 77.3.3.2 for 10 Gb/s links as follows:

local_link_status = OK if registered = true

local_link_status = FAIL if registered = false

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68. Physical medium dependent (PMD) sublayer type 10GBASE-LRM

68.1 Overview

This clause specifies the 10GBASE-LRM PMD and the associated multimode fiber media. In order to form a complete Physical Layer, the PMD is combined with the sublayers appropriate for 10GBASE-R, as specified in Table 52–2, and optionally with the management functions that may be accessible through the management interface defined in Clause 45.

Figure 68–1 depicts the relationships of the PMD (shown hatched) with other sublayers and the ISO/IEC Open System Interconnection (OSI) reference model. Clause 44 contains an introduction to 10 Gigabit Ethernet and the relationship of the 10GBASE-LRM PMD to other sublayers. Further relevant information may be found in Clause 1 (i.e., terminology and conventions, references, definitions and abbreviations) and Annex A (i.e., bibliography, entries referenced here in the format [B*n*]).

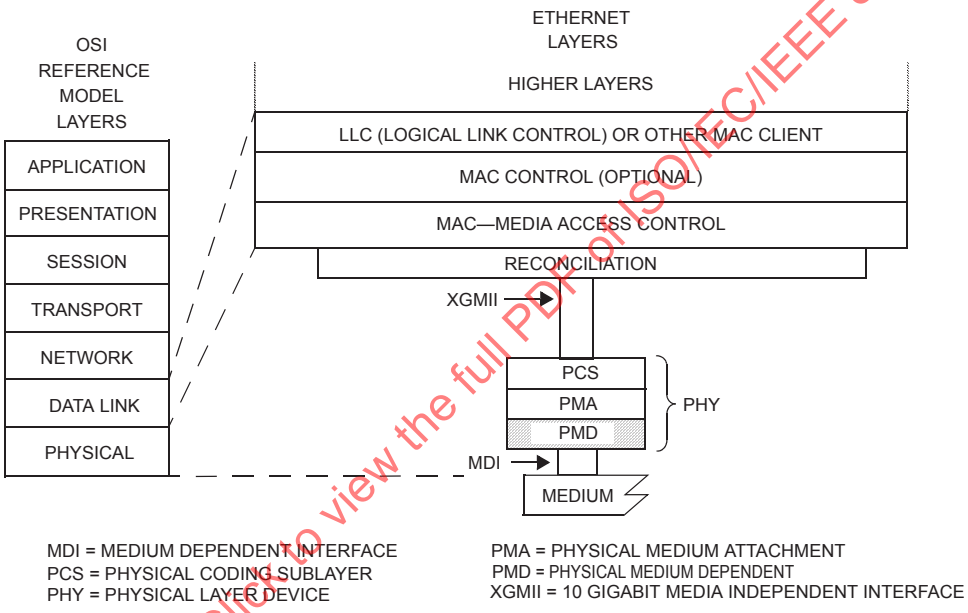

Figure 68–1—10GBASE-LRM PMD relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

68.1.1 Physical Medium Dependent (PMD) sublayer service interface

The PMD service interface is the 10GBASE-R PMD service interface as described in 52.1.1.

68.2 Delay constraints

An upper bound to the delay through the PMA and PMD is required for predictable operation of the MAC Control PAUSE operation. The PMA and PMD shall incur a round-trip delay (transmit and receive) of not more than 9216 bit times, or 18 pause_quanta, while including two meters of fiber. A description of overall system delay constraints and the definitions for bit times and pause_quanta can be found in 44.3.

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68.3 PMD MDIO function mapping

If present, the 10GBASE-LRM PMD MDIO function mapping shall be as specified in 52.3.

68.4 PMD functional specifications

The 10GBASE-LRM PMD performs the transmit and receive functions that convey data between the PMD service interface and the MDI.

68.4.1 PMD block diagram

For the purposes of system conformance, the PMD sublayer is standardized at test points TP2 and TP3, as shown in Figure 68–2. The optical transmit signal is defined at the output end of a patch cord (TP2), of between 2 m and 5 m in length. The optical launch condition at TP2 is either the preferred launch or the alternative launch (at the user's choice), as specified in 68.5.1. A compliant PMD shall support both options. The launch is selected by using either a single-mode fiber offset-launch mode-conditioning patch cord or a regular multimode fiber patch cord inserted between the MDI and TP2, consistent with the media type. Unless specified otherwise, all transmitter measurements and tests defined in 68.6 are made at TP2. The optical receive signal is defined at the output of the fiber optic cabling (TP3) that is the input to the MDI of the optical receiver. Unless specified otherwise, for all receiver measurements and tests defined in 68.6, the test stimulus is applied at TP3.

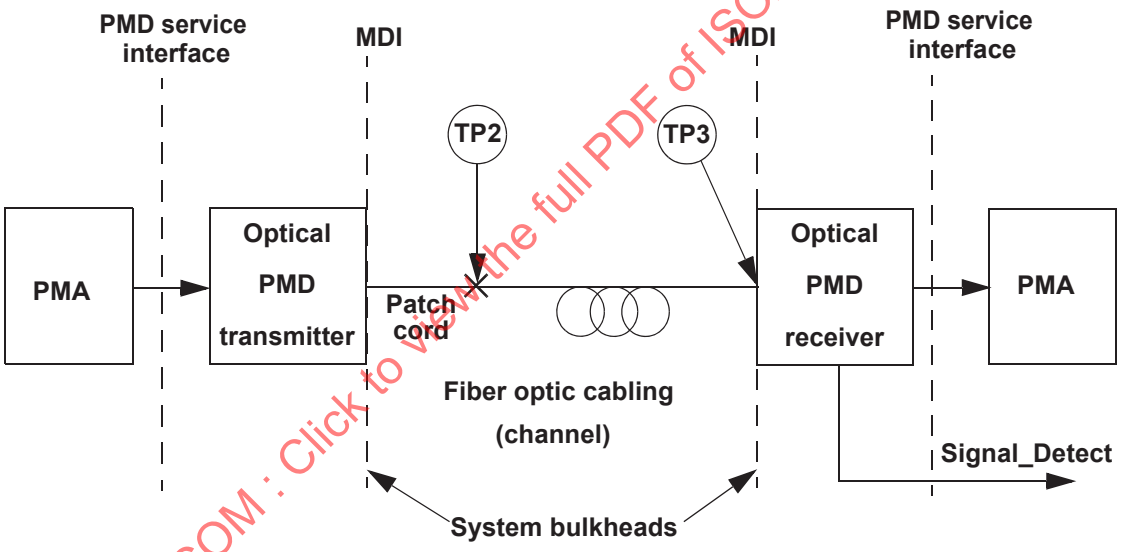

Figure 68–2—Block diagram

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68.4.2 PMD transmit function

The PMD transmit function shall convey the bits requested by the PMD service interface message PMD_UNITDATA.request(tx_bit) to the MDI according to the optical specifications in this clause. The higher optical power level shall correspond to tx_bit = ONE.

68.4.3 PMD receive function

The PMD receive function shall convey the bits received from the MDI according to the optical specifications in this clause to the PMD service interface using the message PMD_UNITDATA.indication(rx_bit). The higher optical power level shall correspond to rx_bit = ONE.

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68.4.4 PMD signal detect function

The PMD signal detect function shall report to the PMD service interface using the message PMD_SIGNAL.indication(SIGNAL_DETECT), which is signaled continuously. PMD_SIGNAL.indication is intended to be an indicator of optical signal presence. If the MDIO interface is implemented, then PMD_global_signal_detect (1.10.0) shall be continuously set to the value of SIGNAL_DETECT as described in 45.2.1.9.7.

The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 68–1. The PMD receiver is not required to verify whether a compliant 10GBASE-R signal is being received. This standard imposes no response time requirements on the generation of the SIGNAL_DETECT parameter.

Table 68–1—SIGNAL_DETECT value definition

Receive conditions	SIGNAL_DETECT value
Input average power < –30 dBm	FAIL
Compliant 10GBASE-R input signal with optical power in OMA > stressed sensitivity in OMA in Table 68–5	OK
All other conditions	Unspecified

As an unavoidable consequence of the requirements for the setting of the SIGNAL_DETECT parameter, implementations must provide adequate margin between the optical power level at which the SIGNAL_DETECT parameter is set to OK, and the inherent noise level of the PMD due to crosstalk, power supply noise, etc.

Various implementations of the signal detect function are permitted, including implementations that generate the SIGNAL_DETECT parameter values in response to the amplitude of the modulation of the received optical signal and implementations that respond to the average power of the received optical signal.

68.4.5 PMD_reset function

If the MDIO interface is implemented, and if PMD_reset is asserted, the PMD shall be reset as specified in 45.2.1.1.1.

68.4.6 PMD_fault function

If the MDIO is implemented, PMD_fault is the logical OR of PMD_receive_fault, PMD_transmit_fault, and any other implementation-specific fault.

68.4.7 PMD_global_transmit_disable function

The PMD_global_transmit_disable function is optional. When asserted, this function shall turn off the optical transmitter so that it meets the requirements of the average launch power of OFF transmitter in Table 68–3.

If a PMD_transmit_fault (optional) is detected, then the PMD_global_transmit_disable function should also be asserted.

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If the MDIO interface is implemented, then this function shall map to the PMD_global_transmit_disable bit as specified in 45.2.1.8.7.

68.4.8 PMD_transmit_fault function

The PMD_transmit_fault function is optional. The faults detected by this function are implementation specific, but should not include the assertion of the PMD_global_transmit_disable function.

If a PMD_transmit_fault (optional) is detected, then the PMD_global_transmit_disable function should also be asserted.

If the MDIO interface is implemented, then this function shall be mapped to the PMD_transmit_fault bit as specified in 45.2.1.7.4.

68.4.9 PMD_receive_fault function

The PMD_receive_fault function is optional. PMD_receive_fault is the logical OR of NOT SIGNAL_DETECT and any implementation-specific fault.

If the MDIO interface is implemented, then this function shall contribute to the PMA/PMD receive fault bit as specified in 45.2.1.7.5.

68.5 PMD to MDI optical specifications

The operating ranges for 10GBASE-LRM are given in Table 68–2. A PMD that exceeds the operational range requirements given in this clause, while meeting all other specifications, is considered compliant.

Table 68–2—10GBASE-LRM fiber types and operating ranges

Multimode fiber type[a]	ISO/IEC 11801:2002 fiber type	Operating range (m)	Maximum channel insertion loss (dB)[b]
62.5 µm 160/500[c]		0.5 to 220	1.9
62.5 µm 200/500	OM1	0.5 to 220	1.9
50 µm 500/500	OM2	0.5 to 220	1.9
50 µm 400/400		0.5 to 100	1.7
50 µm 1500/500[d]	OM3	0.5 to 220	1.9

[a]Each fiber type is identified by its core diameter followed by a pair of OFL bandwidth values separated by "/". The OFL bandwidths are in MHz · km and are for 850 nm and 1300 nm respectively.
[b]Channel insertion loss includes cabled optical fiber attenuation and an allocation of 1.5 dB for connectors.
[c]160/500, 62.5 µm fiber is commonly referred to as "FDDI-grade" fiber.
[d]The OM3 fiber specification includes the 850 nm laser launch bandwidth in addition to the OFL bandwidths.

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68.5.1 Transmitter optical specifications

The 10GBASE-LRM transmitter shall meet the specifications given in Table 68–3 and Figure 68–3, per definitions in 68.6.

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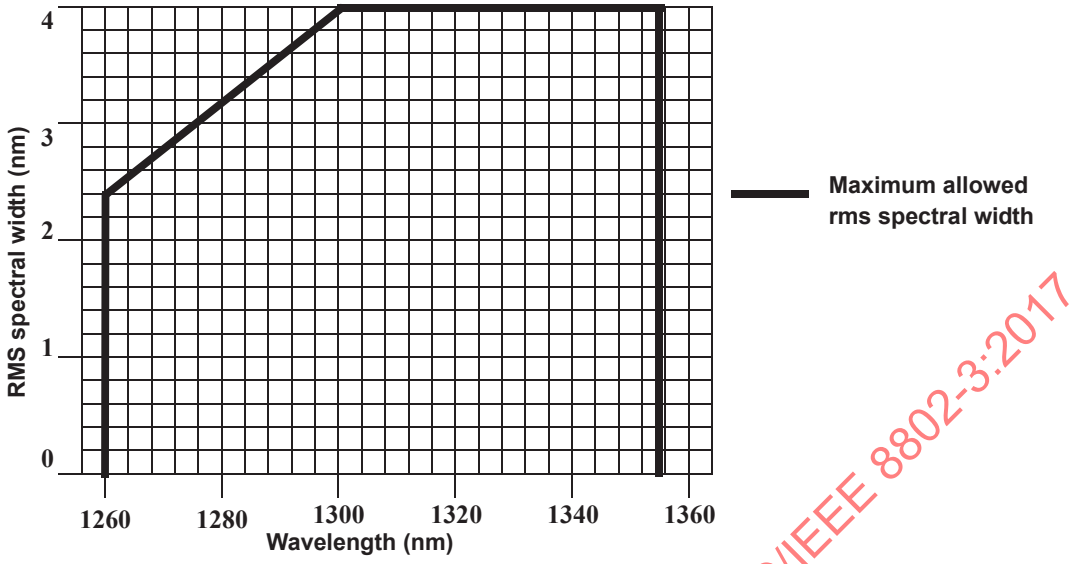

Figure 68–3—10GBASE-LRM Transmitter spectral limits

68.5.2 Characteristics of signal within, and at the receiving end of, a compliant 10GBASE-LRM channel (informative)

Table 68–4 gives the characteristics of a signal within, and at the receiving end of, a compliant 10GBASE-LRM channel. A signal with power in OMA and average power not within the ranges given cannot be compliant. However, a signal with power values within the ranges is not necessarily compliant.

68.5.3 Receiver optical specifications

The 10GBASE-LRM receiver shall meet the specifications given in Table 68–5, per definitions in 68.6.

68.5.3.1 Dynamic response

Channel responses are expected to vary with time at rates of up to 10 Hz. It is highly recommended that receivers tolerate such time varying channel responses.

68.6 Definitions of optical parameters and measurement methods

The following definitions and measurement methods apply to the transmitter and receiver optical parameters given in Table 68–3 and Table 68–5.

68.6.1 Test patterns and related subclauses for optical parameters

Compliance is to be achieved in normal operation. Table 68–6 gives the test patterns to be used in each measurement, unless otherwise specified, and also lists references to the subclauses in which each parameter is defined. The test patterns include pattern 1, pattern 2, pattern 3, and square waves, defined in 52.9.1.1 and 52.9.1.2, as well as the PRBS9 pattern.

NOTE—The longer test patterns are designed to emulate system operation; however, they do not form valid 10GBASE-R frames.

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Table 68–3—10GBASE-LRM transmit characteristics

Description	Type	Value	Unit
Signaling speed	nom	10.3125	GBd
Signaling speed variation from nominal	max	± 100	ppm
Center wavelength	range	1260 to 1355	nm
RMS spectral width[a] at 1260 nm RMS spectral width between 1260 nm and 1300 nm RMS spectral width between 1300 nm and 1355 nm	max max max	2.4 Figure 68–3 4	nm nm nm
Launch power in OMA[b]	max	1.5	dBm
Launch power in OMA[b]	min	–4.5	dBm
Average launch power[b]	max	0.5	dBm
Average launch power[b]	min	–6.5	dBm
Average launch power[b] of OFF transmitter	max	–30	dBm
Extinction ratio	min	3.5	dB
Peak launch power[bc]	max	3	dBm
$RIN_{20}OMA$	max	–128	dB/Hz
Eye mask parameters {X1, X2, X3, Y1, Y2, Y3}		{0.25, 0.40, 0.45, 0.25, 0.28, 0.80}	
Transmitter waveform and dispersion penalty (TWDP)	max	4.7	dB
Uncorrelated jitter (rms)	max	0.033	UI
Optical launch for OM1 and 160/500, 62.5 µm fiber Preferred[d] Encircled flux[e] for alternative launch	 — min min	 62.5 µm mode-conditioning patch cord, as specified in 68.9.3 30% within 5 µm radius 81% within 11 µm radius	
Optical launch for OM2, and 400/400, 50 µm fiber Preferred[d] Encircled flux[e] for alternative launch	 — min min	 50 µm mode-conditioning patch cord, as specified in 68.9.3 30% within 5 µm radius 81% within 11 µm radius	
Optical launch for OM3, 50 µm, fiber Encircled flux[e]	 min min	 30% within 5 µm radius 81% within 11 µm radius	
Optical return loss tolerance	min	20	dB

[a]RMS spectral width is the standard deviation of the spectrum.
[b]The OMA, average launch power and peak launch power specifications apply at TP2. This is after each type of patch cord. For information: Patch cord losses, between MDI and TP2, differ. The range of losses must be accounted for to ensure compliance to TP2.
[c]Peak optical power can be determined as the maximum value from the waveform capture for the TWDP test, or equivalent method.
[d]The PMD must support both the preferred and alternative launch types by the use of a single-mode fiber offset-launch mode-conditioning patch cord, or a regular multimode fiber patch cord, between the MDI and TP2.
[e]This encircled flux specification, measured per IEC 61280-1-4, defines the near field light distribution at TP2 when the MDI is coupled directly into a 50 µm patch cord and when the MDI is coupled directly into a 62.5 µm patch cord.

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Table 68–4—Characteristics of signal within, and at the receiving end of, a compliant 10GBASE-LRM channel (informative)

Description	Type	Value	Unit
Highest power in OMA	max	1.5	dBm
Lowest power in OMA	min	–6.4	dBm
Highest average power	max	0.5	dBm
Lowest average power	min	–8.4	dBm
Peak power	max	3	dBm

68.6.2 Optical modulation amplitude (OMA)

For the purposes of Clause 68, OMA is defined by the measurement method given in 52.9.5, and as illustrated in Figure 68–4. The mean logic ONE and mean logic ZERO values are measured over the center 20% of the two time intervals of the square wave. The OMA is the difference between these two means.

NOTE—An estimate of the OMA value is provided by the variable Measured OMA in 68.6.6.2.

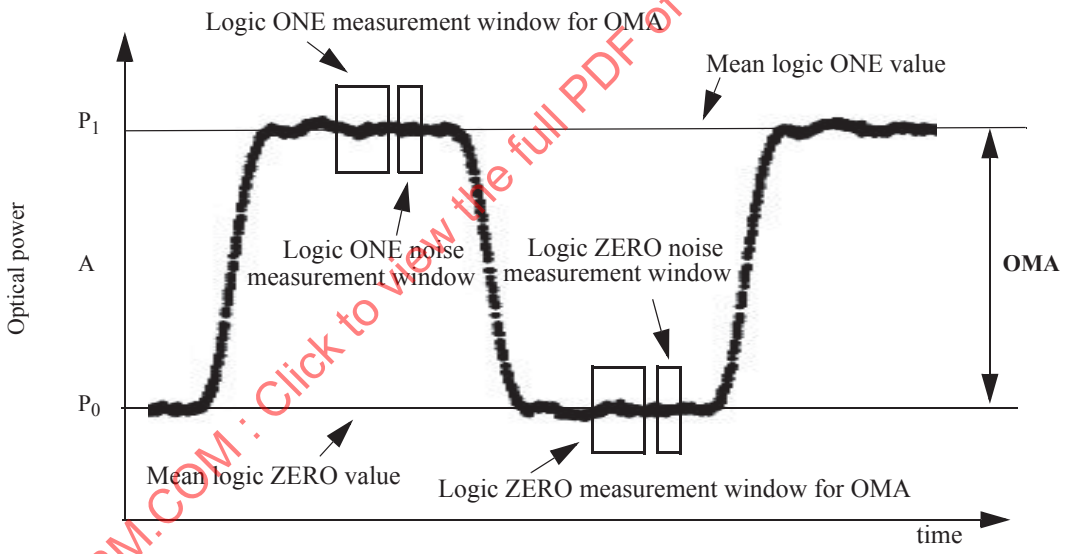

Figure 68–4—Positions of logic ZERO and logic ONE measurement windows for OMA and transmitter noise measurements

68.6.3 Extinction ratio measurement

The extinction ratio shall meet specifications according to 52.9.4.

NOTE—Extinction ratio and OMA are defined with different test patterns (see Table 68–6).

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Table 68–5—10GBASE-LRM receive characteristics

Description		Type	Value	Unit
Signaling speed		nom	10.3125	GBd
Signaling speed variation from nominal		max	±100	ppm
Center wavelength		range	1260 to 1355	nm
Stressed sensitivity in OMA		—	–6.5	dBm
Stressed sensitivity in OMA for symmetrical test		—	–6	dBm
Overload in OMA		—	1.5	dBm
Conditions of comprehensive stressed receiver tests:				
	Bandwidth of Gaussian white noise source[a]	min	10	GHz
	Test transmitter signal to noise ratio, Q_{sq}[b]	—	26.3	
	Tap spacing, Δt, of ISI generator	—	0.75	UI
	Pre-cursor tap weights {A1, A2, A3, A4}	—	{0.158, 0.176, 0.499, 0.167}	
	Symmetrical tap weights {A1, A2, A3, A4}	—	{0.00, 0.513, 0.00, 0.487}	
	Post-cursor tap weights {A1, A2, A3, A4}	—	{0.254, 0.453, 0.155, 0.138}	
Conditions of simple stressed receiver test:				
	Signal rise and fall times (20% to 80%)	—	115	ps
Conditions of receiver jitter tolerance test:				
	Jitter frequency and peak to peak amplitude	—	(75, 5)	(kHz, UI)
	Jitter frequency and peak to peak amplitude	—	(375, 1)	(kHz, UI)
Received average power for damage[c]		—	1.5	dBm
Receiver reflectance		max	–12	dB

[a]Bandwidth of Gaussian white noise source refers to the –3 dB (electrical) frequency of the noise spectrum before any subsequent filtering.
[b]Transmitter signal to noise ratio, Q_{sq}, is defined in 68.6.7 and its use here is qualified by 68.6.9.3.
[c]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average received power level.

Table 68–6—Test-pattern definitions and related subclauses

Test	Pattern	Related subclause
Transmitter OMA (modulated optical power)	Square	68.6.2
Calibration of OMA for receiver tests	Square, eight ONEs and eight ZEROs	68.6.9 and 68.6.10

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Table 68–6—Test-pattern definitions and related subclauses *(continued)*

Test	Pattern	Related subclause
Calibration of noise for receiver tests	Square, eight ONEs and eight ZEROs	68.6.9
Transmitter noise	Square	68.6.7
Transmitter uncorrelated jitter	1, 2, or PRBS9[a]	68.6.8
Extinction ratio	1 or 3	68.6.3
Average optical power	1 or 3	52.9.3
Transmitted waveform (eye mask)	1 or 3	68.6.5
Transmitter waveform and dispersion penalty (TWDP) Pattern 1 subsequence Pattern 1 subsequence key	1 or PRBS9[a] 348 bits, beginning at bit 3258 101010111011011, beginning immediately before the subsequence at bit 3243	68.6.6
Encircled flux	Not specified here	See IEC 61280-1-4
Wavelength, spectral width	1 or 3	52.9.2
Receiver jitter tolerance	1 or 3	68.6.11
Comprehensive stressed receiver sensitivity	2 or 3	68.6.9
Comprehensive stressed receiver overload	1 or 3	68.6.9
Simple stressed receiver sensitivity	1 or 3	68.6.10
Simple stressed receiver overload	1 or 3	68.6.10

[a]The PRBS9 pattern is optional. If used, it is generated by the polynomial $x^9 + x^5 + 1$ as specified in ITU-T O.153. The binary (0,1) data sequence $d(n)$ is given by $d(n) = d(n – 9) + d(n – 5)$, modulo 2. The pattern has a run of nine ones in its length of 511 bits.

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68.6.4 Relationship between OMA, extinction ratio and average power (informative)

The relationship between OMA, extinction ratio and average power is described in 58.7.6. Note that the difference between Clause 68 and Clause 58 measurement methods for OMA causes the equations in 58.7.6 to become approximations for transmitter signals with undershoot, overshoot, or intersymbol interference. It is recommended that these equations not be used for signals at TP3. Figure 68–5 illustrates the approximate region of transmitter compliance and also the approximate relationships between OMA, extinction ratio, and average power.

68.6.5 Transmitter optical waveform—transmitter eye mask

The required transmitter pulse shape characteristics are specified in the form of a mask of the transmitter eye diagram as shown in Figure 68–6. Compliance is to be assured with pattern 1 or 3 defined in 52.9.1. Measurements during system operation or with other patterns, such as a $2^{23}– 1$ PRBS or a valid 10GBASE-R signal, are likely to give very similar results. The transmitter optical waveform of a port transmitting the test pattern specified in Table 68–6 shall meet specifications according to the methods specified below.

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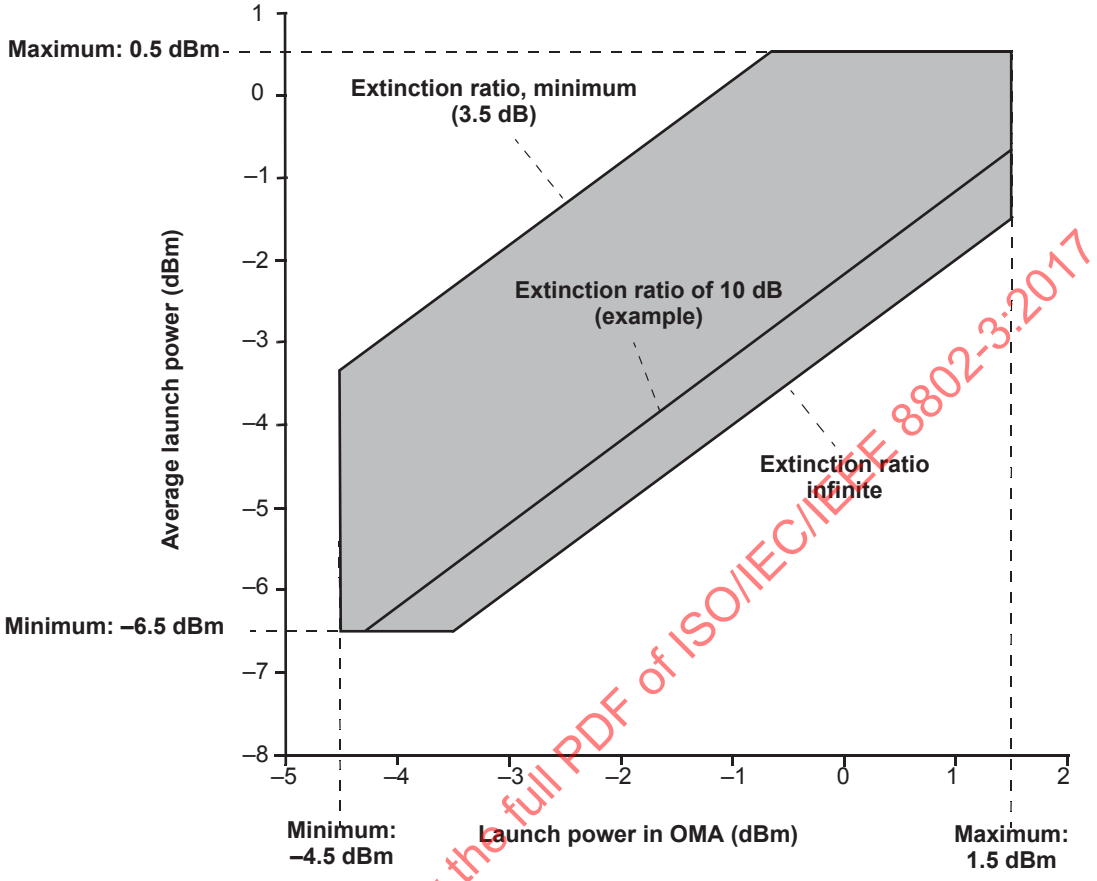

Figure 68–5—Graphical representation of approximate region of transmitter compliance (shown shaded) (informative)

Normalized amplitudes of 0 and 1 represent the amplitudes of logic ZERO and ONE respectively. These are defined by the means of the lower and upper halves of the central 0.2 UI of the eye. Normalized times of 0 and 1 on the unit interval scale are determined by the eye crossing means measured at the average value of the optical eye pattern. A clock recovery unit (CRU) should be used to trigger the oscilloscope for mask measurements, as shown in Figure 52–9. It should have a high-frequency corner bandwidth of 4 MHz and a slope of –20 dB/decade. The CRU tracks acceptable levels of low-frequency jitter and wander.

The eye is measured with respect to the mask using a receiver with the fourth-order Bessel-Thomson response with nominal f_r of 7.5 GHz as specified for STM-64 in ITU-T G.691, with the tolerances there specified. The Bessel-Thomson receiver is not intended to represent the noise filter used within a compliant optical receiver, but is intended to provide uniform measurement conditions at the transmitter. The nominal transfer function is given in Equation (52–2) and Equation (52–3).

The transmitter shall achieve a hit ratio lower than 5×10^{-5} hits per sample, where "hits" are the number of samples within the grey areas of Figure 68–6, and the sample count is the total number of samples from 0 UI to 1 UI. Some illustrative examples are provided in 68.6.5.1.

Further information on optical eye pattern measurement procedures may be found in IEC 61280-2-2.

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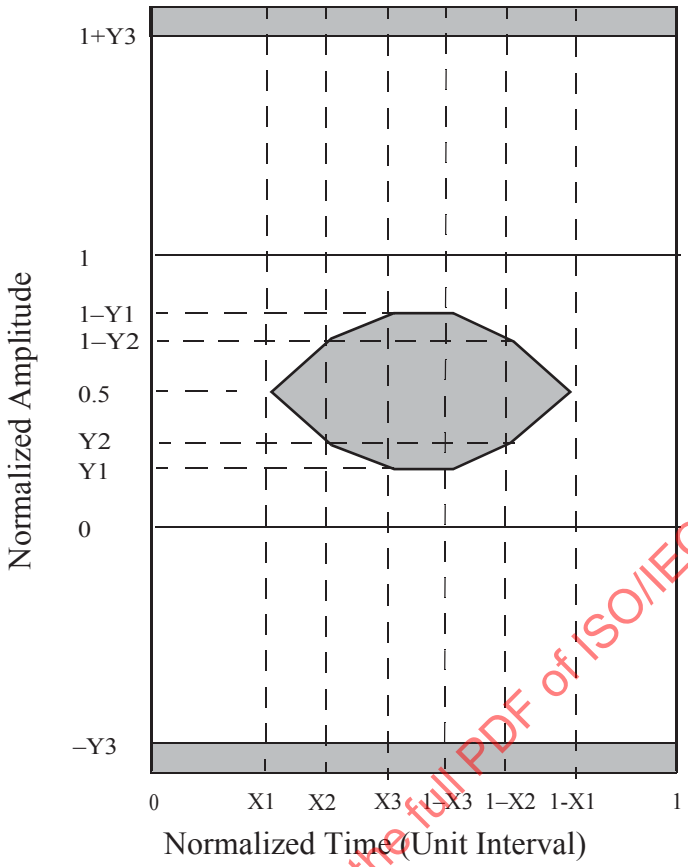

Figure 68–6—Transmitter eye mask definition

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68.6.5.1 Transmitter eye mask acceptable hit count examples (informative)

If an oscilloscope records 1350 samples/screen, and the time-base is set to 0.2 UI per division with 10 divisions across the screen, and the measurement is continued for 200 waveforms, then a transmitter with an expectation of less than 6.75 hits is compliant. i.e.,

$$\frac{5 \times 10^{-5} \times 200 \times 1350}{0.2 \times 10} = 6.75 \qquad (68–1)$$

Likewise, if a measurement is continued for 1000 waveforms, then an expectation of less than 33.75 hits is compliant. An extended measurement is expected to give a more accurate result, and a single reading of 6 hits in 200 waveforms would not give a statistically significant pass or fail. Measurements to "zero hits," which involve finding the position of the worst single sample in the measurement, have degraded reproducibility because random processes cause the position of such a single low-probability event to vary.

The hit ratio limit has been chosen to avoid misleading results due to transmitter and oscilloscope noise.

68.6.6 Transmitter waveform and dispersion penalty (TWDP)

The transmitter waveform shall meet the transmitter waveform and dispersion penalty (TWDP) specification given in Table 68–3.

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TWDP is a measure of the deterministic dispersion penalty due to a particular transmitter with reference emulated multimode fibers and receiver. Figure 68–7 shows the TWDP measurement configuration. A waveform from TP2 of the system under test is captured for analysis using an oscilloscope having a fourth-order, 7.5 GHz Bessel-Thomson response.

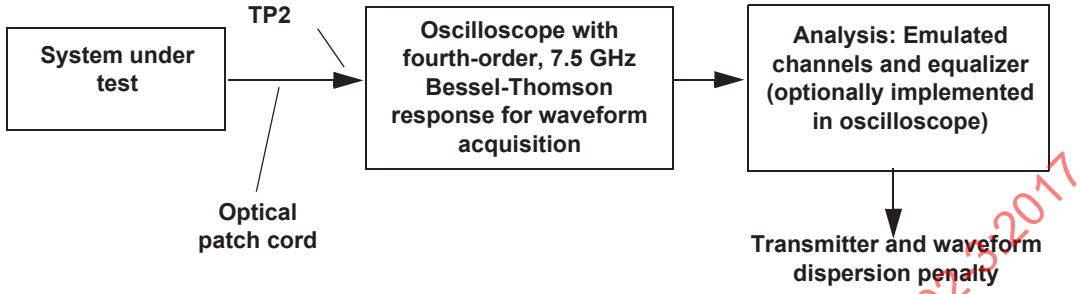

Figure 68–7—Transmitter waveform and dispersion penalty measurement configuration

68.6.6.1 TWDP measurement procedure

The system under test repetitively transmits a test pattern, as specified in Table 68–6. The waveform is captured using averaging to avoid a pessimistic estimate of TWDP. An effective sample rate of at least seven samples per unit interval is required. If test pattern 1 is transmitted, then the specified sub-pattern is to be captured. If PRBS9 is used, then the entire pattern is to be captured.

NOTE—The algorithm assumes 16 samples per unit interval. Interpolation is required for a waveform not captured with 16 samples per unit interval. Use of the $\sin(x)/x$ method or the cubic spline method is recommended. Linear interpolation is not recommended.

The captured waveform is analyzed using the algorithm given below, or equivalent. This algorithm analyses the waveform in combination with each of three emulated channels, equivalent to those given in Table 68–5 for the comprehensive stressed receiver specifications, and with an emulated reference receiver equalizer. A penalty is computed for each of the three emulated channels and the TWDP value is the largest of the three penalty results.

The reference equalizer is a decision feedback equalizer with defined tap number and spacing, as specified in 68.6.6.2. This is not intended to represent the equalizer used within an optical receiver, but is intended to provide uniform measurement conditions at the transmitter.

See Swenson, et al. [B58] for a detailed explanation of the TWDP algorithm.

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68.6.6.2 TWDP signal processing algorithm[23, 24]

```
%%%%%%% MATLAB (R) script to compute TWDP %%%%%%%%%%%%%%%%%%%%%%%%

%% TP2 test inputs
%% The values given below for TxDataFile and MeasuredWaveformFile are examples and should be
%% replaced by actual path\filenames for each waveform tested.
%% Transmit data file: The transmit data sequence is one of the TWDP test patterns defined in
%% Table 68–6. The file format is ASCII with a single column of chronological ones and zeros
%% with no headers or footers.
TxDataFile = 'prbs9_950.txt';
%% Measured waveform: The waveform consists of exactly N samples per unit interval T, where N is the
%% oversampling rate. The waveform must be circularly shifted to align with the data sequence. The file
%% format for the measured waveform is ASCII with a single column of chronological numerical samples,
%% in optical power, with no headers or footers.
MeasuredWaveformFile = 'preproc-1207-01.txt';
OverSampleRate = 16; % Oversampling rate, must be even
%% Simulated fiber responses, modeled as a set of ideal delta functions with specified amplitudes in optical
%% power and delays in nanoseconds, in rows. The three cases specified in Table 68–5 for the
%% comprehensive stressed receiver tests are used. The vector 'PCoefs' contains the amplitudes, and the
%% vector 'Delays' contains the delays.
FiberResp = [...
   0.000000 0.072727 0.145455 0.218182
   0.158 0.176 0.499 0.167
   0.000 0.513 0.000 0.487
   0.254 0.453 0.155 0.138];
Delays = FiberResp(1,:)';

%% Program constants %%
SymbolPeriod = 1/10.3125; % Symbol period (ns)
EqNf = 14; EqNb = 5; % 14 T/2-spaced feedforward equalizer taps; 5 T-spaced feedback equalizer taps
%% Set search range for equalizer delay, specified in symbol periods. Lower end of range is minimum
%% channel delay. Upper end of range is the sum of the lengths of the FFE and channel. Round up and add
%% 5 to account for the antialiasing filter.
EqDelMin = floor(min(Delays)/SymbolPeriod);
EqDelMax = ceil(EqNf/2 + max(Delays)/SymbolPeriod)+5;
EqDelVec = [EqDelMin:EqDelMax];
PAlloc = 6.5; % Total allocated dispersion penalty (dBo)
Q0 = 7.03; % BER = 10^(-12)
N0 = SymbolPeriod/2 / (Q0 * 10^(PAlloc/10))^2;

%% Load input waveform and data sequence, generate filter and other matrices
yout0 = load(MeasuredWaveformFile);
XmitData = load(TxDataFile);
PtrnLength = length(XmitData);
TotLen = PtrnLength*OverSampleRate;
Fgrid = [-TotLen/2:TotLen/2-1].'/(PtrnLength*SymbolPeriod);
%% Compute frequency response of 7.5 GHz 4th order Butterworth antialiasing filter
a = [1 123.1407 7581.811 273453.7 4931335]; % Denominator polynomial for frequency response
b = 4931335; % Numerator for frequency response
ExpArg = -j*2*pi*Fgrid;
H_r = b./polyval(a,-ExpArg); % Frequency response of Butterworth antialiasing filter
```

[23] *Copyright release for MATLAB code:* Users of this standard may freely copy or reproduce the MATLAB code in this subclause so it can be used for its intended purpose. Users should be aware, however, that this copyright release does not cover any patent rights that a third party may have in the MATLAB code.

[24] The script and associated files are available at http://standards.ieee.org/downloads/802.3/.

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```
ONE=ones(PtrnLength,1);

%% Normalize the received OMA to 1. Estimate the OMA of the captured waveform by using a linear fit to
%% estimate a pulse response, synthesize a square wave, and calculate the OMA of the synthesized square
%% wave per 52.9.5
ant=4; mem=40; % Anticipation and memory parameters for linear fit
X=zeros(ant+mem+1,PtrnLength); % Size data matrix for linear fit
Y=zeros(OverSampleRate,PtrnLength); % Size observation matrix for linear fit
for ind=1:ant+mem+1
   X(ind,:)=circshift(XmitData,ind-ant-1)'; % Wrap appropriately for lin fit
end
X=[X;ones(1,PtrnLength)]; % The all-ones row is included to compute the bias
for ind=1:OverSampleRate
   Y(ind,:)=yout0([0:PtrnLength-1]*OverSampleRate+ind)'; % Each column is one bit period
end
Qmat=Y*X'*(X*X')^(-1); % Coefficient matrix resulting from linear fit. Each column (except
%% the last) is one bit period of the pulse response. The last column is the bias.
SqWvPer=16; % Even number; sets the period of the square wave used to compute the OMA
SqWv=[zeros(SqWvPer/2,1);ones(SqWvPer/2,1)]; % One period of square wave (column)
X=zeros(ant+mem+1,SqWvPer); % Size data matrix for synthesis
for ind=1:ant+mem+1
   X(ind,:)=circshift(SqWv,ind-ant-1)'; % Wrap appropriately for synthesis
end
X=[X;ones(1,SqWvPer)]; % Include the bias
Y=Qmat*X;Y=Y(:); % Synthesize the modulated square wave, put into one column
avgpos=[0.4*SqWvPer/2*OverSampleRate:0.6*SqWvPer/2*OverSampleRate]; % samples to average over
ZeroLevel=mean(Y(round(avgpos),:)); % Average over middle 20% of "zero" run
% Average over middle 20% of "one" run, compute OMA
MeasuredOMA=mean(Y(round(SqWvPer/2*OverSampleRate+avgpos),:))-ZeroLevel;
%% Subtract zero level and normalize OMA
yout0 = (yout0-ZeroLevel)/MeasuredOMA;

%% Compute the noise autocorrelation sequence at the output of the front-end antialiasing filter and
%% rate-2/T sampler.
Snn = N0/2 * fftshift(abs(H_r).^2) * 1/SymbolPeriod * OverSampleRate;
Rnn = real(ifft(Snn));
Corr = Rnn(1:OverSampleRate/2:end);
C = toeplitz(Corr(1:EqNf));

%% Compute the minimum slicer MSE and corresponding TWDP for the three stressor fibers
X = toeplitz(XmitData, [XmitData(1); XmitData(end:-1:2)]); % Used in MSE calculation
Rxx = X'*X; % Used in MSE calculation
TrialTWDP = [];
for ii=1:3 % index for stressor fiber
   %% Propagate the waveform through fiber ii.
   %% The DC response of each fiber is normalized to 1.
   PCoefs = FiberResp(ii+1,:)';
   Hsys = exp(ExpArg * Delays') * PCoefs; Hx = fftshift(Hsys/sum(PCoefs));
   yout = real(ifft(fft(yout0).*Hx));
   %% Process signal through front-end antialiasing filter %%%%%%%%%%%%%%%%%%%%
   yout = real(ifft(fft(yout) .* fftshift(H_r)));
   %% Compute MMSE-DFE %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
   %% The MMSE-DFE filter coefficients computed below minimize mean-squared error at the slicer input.
   %% The derivation follows from the fact that the slicer input over the period of the data sequence can be
   %% expressed as Z = (R+N)*W - X*[0 B]', where R and N are Toeplitz matrices constructed from the
   %% signal and noise components, respectively, at the sampled output of the antialiasing filter, W is the
   %% feedforward filter, X is a Toeplitz matrix constructed from the input data sequence, and B is the
   %% feedback filter. The computed W and B minimize the mean square error between the input to the
   %% slicer and the transmitted sequence due to residual ISI and Gaussian noise. Minimize MSE over 2/T
```

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```
    %% sampling phase and FFE delay and determine BER
    MseOpt = Inf;
    for jj= [0:OverSampleRate-1]-OverSampleRate/2 % sampling phase
       %% Sample at rate 2/T with new phase (wrap around as required)
       yout_2overT = yout(mod([1:OverSampleRate/2:TotLen]+jj-1,TotLen)+1);
       Rout = toeplitz(yout_2overT, [yout_2overT(1); yout_2overT(end:-1:end-EqNf+2)]);
       R = Rout(1:2:end, :);
       RINV = inv([R'*R+PtrnLength*C R'*ONE;ONE'*R PtrnLength]);
       R=[R ONE]; % Add all-ones column to compute optimal offset
       Rxr = X'*R; Px_r = Rxx - Rxr*RINV*Rxr';
       %% Minimize MSE over equalizer delay
       for kk = 1:length(EqDelVec)
          EqDel = EqDelVec(kk);
          SubRange = [EqDel+1:EqDel+EqNb+1];
          SubRange = mod(SubRange-1,PtrnLength)+1;
          P = Px_r(SubRange,SubRange);
          P00 = P(1,1); P01 = P(1,2:end); P11 = P(2:end,2:end);
          Mse = P00 - P01*inv(P11)*P01';
          if (Mse<MseOpt)
             MseOpt = Mse;
             B = -inv(P11)*P01'; % Feedback filter
             XSel = X(:,SubRange);
             W = RINV*R'*XSel*[1;B]; % Feedforward filter
             Z = R*W - XSel*[0;B]; % Input to slicer
             %% STEP 6 - Compute BER using semi-analytic method %%%%%%%%%%%%%%%%%%
             MseGaussian = W(1:end-1)'*C*W(1:end-1);
             Ber = mean(0.5*erfc((abs(Z-0.5)/sqrt(MseGaussian))/sqrt(2)));
          end
       end
    end

    %% Compute equivalent SNR %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    %% This function computes the inverse of the Gaussian error probability function. The
    %% built-in function erfcinv() is not sensitive enough for low probability of error cases.
    if Ber>10^(-12) Q = sqrt(2)*erfinv(1-2*Ber);
    elseif Ber>10^(-323) Q = 2.1143*(-1.0658-log10(Ber)).^0.5024;
    else Q = inf;
    end

    %% Compute penalty %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    RefSNR = 10 * log10(Q0) + PAlloc;
    TrialTWDP(ii) = RefSNR-10*log10(Q);
end

%% Pick highest value due to the multiple fiber responses from TrialTWDP.
TWDP = max(TrialTWDP)
%% End of program
```

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68.6.7 Transmitter signal to noise ratio

The system under test shall meet the *RIN$_x$OMA* specification, given in Table 68–3 as *RIN$_{20}$OMA*, when measured using the procedure given in 58.7.7. A different measurement procedure for the same quantity, giving approximately the same results, uses the setup shown in Figure 68–8 and proceeds as follows:

a) Measure OMA, using a square wave and following the method of 68.6.2
b) Using the same square wave, measure the rms noise over flat regions of the logic ONE and logic ZERO portions of the square wave, as indicated in Figure 68–4, compensating for noise in the

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measurement system. The optical path and detector combination are configured for a single dominant reflection with the reflector adjusted to produce an optical return loss, as seen by the system under test, equal to the optical return loss tolerance (min) specified in Table 68–3. The length of the single-mode fiber is not critical, but should be in excess of 2 m. The polarization rotator is capable of transforming an arbitrary orientation elliptically polarized wave into a fixed orientation linearly polarized wave, and should be adjusted to maximize the noise. The receiver of the system under test should be receiving a signal that is asynchronous to that being transmitted. If possible, means should be used to prevent noise of frequency less than 1 MHz from affecting the result. Q_{sq} is given by Equation 68–2:

$$Q_{sq} = \frac{\text{OMA}}{\text{logic ONE noise (rms)} + \text{logic ZERO noise (rms)}} \quad (68–2)$$

where OMA and rms noise are measured in the same linear units of optical power, for example mW.

c) RIN_xOMA is then computed using the relationship shown in Equation 68–3:

$$RIN_xOMA = -20 \times \log_{10}(Q_{sq}) - 10 \times \log_{10}(BW) \quad \text{dB/Hz} \quad (68–3)$$

where BW is the low-pass bandwidth of oscilloscope minus high-pass bandwidth of the measurement system. For the specified measurement setup, BW is approximately 7.5×10^9 Hz.

Q_{sq} may be computed from the RIN_xOMA using the relationship shown in Equation 68–4:

$$Q_{sq} = 10^{-RINxOMA/20} / \sqrt{BW} \quad (68–4)$$

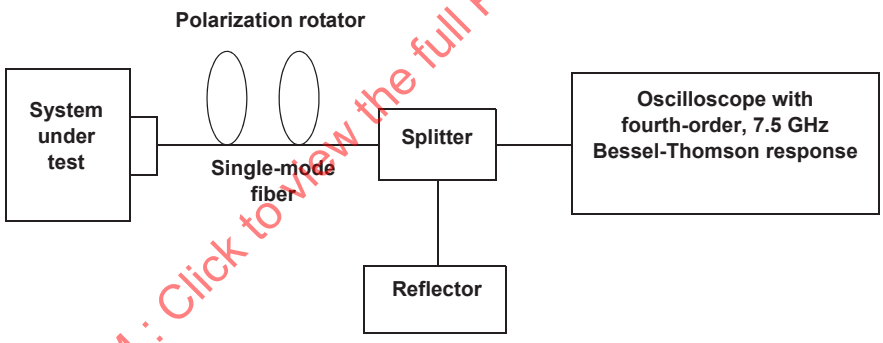

Figure 68–8—Transmitter signal to noise measurement setup

68.6.8 Transmitter uncorrelated jitter

Uncorrelated jitter refers to the component of jitter in the transmitted optical signal that is not correlated to the transmitter data.

The uncorrelated jitter specification of Table 68–3 shall be met when measured using an oscilloscope with a fourth-order, 7.5 GHz Bessel-Thomson response. The test pattern specified in Table 68–6 is used. A clock recovery unit (CRU) should be used to trigger the oscilloscope as shown in Figure 52–9. It should have a high frequency corner bandwidth of 4 MHz and a slope of –20 dB/decade. The CRU tracks acceptable levels of low-frequency jitter and wander. The oscilloscope is to be synchronized to the data pattern. The receiver of the system under test should be receiving a signal that is asynchronous to that being transmitted.

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Figure 68–9 illustrates two measurement window positions, one on a rising edge, the other on a falling edge and both placed at the average power level of the pattern. The uncorrelated jitter (rms) is given by the RMS value of the standard deviations of the two distributions, as shown in Equation 68–5:

$$\text{Uncorrelated jitter (rms)} = \sqrt{(\sigma_r^2 + \sigma_f^2)/2} \tag{68–5}$$

where

σ_r is the standard deviation of the jitter on the rising edge

σ_f is the standard deviation of the jitter on the falling edge

Compensation for measurement system jitter is encouraged.

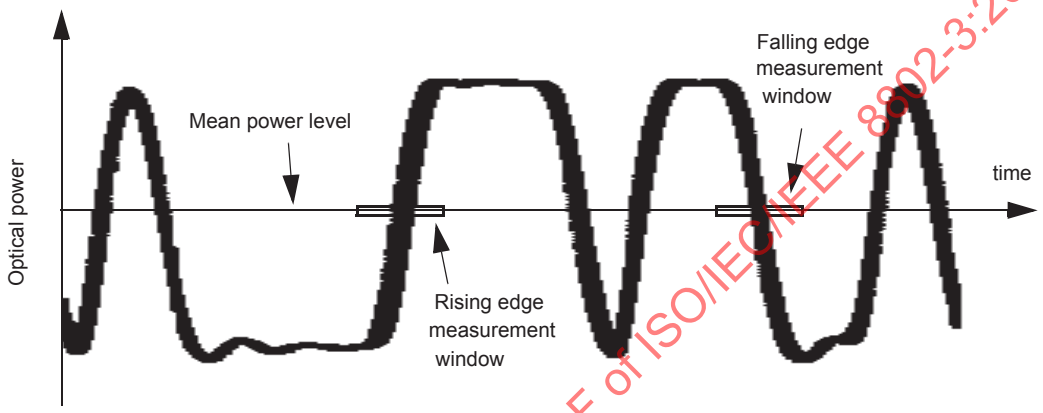

Figure 68–9—Measurement windows for transmitter uncorrelated jitter

68.6.9 Comprehensive stressed receiver sensitivity and overload

The PMD's receiver shall satisfy the comprehensive stressed receiver sensitivity and comprehensive stressed receiver overload specifications given in Table 68–5. These parameters are defined by reference to the procedures of 68.6.9.1 to 68.6.9.4. A BER of better than 10^{-12} shall be achieved with asynchronous transmission from the system under test. The received and transmitted patterns are the same, and as specified in Table 68–6 for the comprehensive stressed receiver sensitivity and the comprehensive stressed receiver overload.

68.6.9.1 Comprehensive stressed receiver sensitivity and overload test block diagram

Figure 68–10 shows the reference block diagram for the comprehensive stressed receiver test. As shown in the figure, an electrical signal is created using a pattern generator with pattern according to Table 68–6, and impaired by the following:

Gaussian low-pass filter

a) Gaussian white noise source
b) Intersymbol interference (ISI)

NOTE—Gaussian noise that extends, positively and negatively, to at least seven times its rms value is adequate.

The resulting electrical signal is converted to an optical signal using a linear electrical/optical converter, and the optical waveform is connected to an optical attenuator, and to the receiver under test via a mode-conditioning patch cord of the type defined in 38.11.4 or 59.9.5 for use with 62.5/125 μm fiber.

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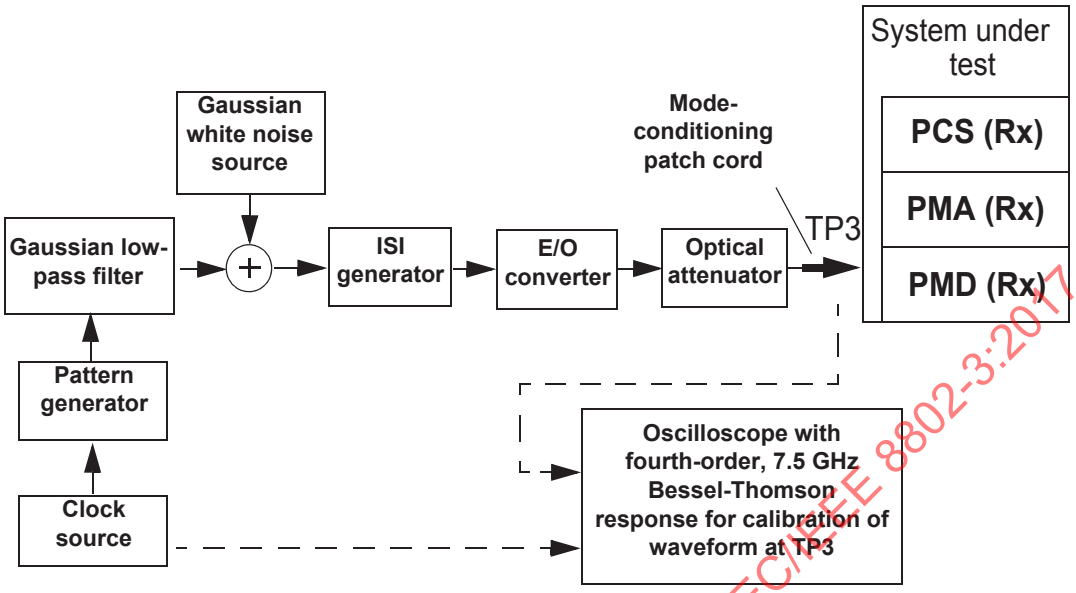

Figure 68–10—Reference measurement configuration for comprehensive stressed receiver sensitivity and overload test

The characteristics of the stressed test signal are defined in 68.6.9.2 and are based upon the parameters in Table 68–5. These parameters and the definition in 68.6.9.2 describe an ISI generator as a tapped delay line with four weighted taps, having equally spaced delays and with impulse response as illustrated in Figure 68–11.

Any implementation of the measurement configuration may be used, provided that the resulting signal and noise in the optical domain match those defined here. This consideration includes the shaping of the noise by the ISI generator.

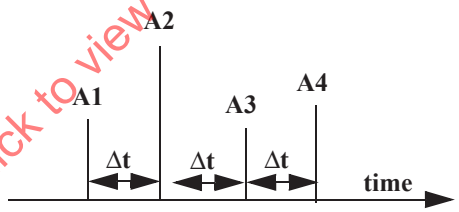

Figure 68–11—Illustration of parameters defining ISI generator impulse responses

68.6.9.2 Comprehensive stressed receiver test signal characteristics

The comprehensive stressed receiver test signal impairments are specified in Table 68–5 as the conditions of the comprehensive stressed receiver tests. These conditions include three sets of ISI parameters that are applied in turn. The ISI impaired test signal is defined by Equation 68–6:

$$S_{ISI}(t) = S(t) * G_{47}(t) * \left[\sum_{i=1}^{4} A_i \times \delta(t - i \times \Delta t) \right] \quad (68–6)$$

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where

$S(t)$ is an ideal NRZ test pattern signal specified in Table 68–6
$G_{47}(t)$ is a Gaussian low-pass filter with a 20% to 80% step response of 47 ps
A_i are the amplitudes of the four impulses
Δt is their spacing
δ is the Dirac delta function
* denotes convolution

The impulse spacing, and the amplitudes of the impulses for the three different test cases, are specified in Table 68–5.

The test signal is also impaired by broadband white Gaussian noise with a minimum bandwidth specified in Table 68–5 and with the amplitude adjusted such that Q_{sq} of the test signal, without ISI impairment, is as specified in Table 68–5.

Two different optical signal powers, in OMA, are used for the comprehensive stressed receiver sensitivity test. For the test with pre-cursor ISI tap weights, and the test with the post-cursor ISI tap weights, the OMA is set to the stressed sensitivity in OMA, given in Table 68–5. For the test with the symmetrical ISI tap weights, the OMA is set to the stressed sensitivity in OMA for symmetrical test, given in Table 68–5. For all three tests, the minimum extinction ratio specified in Table 68–3 is used.

For the comprehensive stressed receiver overload test, the OMA is set to the overload in OMA, given in Table 68–5, and with the maximum average power specified in Table 68–3.

68.6.9.3 Comprehensive stressed receiver test signal calibration

The test signal is calibrated as follows, using an optical reference receiver with a multimode compatible input and a 7.5 GHz fourth-order ideal Bessel-Thomson response.

The extinction ratio of the optical output is calibrated with the Gaussian low-pass filter but without the ISI generator.

Without ISI impairment due to the ISI generator, the level of the Gaussian noise is adjusted such that Q_{sq} is as specified in Table 68–5. See 68.6.7 for the definition of signal to noise ratio Q_{sq}.

The ISI generator is configured and calibrated for each of the three ISI cases specified in Table 68–5. The calibration of the ISI may be done with any portion of a repeating test signal. One convenient example is an isolated ONE bit with at least ten ZERO bits before and after. The ISI generator is adjusted such that the signal, S_{meas}, recorded on the reference receiver is given by Equation 68–7:

$$S_{meas}(t) = S_{cal}(t) * G_{47}(t) * \left[\sum_{i=1}^{4} A_i \times \delta(t - i \times \Delta t) \right] * BT4_{7.5GHz}(t) \quad (68–7)$$

where

S_{cal} is an ideal NRZ calibration test signal
G_{47}, A_i , Δt, and * are defined as in 68.6.9.2
$BT4_{7.5GHz}(t)$ is the impulse response of an ideal 7.5 GHz fourth-order Bessel-Thomson filter representing the optical reference receiver response

In practice, the bandwidth of, or need for, the Gaussian low-pass filter shown in block diagram of Figure 68–10 is determined by the characteristics of the signal source, ISI generator and E/O converter such that the final measured signal has the overall pulse response given by Equation 68–7.

Figure 68–12 illustrates the required measured test signals for the three cases specified in Table 68–5, where the test signal, S_{cal}, is a single ONE bit (rectangular pulse with 1 UI width) surrounded by ZEROs. Table 68–7 gives the tabulated amplitude vs. time for these curves.

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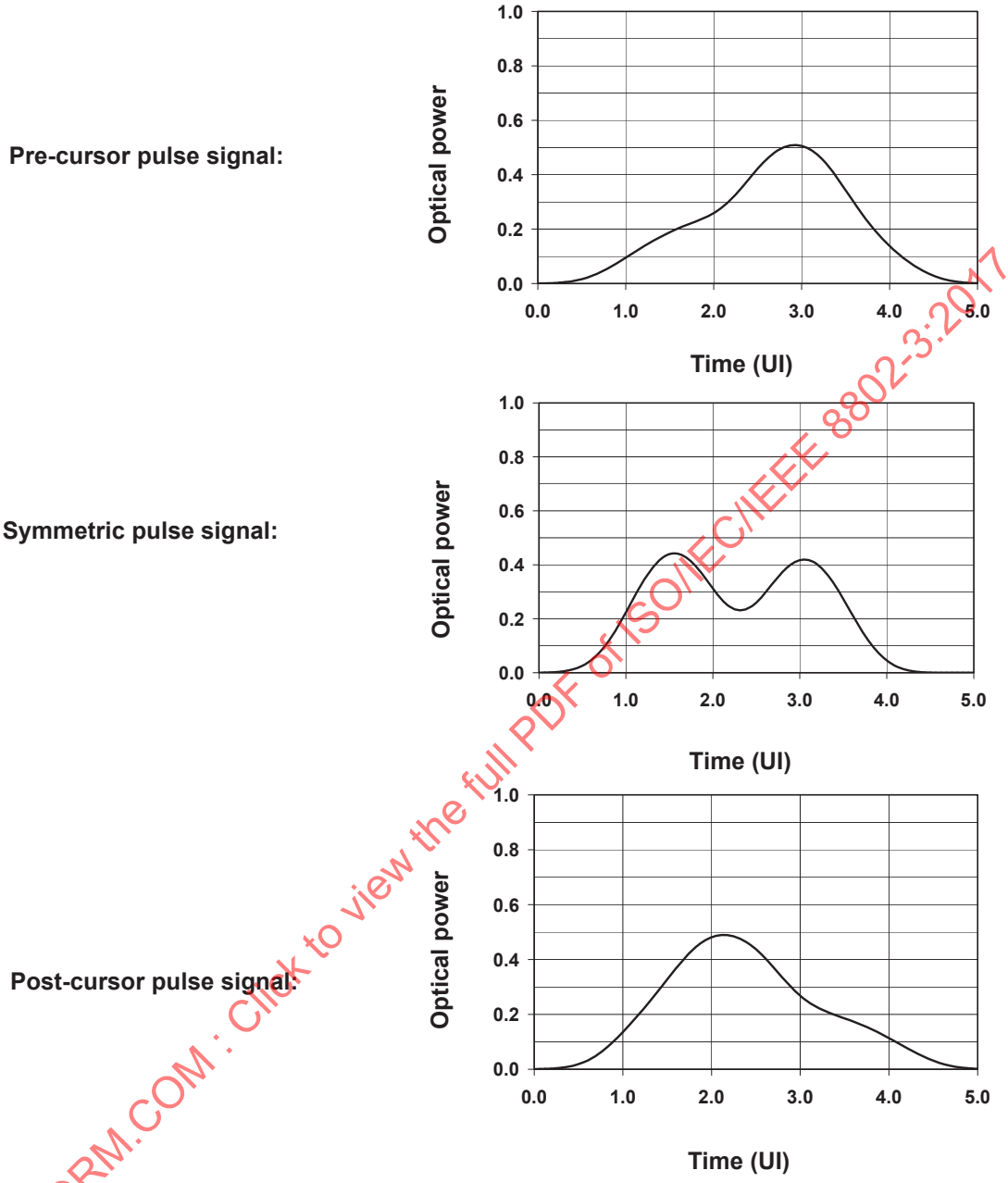

Figure 68–12—Comprehensive stressed receiver test pulse signals (i.e., signals corresponding to an isolated ONE bit)

NOTE—The optical powers have been normalized to correspond to waveforms with OMA of one.

NOTE—The TWDP values without simulated channels, which are measured using the same method as TWDP except that the simulated fiber stressors are set to (0,1,0,0), are 4.1 dB, 3.9 dB, and 4.2 dB for the pre-cursor, symmetrical and post-cursor tests, respectively. Significant differences from these values indicate problems with the test equipment (possibly nonlinearities) and that the test will not provide valid results. For small differences, the ISI generator should be adjusted to obtain the expected values. Also, one should ensure that the test system has adequate low-frequency response to avoid baseline wander problems with the longer test patterns used for the test.

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Table 68–7—Tabulated amplitude vs. time values for test signals of Figure 68–13

Time (UI)	Pre-cursor	Symmetrical	Post-cursor
0.000	0.000	0.000	0.000
0.125	0.001	0.001	0.001
0.250	0.003	0.004	0.003
0.375	0.008	0.011	0.009
0.500	0.016	0.026	0.019
0.625	0.029	0.053	0.036
0.750	0.048	0.095	0.061
0.875	0.071	0.154	0.095
1.000	0.096	0.224	0.136
1.125	0.121	0.298	0.180
1.250	0.146	0.364	0.227
1.375	0.168	0.413	0.276
1.500	0.189	0.439	0.327
1.625	0.207	0.439	0.378
1.750	0.223	0.413	0.423
1.875	0.239	0.367	0.459
2.000	0.259	0.312	0.481
2.125	0.288	0.264	0.489
2.250	0.327	0.235	0.484
2.375	0.374	0.234	0.467
2.500	0.422	0.261	0.437
2.625	0.464	0.305	0.398
2.750	0.494	0.355	0.352
2.875	0.508	0.395	0.307
3.000	0.506	0.417	0.268
3.125	0.487	0.415	0.238
3.250	0.451	0.388	0.216
3.375	0.402	0.338	0.200
3.500	0.344	0.273	0.186
3.625	0.284	0.203	0.171
3.750	0.228	0.137	0.154
3.875	0.180	0.084	0.135
4.000	0.138	0.046	0.114
4.125	0.103	0.022	0.091
4.250	0.072	0.009	0.069
4.375	0.048	0.003	0.048
4.500	0.029	0.001	0.031
4.625	0.016	0.000	0.018
4.750	0.007	0.000	0.009
4.875	0.003	0.000	0.004
5.000	0.001	0.000	0.001

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With the ISI generator present, the Q_{sq} values are as follows for the three different ISI impairments—pre-cursor: 45.6; symmetrical: 37.2; post-cursor: 47.0. Significant differences from these values indicate problems with the test equipment (possibly noise sources within the ISI generator), and the test will not provide valid results. For small differences, the amplitude of the added Gaussian white noise should be adjusted to obtain the expected values.

The attenuator setting is determined by measuring the OMA of the impaired test signal according to 68.6.2.

68.6.9.4 Comprehensive stressed receiver test procedure

The three ISI impairments defined in Table 68–5 and 68.6.9.2, together with the appropriate OMA values, also as specified in Table 68–5, define six discrete signal conditions.

With the test system setup as described in 68.6.9.2 and 68.6.9.3, for each case, select the required ISI impairment and set the attenuator and Gaussian white noise source to obtain either the stressed sensitivity in OMA, stressed sensitivity in OMA for symmetrical test or overload in OMA, with the appropriate noise, as specified in Table 68–5. Set the pattern generator to one of the patterns specified in Table 68–6 for these measurements. Connect the test signal to the system receiver TP3 and a BER of better than 10^{-12} shall be achieved for each case.

68.6.10 Simple stressed receiver sensitivity and overload (informative)

The simple stressed receiver sensitivity and simple stressed receiver overload are informative and compliance is not required. If measured, the receiver under test will be expected to satisfy the simple stressed receiver sensitivity and simple stressed receiver overload specifications in Table 68–5.

Figure 68–13 gives the block diagram for the simple stressed receiver test. A pattern generator output is impaired by a low-pass filter and the resulting electrical signal is converted to an optical signal using a linear electrical/optical converter. Other signal impairments, such as jitter and RIN, should be negligible. The optical waveform is connected to an optical attenuator, and to the receiver under test via a mode-conditioning patch cord of the type defined in 38.11.4 or 59.9.5 for use with 62.5/125 μm fiber.

The filter should be chosen so as to produce an optical output with the rise and fall times given in Table 68–5, and dominated by a fourth-order Bessel-Thomson response. The rise and fall times of the test signal are defined as measured with a 7.5 GHz Bessel-Thomson reference receiver and with the square wave pattern used for calibrating OMA for the comprehensive stressed receiver test of 68.6.9.

Other implementations may be used provided that the resulting signal in the optical domain matches that created using the implementation described.

NOTE—The TWDP without simulated channels, which is measured using the same method as TWDP except that the simulated fiber stressors are set to (0, 1, 0, 0), for this test signal is 4 dB.

For the two OMA values (i.e., the stressed sensitivity in OMA, and the overload in OMA, both specified in Table 68–5), a BER of better than 10^{-12} should be achieved. For the simple stressed receiver sensitivity test, the minimum extinction ratio specified in Table 68–3 is used. For the simple stressed receiver overload test, the maximum average power specified in Table 68–3 is used.

68.6.11 Receiver jitter tolerance

The receiver jitter tolerance specification given in Table 68–5 shall be met when measured as described here. This specification addresses the need for the receiver to track low-frequency jitter without the occurrence of errors.

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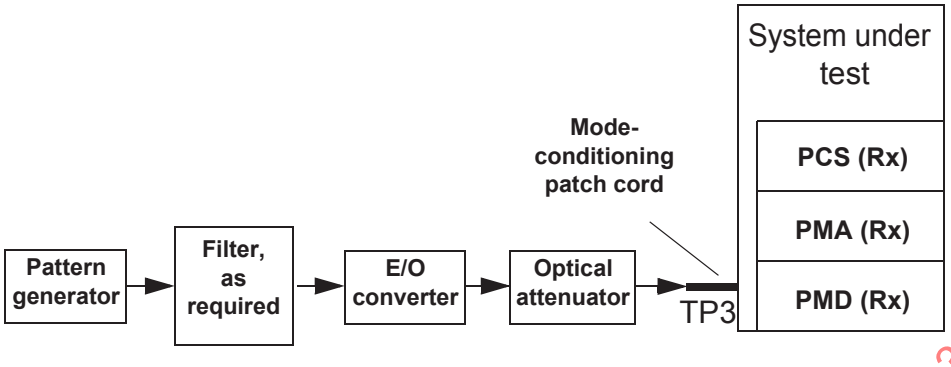

Figure 68–13—Measurement configuration for simple stressed receiver sensitivity test (informative)

Figure 68–14 gives the measurement configuration for the receiver jitter tolerance test. An optical pattern generator output is impaired by frequency modulation of the generating clock. The optical waveform is connected to the receiver under test via an optical attenuator and mode-conditioning patch cord suitable for 62.5/125 μm fiber.

Two jitter frequency and amplitude combinations are specified in Table 68–5. These are applied as the conditions of two separate receiver jitter tolerance tests. For each, the power in OMA at the receiver is adjusted, using the optical attenuator, to be equal to the stressed sensitivity in OMA, also given in Table 68–5, and a BER of better than 10^{-12} shall be achieved.

Various implementations may be used, provided that the resulting jitter in the optical domain matches that specified. Phase or frequency modulation may be applied to induce the sinusoidal jitter, and the modulation may be applied to the clock source or to the data stream itself.

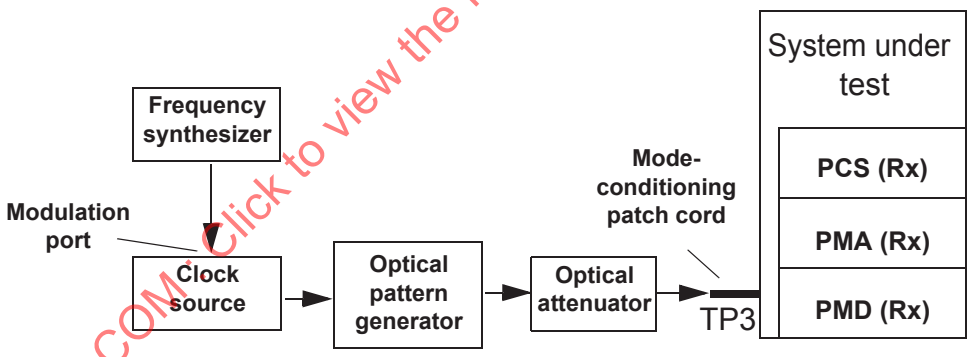

Figure 68–14—Measurement configuration for receiver jitter tolerance test

68.7 Safety, installation, environment, and labeling

68.7.1 Safety

The 10GBASE-LRM environmental specifications are as defined in 52.10.1 for general safety, and as defined in 52.10.2 for laser safety.

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68.7.2 Installation

It is recommended that proper installation practices, as defined by applicable local codes and regulation, be followed in every instance in which such practices are applicable.

NOTE—The preferred launch (as specified in Table 68–3) is expected to provide more stable operation. It is recommended that link stability be confirmed by physical manipulation of the transmitter patch cord.

68.7.3 Environment

The 10GBASE-LRM operating environment specifications are as defined in 52.11, as defined in 52.11.1 for electromagnetic emission, and as defined in 52.11.2 for temperature, humidity, and handling.

68.7.4 PMD labeling

The 10GBASE-LRM labeling recommendations and requirements are as defined in 52.12.

68.8 Fiber optic cabling model

The fiber optic cabling model is shown in Figure 38–7.

A channel may contain additional connectors or other optical elements as long as the optical characteristics of the channel such as attenuation, dispersion, reflections, modal bandwidth and total connector loss meet the specifications. Insertion loss measurements of installed multimode fiber cables are made in accordance with IEC 61280-4-1/Method 2. The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment. The term channel is used here for consistency with generic cabling standards.

68.9 Characteristics of the fiber optic cabling (channel)

The channel consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together. The fiber optic cabling shall meet the requirements of Table 68–8.

Table 68–8—Fiber optic cabling (channel)

Description	Type	Value	Unit
Cabled optical fiber insertion loss at 1300 nm	max	0.4	dB
Losses of all connectors and splices	max	1.5	dB

68.9.1 Optical fiber and cable

The optical fiber shall meet the requirements of IEC 60793-2-10 and the requirements given in Table 68–9, where they differ. Multimode cables chosen from IEC 60794-2-11 or IEC 60794-3-12 may be suitable.

68.9.2 Optical fiber connections

An optical fiber connection, as shown in Figure 38–7, consists of a mated pair of optical connectors.

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Table 68–9—Optical fiber and cable

Description	Type	Value	Unit
Cabled optical fiber attenuation at 1300 nm	max	1.5	dB/km
Modal bandwidth at 1300 nm	min	Value used as 1300 nm modal bandwidth portion of fiber identifier in Table 68–2	MHz · km
Zero dispersion wavelength (λ_0) for 62.5 µm MMF	range	$1320 \le \lambda_0 \le 1365$	nm
Chromatic dispersion slope for 62.5 µm MMF	max	0.11 for $1320 \le \lambda_0 \le 1348$ and $0.001(1458 - \lambda_0)$ for $1348 \le \lambda_0 \le 1365$	ps/nm^2 · km
Zero dispersion wavelength (λ_0) for 50 µm MMF	range	$1295 \le \lambda_0 \le 1320$	nm
Chromatic dispersion slope for 50 µm MMF	max	0.11 for $1300 \le \lambda_0 \le 1320$ and $0.001(\lambda_0 - 1190)$ for $1295 \le \lambda_0 \le 1300$	ps/nm^2 · km

68.9.2.1 Connection insertion loss

The insertion loss is specified for a connection, which consists of a mated pair of optical connectors.

The maximum link distances for multimode fiber are calculated based on an allocation of 1.5 dB total connector and splice loss. For example, this allocation supports three connections with an insertion loss equal to 0.5 dB (or less) per connection, or two connections (as shown in Figure 38–7) with an insertion loss equal to 0.75 dB per connection. Connections with different loss characteristics may be used provided the requirements of Table 68–8 are met.

68.9.2.2 Maximum discrete reflectance

The maximum discrete reflectance shall be less than –20 dB.

68.9.3 Single-mode fiber offset-launch mode-conditioning patch cord

Single-mode fiber offset-launch mode-conditioning patch cords shall satisfy the requirements of 38.11.4 or 59.9.5. Any discrete reflectance within the patch cord shall be less than –20 dB.

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68.10 Protocol implementation conformance statement (PICS) proforma for Clause 68, Physical medium dependent (PMD) sublayer type 10GBASE-LRM[25]

68.10.1 Introduction

The supplier of a protocol implementation that is claimed to conform to IEEE Std 802.3, Physical medium dependent (PMD) sublayer type 10GBASE-LRM, shall complete the following protocol implementation conformance statement (PICS) proforma. A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

68.10.2 Identification

68.10.2.1 Implementation identification

Supplier[1]	
Contact point for inquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1,3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

68.10.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 68, Physical medium dependent (PMD) sublayer type 10GBASE-LRM
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	

Date of Statement	

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[25] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that if can be used for its intended purpose and may further publish the completed PICS.

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68.10.2.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*MD	MDIO capability	68.3	Registers and interface supported	O	Yes [ ] No [ ]
*INS	Installation / Cable	68.9	Items marked with INS include installation practices and cable specifications not applicable to a PHY manufacturer	O	Yes [ ] No [ ]
DLY	Delay constraints	68.2	Device conforms to delay constraints	M	Yes [ ]

68.10.3 PICS proforma tables for physical medium dependent (PMD) sublayer type 10GBASE-LRM

68.10.3.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FS1	Optical launch	68.4.1, 68.5.1	PMD supports both preferred and alternative launches	M	Yes [ ]
FS2	Transmit function	68.4.2	Conveys bits from PMD service interface to MDI	M	Yes [ ]
FS3	Transmitter optical signal	68.4.2	Higher optical power transmitted is a logic 1	M	Yes [ ]
FS4	Receive function	68.4.3	Conveys bits from MDI to PMD service interface	M	Yes [ ]
FS5	Receiver optical signal	68.4.3	Higher optical power received is a logic 1	M	Yes [ ]
FS6	Signal detect function	68.4.4	Mapping to PMD service interface	M	Yes [ ]
FS7	Signal detect parameter	68.4.4	Generated according to Table 68–1	M	Yes [ ]

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68.10.3.2 Management functions

Item	Feature	Subclause	Value/Comment	Status	Support
MD1	Management register set	68.3	Mapped as per Table 52–3 and Table 52–4	MD:M	Yes [ ] N/A [ ]
MD2	PMD_reset bit	68.4.5, 45.2.1.1.1		MD:M	Yes [ ] N/A[ ]
MD3	PMD_global_transmit_disable bit	68.4.7, 45.2.1.8.7		MD:O	Yes [ ] No [ ] N/A [ ]
MD4	PMD_transmit_fault bit	68.4.8, 45.2.1.7.4		MD:O	Yes [ ] No [ ] N/A [ ]
MD5	PMD receive fault bit	68.4.9, 45.2.1.7.5		MD:O	Yes [ ] No [ ] N/A [ ]
MD6	PMD fault bit	68.4.6		MD:O	Yes [ ] No [ ] N/A [ ]
MD7	PMD_signal_detect bit	68.4.4, 45.2.1.9.7		MD:M	Yes [ ] N/A [ ]

68.10.3.3 PMD to MDI optical specifications

Item	Feature	Subclause	Value/Comment	Status	Support
LRM1	10GBASE-LRM transmitter	68.5.1	Meets specifications in Table 68–3	M	Yes [ ]
LRM2	10GBASE-LRM receiver	68.5.3	Meets specifications in Table 68–5	M	Yes [ ]

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68.10.3.4 Definitions of optical parameters and measurement methods

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	Optical modulation amplitude	68.6.2		M	Yes [ ]
OM2	Extinction ratio	68.6.3		M	Yes [ ]
OM3	Transmitter optical wave-form— transmitter eye mask	68.6.5		M	Yes [ ]
OM4	Transmitter optical wave-form— transmitter waveform and dispersion penalty (TWDP)	68.6.6		M	Yes [ ]
OM5	Transmitter signal to noise ratio	68.6.7		M	Yes [ ]
OM6	Transmitter uncorrelated jitter	68.6.8		M	Yes [ ]
OM7	Comprehensive stressed receiver sensitivity	68.6.9		M	Yes [ ]
OM8	Comprehensive stressed receiver overload	68.6.9		M	Yes [ ]
OM9	Simple stressed receiver sensitivity	68.6.10		O	Yes [ ] No [ ]
OM10	Simple stressed receiver overload	68.6.10		O	Yes [ ] No [ ]
OM11	Receiver jitter tolerance	68.6.11		M	Yes [ ]

68.10.3.5 Safety, installation, environment, and labeling

Item	Feature	Subclause	Value/Comment	Status	Support
SE1	General safety	68.7.1	As 52.10.1. Conforms to IEC-60950-1	M	Yes [ ]
SE2	Laser safety — IEC Hazard Level 1	68.7.1	As 52.10.2. Conform to Hazard Level 1 laser requirements defined in IEC 60825-1 and IEC 60825-2.	M	Yes [ ]
SE3	Electromagnetic interference	68.7.3	As 52.11.1. Comply with applicable local and national codes for the limitation of electromagnetic interference	M	Yes [ ]
SE4	PMD labeling	68.7.4	As 52.12.	M	Yes [ ]

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68.10.3.6 Characteristics of the fiber optic cabling (channel)

Item	Feature	Subclause	Value/Comment	Status	Support
FO1	Characteristics of fiber optic cabling (channel)	68.9	Meet the requirements of	INS:M	Yes [ ] N/A [ ]
FO2	Optical fiber characteristics	68.9.1	Meet the requirements given, including those of Table 68–9	INS:M	Yes [ ] N/A [ ]
FO3	Optical fiber connections	68.9.2	Insertion loss within specification of 68.9.2.1	INS:M	Yes [ ] N/A [ ]
FO4	Patch cords	68.9.3		INS:M	Yes [ ] N/A [ ]

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69. Introduction to Ethernet operation over electrical backplanes

69.1 Overview

69.1.1 Scope

Ethernet operation over electrical backplanes, also referred to as "Backplane Ethernet," combines the IEEE 802.3 Media Access Control (MAC) and MAC Control sublayers with a family of Physical Layers defined to support operation over a modular chassis backplane.

Backplane Ethernet supports the IEEE 802.3 full duplex MAC operating at 1000 Mb/s, 10 Gb/s, 40 Gb/s, or 100 Gb/s providing a bit error ratio (BER) better than or equal to 10^{-12} at the MAC/PLS service interface. The following Physical Layers are supported:

— 1000BASE-KX for 1 Gb/s operation over a single lane
— 10GBASE-KX4 for 10 Gb/s operation over four lanes
— 10GBASE-KR for 10 Gb/s operation over a single lane
— 40GBASE-KR4 for 40 Gb/s operation over four lanes
— 100GBASE-KR4 and 100GBASE-KP4 for 100 Gb/s operation over four lanes

Auto-Negotiation enables PHY selection amongst Backplane Ethernet Physical Layer signaling systems.

Energy Efficient Ethernet (EEE) is optionally supported for all Backplane Ethernet PHYs.

69.1.2 Relationship of Backplane Ethernet to the ISO OSI reference model

Backplane Ethernet couples the IEEE 802.3 MAC to a family of Physical Layers defined for operation over electrical backplanes. The relationships among Backplane Ethernet, the IEEE 802.3 MAC, and the ISO Open System Interconnection (OSI) reference model are shown in Figure 69–1 and Figure 69–2.

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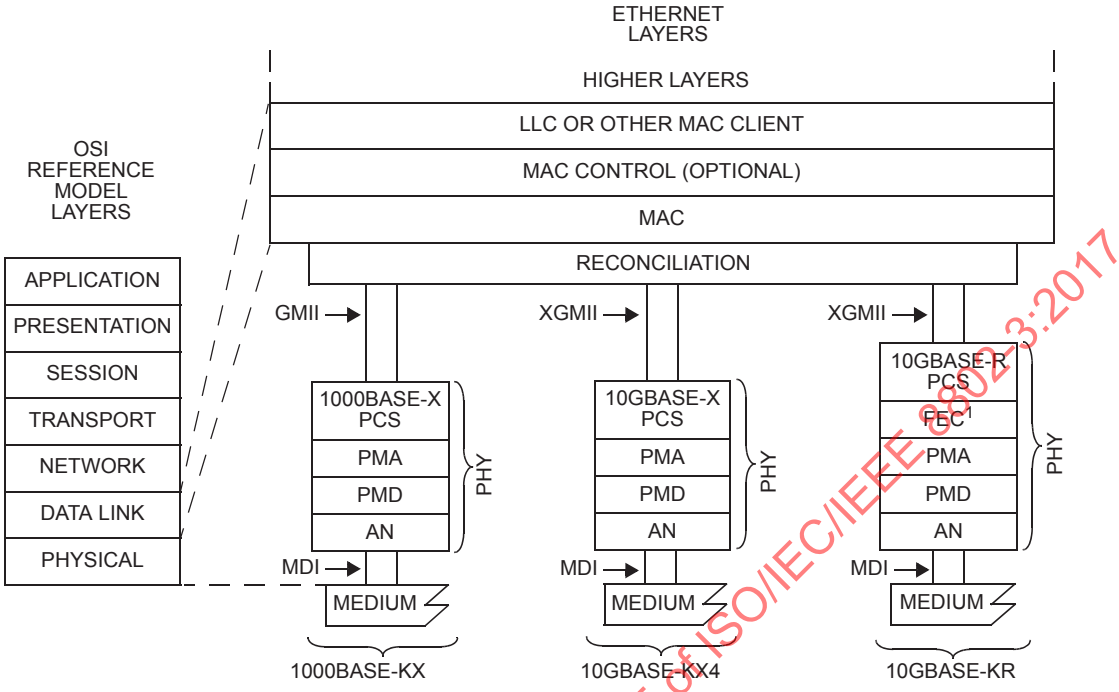

AN = AUTO-NEGOTIATION
FEC = FORWARD ERROR CORRECTION
GMII = GIGABIT MEDIA INDEPENDENT INTERFACE
LLC = LOGICAL LINK CONTROL
MAC = MEDIA ACCESS CONTROL
MDI = MEDIUM DEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT
XGMII = 10 GIGABIT MEDIA INDEPENDENT INTERFACE

NOTE 1—OPTIONAL

Figure 69–1—Architectural positioning of 1 Gb/s and 10 Gb/s Backplane Ethernet

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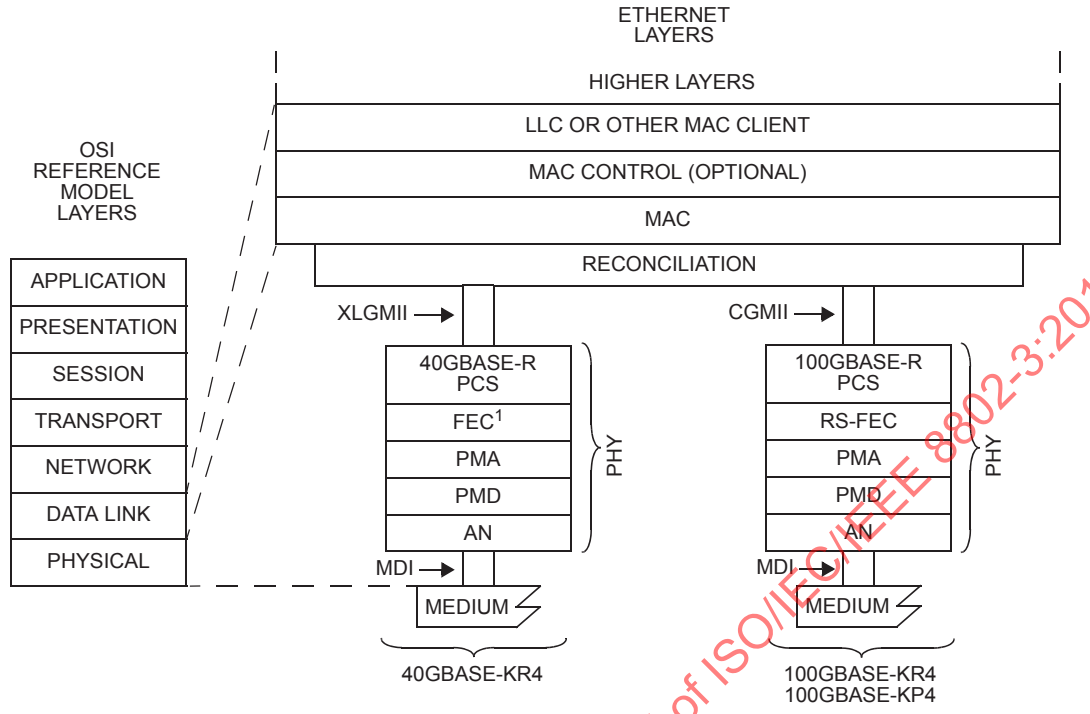

AN = AUTO-NEGOTIATION
CGMII = 100 Gb/s MEDIA INDEPENDENT INTERFACE
FEC = FORWARD ERROR CORRECTION
LLC = LOGICAL LINK CONTROL
MAC = MEDIA ACCESS CONTROL
MDI = MEDIUM DEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT
RS-FEC = REED-SOLOMON FEC
XLGMII = 40 Gb/s MEDIA INDEPENDENT INTERFACE

NOTE 1—OPTIONAL

Figure 69–2—Architectural positioning of 40 Gb/s and 100 Gb/s Backplane Ethernet

It is important to note that, while this specification defines interfaces in terms of bits, octets, and frames, implementers may choose other data-path widths for implementation convenience. The only exceptions are as follows:

a) The GMII, which, when implemented at an observable interconnection point, uses an octet-wide data path as specified in Clause 35.
b) The XGMII, which, when implemented at an observable interconnection point, uses a 4-octet-wide data path as specified in Clause 46.
c) The management interface, when implemented as the MDIO/MDC (Management Data Input/Output, Management Data Clock) at an observable interconnection point, uses a bit-wide data path as specified in Clause 45.
d) The 1000BASE-X PMA service interface, when implemented at an observable interconnection point (TBI), uses the 10-bit-wide data path as specified in Clause 36.
e) The PMA service interface for 10Gb/s serial, when implemented at an observable interconnection point (XSBI), uses the 16-bit-wide data path as specified in Clause 51.
f) The PMA service interface, which, when physically implemented as XLAUI (40 Gb/s Attachment Unit Interface) or as CAUI-4 (100 Gb/s four-lane Attachment Unit Interface) at an observable interconnection port, uses a four-lane data path as specified in Annex 83A or Annex 83D, respectively.

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g) The PMA service interface, which, when physically implemented as CAUI-10 (100 Gb/s ten-lane Attachment Unit Interface) at an observable interconnection port, uses a ten-lane data path as specified in Annex 83A.
h) The MDIs for 1000BASE-KX and 10GBASE-KR use a serial data path while the MDIs for 10GBASE-KX4, 40GBASE-KR4, 100GBASE-KR4, and 100GBASE-KP4 use a four-lane data path.

69.2 Summary of Backplane Ethernet Sublayers

69.2.1 Reconciliation sublayer and media independent interfaces

The Clause 35 RS and GMII, the Clause 46 RS and XGMII, and the Clause 81 RS, XLGMII, and CGMII are employed for the same purpose in Backplane Ethernet, that being the interconnection between the MAC sublayer and the PHY.

69.2.2 Management interface

The MDIO/MDC management interface (Clause 45) is intended to provide an interconnection between MDIO Manageable Devices (MMD) and Station Management (STA) entities.

69.2.3 Physical Layer signaling systems

Backplane Ethernet extends the family of 1000BASE-X Physical Layer signaling systems to include 1000BASE-KX. This embodiment specifies operation at 1 Gb/s over two differential, controlled impedance pairs of traces (one pair for transmit, one pair for receive). This system employs the 1000BASE-X PCS and PMA as defined in Clause 36. The 1000BASE-KX PMD is defined in Clause 70.

Backplane Ethernet also extends the family of 10GBASE-X Physical Layer signaling systems to include 10GBASE-KX4. This embodiment is based on XAUI with 10GBASE-CX4 extensions and specifies 10 Gb/s operation over four differential paths in each direction for a total of eight pairs. This system employs the 10GBASE-X PCS and PMA as defined in Clause 48. The 10GBASE-KX4 PMD is defined in Clause 71.

Backplane Ethernet also extends the family of 10GBASE-R Physical Layer signaling systems to include the 10GBASE-KR. This embodiment specifies 10 Gb/s operation over two differential, controlled impedance pairs of traces (one pair for transmit, one pair for receive). This system employs the 10GBASE-R PCS as defined in Clause 49 and the serial PMA as defined in Clause 51. The 10GBASE-KR PMD is defined in Clause 72. The 10GBASE-KR PHY may optionally include 10GBASE-R Forward Error Correction (FEC), as defined in Clause 74.

Backplane Ethernet also specifies 40GBASE-KR4. This embodiment employs the PCS defined in Clause 82, the PMA defined in Clause 83, and the PMD defined in Clause 84 and specifies 40 Gb/s operation over four differential paths in each direction for a total of eight pairs.

Backplane Ethernet also specifies 100GBASE-KR4 for 100 Gb/s operation using 2-level pulse amplitude modulation (PAM) over four differential signal pairs in each direction for a total of eight pairs where the insertion loss of each pair does not exceed 35 dB at 12.9 GHz. The embodiment of 100GBASE-KR4 employs the PCS defined in Clause 82, the RS-FEC defined in Clause 91, the PMA defined in Clause 83, and the PMD defined in Clause 93.

Backplane Ethernet also specifies 100GBASE-KP4 for 100 Gb/s operation using 4-level PAM over four differential signal pairs in each direction for a total of eight pairs where the insertion loss of each pair does not exceed 33 dB at 7 GHz. The embodiment of 100GBASE-KP4 employs the PCS defined in Clause 82, the RS-FEC defined in Clause 91, and the PMA and PMD defined in Clause 94.

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Table 69–1 and Table 69–2 specify the correlation between nomenclature and clauses. A complete implementation conforming to one or more nomenclatures meets the requirements of the corresponding clauses.

Table 69–1—Nomenclature and clause correlation for 1 Gb/s and 10 Gb/s Backplane Ethernet Physical Layers

Nomenclature	Clause													
	35		36	46		48	49	51	70	71	72	73	74	78
	RS	GMII	1000BASE-X PCS/PMA	RS	XGMII	10GBASE-X PCS/PMA	10GBASE-R PCS	Serial PMA	1000BASE-KX PMD	10GBASE-KX4 PMD	10GBASE-KR PMD	Auto-Negotiation	BASE-R FEC	Energy-Efficient Ethernet (EEE)
1000BASE-KX	M[a]	O[a]	M						M			M		O
10GBASE-KX4				M	O	M				M		M		O
10GBASE-KR				M	O		M	M			M	M	O	O

[a]O = Optional, M = Mandatory

Table 69–2—Nomenclature and clause correlation for 40 Gb/s and 100 Gb/s Backplane Ethernet Physical Layers

Nomenclature	Clause															
	73	74	78	81			82		83		83A		83D	84	91	93	94
	Auto-Negotiation	BASE-R FEC	Energy-Efficient Ethernet (EEE)	RS	XLGMII	CGMII	40GBASE-R PCS	100GBASE-R PCS	40GBASE-R PMA	100GBASE-R PMA	XLAUI	CAUI-10	CAUI-4	40GBASE-KR4 PMD	RS-FEC	100GBASE-KR4 PMD	100GBASE-KP4 PMA/PMD
40GBASE-KR4	M[a]	O[a]	O	M	O		M		M		O			M			
100GBASE-KR4	M		O	M		O		M		M		O	O		M	M	
100GBASE-KP4	M		O	M		O		M				O	O		M		M

[a]O = Optional, M = Mandatory

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69.2.4 Auto-Negotiation

Auto-Negotiation provides a linked device with the capability to detect the abilities (modes of operation) supported by the device at the other end of the link, determine common abilities, and configure for joint operation.

Auto-Negotiation for Backplane Ethernet is based on the Clause 28 definition of Auto-Negotiation for twisted-pair link segments. Auto-Negotiation for Backplane Ethernet utilizes an extended Base Page and Next Page format and modifies the timers to allow rapid convergence. Furthermore, Auto-Negotiation does not utilize Fast Link Pulses (FLPs) for link codeword signaling and instead uses a signaling more suitable for electrical backplanes.

Auto-Negotiation for Backplane Ethernet is defined in Clause 73.

69.2.5 Management

Managed objects, attributes, and actions are defined for all Backplane Ethernet components. These items are defined in Clause 30.

69.2.6 Low-Power Idle

With the optional EEE feature, described in Clause 78, Backplane Ethernet PHYs can achieve lower power consumption during periods of low link utilization. The EEE capabilities are advertised during Auto-Negotiation for Backplane Ethernet. The Backplane Ethernet LPI allows each link direction to enter sleep, refresh, or wake states asymmetric from the other direction.

69.3 Delay constraints

Predictable operation of the MAC Control PAUSE operation (Clause 31, Annex 31B) demands that there be an upper bound on the propagation delays through the network. This implies that MAC, MAC Control sublayer, and PHY implementers must conform to certain delay maxima, and that network planners and administrators conform to constraints regarding the cable topology and concatenation of devices.

Table 69–3 contains the values of maximum sublayer round-trip (sum of transmit and receive) delay for the 1000BASE-KX port types in bit time as specified in 1.4.

Table 69–3—Round-trip delay constraints for 1000BASE-KX

Sublayer	Maximum (bit time)	Notes
MAC Control, MAC, and RS	696	
1000BASE-X PCS, PMA, and PMD	328	See 36.5.1
Medium	16	See 70.4
Total delay	1040[a]	

[a]Per 31B.3.7, a station incorporating the 1000BASE-KX PHY will not begin to transmit a new frame more than two pause_quanta after the reception of a valid PAUSE frame that contains a non-zero value of pause_time, as measured at the MDI.

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Table 69–4 contains the values of maximum sublayer round-trip (sum of transmit and receive) delay for the 10GBASE-KX4 and 10GBASE-KR port types in bit time as specified in 1.4 and pause_quanta as specified in 31B.2.

For 40GBASE-KR4, normative delay specifications may be found in 81.1.4, 82.5, 83.5.4, and 84.4 and also referenced in 80.4

For 100GBASE-KR4, normative delay specifications may be found in 81.1.4, 82.5, 83.5.4, 91.4, and 93.4 and also referenced in 80.4.

For 100GBASE-KP4, normative delay specifications may be found in 81.1.4, 82.5, 91.4, and 94.3.3 and also referenced in 80.4.

.

Table 69–4—Round-trip delay constraints for 10GBASE-KX4 and 10GBASE-KR

Sublayer	Maximum (bit time)	Maximum (pause_quanta)	Notes
MAC Control, MAC, and RS	8192	16	See 46.1.4
XGXS and XAUI	4096	8	Round-trip of 2 XGXS and trace for both directions, see 47.2.2
10GBASE-X PCS and PMA	2048	4	See 48.5
10GBASE-R PCS	3584	7	See 49.2.15
10GBASE-R FEC	6144	12	See 74.6
10GBASE-KX4 PMD[a]	512	1	See 71.3
10GBASE-KR PMA and PMD[a]	1024	2	See 72.4

[a]The 10GBASE-KX4 PMD and 10GBASE-KR PMA and PMD delays include the delay associated with the backplane medium.

69.4 State diagrams

In the case of any ambiguity between the text and the state diagrams, the state diagrams take precedence.

The conventions of 1.2 are adopted, along with the extensions listed in 21.5.

69.5 Protocol implementation conformance statement (PICS) proforma

The supplier of a protocol implementation that is claimed to conform to any part of IEEE Std 802.3, Clause 70 through Clause 74, Clause 84, Clause 91, Clause 93, Clause 94, and related annexes demonstrates compliance by completing a protocol implementation conformance statement (PICS) proforma.

A completed PICS proforma is the PICS for the implementation in question. The PICS is a statement of which capabilities and options of the protocol have been implemented. A PICS is included at the end of each clause as appropriate. Each of the Backplane Ethernet PICS uses the notation and conventions specified in 21.6.

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70. Physical Medium Dependent sublayer and baseband medium, type 1000BASE-KX

70.1 Overview

This clause specifies the 1000BASE-KX PMD and baseband medium. When forming a complete PHY, a PMD shall be combined with the appropriate sublayers (see Table 70–1), and with the management functions that are optionally accessible through the management interface defined in Clause 45.

Table 70–1—Physical Layer clauses associated with the 1000BASE-KX PMD

Associated clause	1000BASE-KX
35—GMII[a]	Optional
36—1000BASE-X PCS/PMA	Required
73—Auto-Negotiation for Backplane Ethernet	Required
78—Energy-Efficient Ethernet	Optional

[a]The GMII is an optional interface. However, if the GMII is not implemented, a conforming implementation must behave functionally as though the RS and GMII were present.

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The Clause 36 PCS/PMA when used with 1000BASE-KX PMD shall support full duplex operation only.

A 1000BASE-KX PHY with the optional Energy-Efficient Ethernet (EEE) capability may optionally enter the Low Power Idle (LPI) mode to conserve energy during periods of low link utilization. The “Assert LPI” request at the GMII is encoded in the transmitted symbols. Detection of LPI signaling in the received symbols is indicated as “Assert LPI” at the GMII. Upon the detection of “Assert LPI” at the GMII, an energy-efficient 1000BASE-KX PHY continues transmitting for a predefined period, then ceases transmission and deactivates transmit functions to conserve energy. The PHY periodically transmits during this quiet period to allow the remote PHY to refresh its receiver state (e.g., timing recovery, adaptive filter coefficients) and thereby track long-term variations in the timing of the link or the underlying channel characteristics. If, during the quiet or refresh periods, normal interframes resume at the GMII, the PHY reactivates transmit functions and initiates transmission. This transmission will be detected by the remote PHY, causing it to also exit the LPI mode.

70.2 Physical Medium Dependent (PMD) service interface

The 1000BASE-KX PMD performs the following three functions in support of the matching service interface primitives of 38.1.1: Transmit, Receive, and Signal Detect.

The PMD provides the following service interface signals if EEE is supported:

PMD_RXQUIET.request(rx_quiet)
PMD_TXQUIET.request(tx_quiet)

These messages signals are defined for the PCS in 36.2.5.1.6.

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70.2.1 PMD_RXQUIET.request

This primitive is generated by the PCS Receive Process when EEE is supported to indicate that the input signal is quiet and the PMA and PMD receiver may go into low power mode. See 36.2.4.13. When EEE is not supported, the primitive is never invoked and the PMD behaves as if rx_quiet = FALSE.

70.2.1.1 Semantics of the service primitive

PMD_RXQUIET.request (rx_quiet)

The rx_quiet parameter takes on one of two values: TRUE or FALSE.

70.2.1.2 When generated

The PCS generates this primitive to request the appropriate PMD receive LPI state.

70.2.1.3 Effect of receipt

This variable is from the receive process of the PCS to control the power-saving function of the local PMD receiver. The 1000BASE-KX PHY receiver should put unused functional blocks into a low power state to save energy.

70.2.2 PMD_TXQUIET.request

This primitive is generated by the PCS Transmit Process when EEE is supported to indicate that the PMA and PMD transmit functions may go into a low power mode and to disable the PMD transmitter. See 70.6.5. When EEE is not supported, the primitive is never invoked and the PMD behaves as if tx_quiet = FALSE.

70.2.2.1 Semantics of the service primitive

PMD_TXQUIET.request (tx_quiet)

The tx_quiet parameter takes on one of two values: TRUE or FALSE.

70.2.2.2 When generated

The PCS generates this primitive to request the appropriate PMD transmit LPI state.

70.2.2.3 Effect of receipt

This primitive affects operation of the PMD Transmit disable function as described in 70.6.5. The 1000BASE-KX PHY transmitter should put unused functional blocks into a lower power state to save energy.

70.3 PCS requirements for Auto-Negotiation (AN) service interface

The PCS associated with this PMD shall support the AN service interface primitive AN_LINK.indication as defined in 73.9. (See 36.2.5.2.7.)

70.4 Delay constraints

Predictable operation of the MAC Control PAUSE operation (Clause 31, Annex 31B) demands that there be an upper bound on the propagation delays through the network. This implies that MAC, MAC Control

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sublayer, and PHY implementers must consider the delay maxima, and that network planners and administrators consider the delay constraints regarding the physical topology and concatenation of devices. A description of overall system delay constraints and the definitions for bit-times and pause_quanta can be found in 69.3

The sum of transmit and receive delays contributed by the 1000BASE-KX PCS, PMA, and PMD shall be no more than 328 bit times. It is assumed that the round-trip delay through the medium is 16 bit times.

70.5 PMD MDIO function mapping

The optional MDIO capability described in Clause 45 defines several variables that provide control and status information for and about the PMD. If the MDIO is implemented, it shall map MDIO control variables to PMD control variables as shown in Table 70–2, and MDIO status variables to PMD status variables as shown in Table 70–3.

Table 70–2—MDIO/PMD control variable mapping

MDIO control variable	PMA/PMD register name	Register/ bit number	PMD control variable
Reset	Control register 1	1.0.15	PMD_reset
PMD Transmit Disable	1000BASE-KX control register	1.160.0	PMD_transmit_disable

Table 70–3—MDIO/PMD status variable mapping

MDIO status variable	PMA/PMD register name	Register/ bit number	PMD status variable
Fault	Status register 1	1.1.7	PMD_fault
Transmit fault ability	1000BASE-KX status register	1.161.13	PMD_Transmit_fault_ability
Receive fault ability	1000BASE-KX status register	1.161.12	PMD_Receive_fault_ability
Transmit fault	1000BASE-KX status register	1.161.11	PMD_transmit_fault
Receive fault	1000BASE-KX status register	1.161.10	PMD_receive_fault
PMD transmit disable ability	1000BASE-KX status register	1.161.8	PMD_transmit_disable_ability
Signal detect from PMD	1000BASE-KX status register	1.161.0	PMD_signal_detect

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70.6 PMD functional specifications

The 1000BASE-KX PMD performs the following three functions in support of the matching service interface primitives of 38.1.1: Transmit, Receive, and Signal Detect (see service interface definition in 70.2).

70.6.1 Link block diagram

For purposes of system conformance, the PMD sublayer is standardized at test points TP1 and TP4 as shown in Figure 70–1. The transmitter and receiver blocks include all off-chip components associated with the

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respective block. For example, external AC-coupling capacitors, if required, are to be included in the receiver block.

The electrical path from the transmitter block to TP1, and from TP4 to the receiver block, will affect link performance and the measured values of electrical parameters used to verify conformance to this specification. It is therefore recommended that this path be carefully designed.

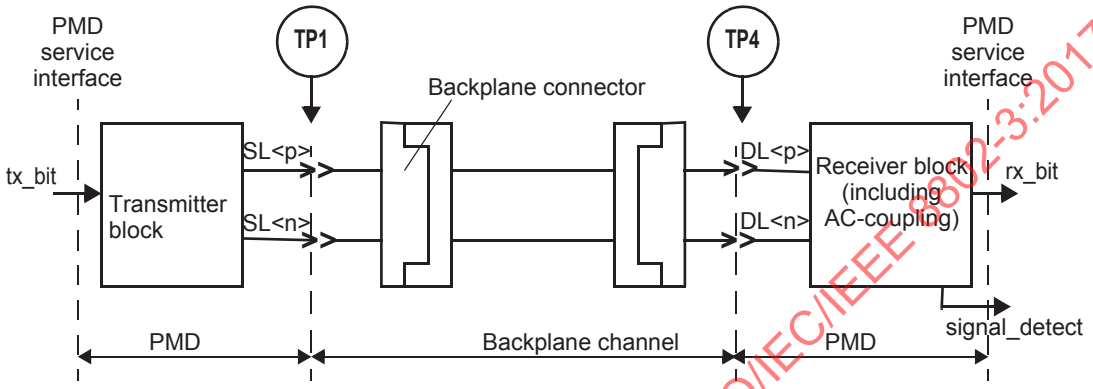

Figure 70–1—Link block diagram

70.6.2 PMD transmit function

The PMD Transmit function shall convey the bits requested by the PMD service interface message PMD_UNITDATA.request(tx_bit) to the MDI according electrical specifications in 70.7.1. A positive output voltage of SL<p> minus SL<n> (differential voltage) shall correspond to tx_bit = ONE.

70.6.3 PMD receive function

The PMD Receive function shall convey the bits received at the MDI in accordance with the electrical specifications of 70.7.2 to the PMD service interface using the message PMD_UNITDATA.indication(rx_bit). A positive input voltage of DL<p> minus DL<n> (differential voltage) shall correspond to rx_bit = ONE.

70.6.4 PMD signal detect function

For 1000BASE-KX operation PMD signal detect is mandatory if EEE is supported. When EEE is not supported, the PMD signal detect is optional for 1000BASE-KX and its definition is beyond the scope of this specification. When PMD signal detect is not implemented, the value of SIGNAL_DETECT shall be set to OK for purposes of management and signaling of the primitive.

If EEE is supported, a local PMD signal detect function shall report to the PMD service interface using the message PMD_SIGNAL.indication(SIGNAL_DETECT). This message is signaled continuously. For EEE, the SIGNAL_DETECT parameter can take on one of two values, OK or FAIL, indicating whether the PMD is detecting electrical energy at the receiver (OK) or not (FAIL). When SIGNAL_DETECT = FAIL, PMD_UNITDATA.indication is undefined. The signal energy from a compliant transmitter shall set SIGNAL_DETECT to OK within 750 ns when transitioning from LPI quiet to active and set SIGNAL_DETECT to FAIL within 750 ns when transitioning from active to LPI quiet.

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70.6.5 PMD transmit disable function

The PMD_transmit_disable function is mandatory if EEE is supported and is otherwise optional. When implemented, it allows the transmitter to be disabled with a single variable.

a) When the PMD_transmit_disable variable is set to ONE, this function shall turn off the transmitter such that it drives a constant level (i.e., no transitions) and does not exceed the maximum differential peak-to-peak output voltage specified in Table 70–4.
b) If a PMD_fault (70.6.7) is detected, then the PMD may turn off the electrical transmitter.
c) Loopback, as defined in 70.6.6, shall not be affected by PMD_transmit_disable.
d) For EEE capability, the PMD_transmit_disable function shall turn off the transmitter after tx_quiet is asserted within the time and voltage level specified in 70.7.1.5. The PMD_transmit_disable function shall turn on the transmitter after tx_quiet is de-asserted within a time and voltage level specified in 70.7.1.5.

70.6.6 Loopback mode

Loopback mode shall be provided for the 1000BASE-KX PMA/PMD by the transmitter and receiver of a device as a test function to the device. When loopback mode is selected, transmission requests passed to the transmitter are shunted directly to the receiver, overriding any signal detected by the receiver on its attached link. Transmitter operation shall be independent of loopback mode. A device must be explicitly placed in loopback mode because loopback mode is not the normal mode of operation of a device. The method of implementing loopback mode is not defined by this standard.

Control of the loopback function is specified in 45.2.1.1.5.

NOTE 1—The signal path that is exercised in the loopback mode is implementation specific, but it is recommended that this signal path encompass as much of the circuitry as is practical. The intention of providing this loopback mode of operation is to permit diagnostic or self-test functions to test the transmit and receive data paths using actual data. Other loopback signal paths may also be enabled independently using loopback controls within other devices or sublayers.

NOTE 2—Placing a network port into loopback mode can be disruptive to a network.

70.6.7 PMD fault function

If the MDIO is implemented, and the PMD has detected a local fault, the PMD shall set PMD_fault to ONE; otherwise, the PMD shall set PMD_fault to ZERO.

70.6.8 PMD transmit fault function

If the MDIO is implemented, and the PMD has detected a local fault on the transmitter, the PMD shall set the PMD_transmit_fault variable to ONE; otherwise, the PMD shall set PMD_transmit_fault to ZERO.

70.6.9 PMD receive fault function

If the MDIO is implemented, and the PMD has detected a local fault on the receiver, the PMD shall set the PMD_receive_fault variable to ONE; otherwise, the PMD shall set PMD_receive_fault to ZERO.

70.6.10 PMD LPI function

The PMD LPI function responds to the transitions between Active, Sleep, Quiet, Refresh, and Wake states via the PMD_TXQUIET and PMD_RXQUIET requests. Implementation of the function is optional. EEE capabilities and parameters are advertised during the Backplane Auto-negotiation as described in 45.2.7.13. The transmitter on the local device informs the link partner's receiver when to sleep, refresh, and wake. The

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local receiver's transitions are controlled by the link partner's transmitter and change independently from the local transmitter's states and transitions.

The transmitter sends /LI/ ordered sets during the sleep and refresh states, disables the transmitter during quiet, and forwards /I/ during the wake phase.

If EEE is supported, the PMD transmit function enters into a low power mode when tx_quiet is set to TRUE and exits when tx_quiet is set to FALSE. While tx_quiet is TRUE the PMD transmitter functional blocks should be deactivated to conserve energy. The PMD receive function enters into a low power mode when rx_quiet is set to TRUE and exits when rx_quiet is set to FALSE. While rx_quiet is TRUE the PMD receiver functional blocks should be deactivated to conserve energy.

70.7 1000BASE-KX electrical characteristics

70.7.1 Transmitter characteristics

Transmitter characteristics at TP1 are summarized in Table 70–4 and detailed in 70.7.1.1 through 70.7.1.9.

Table 70–4—Transmitter characteristics for 1000BASE-KX

Parameter	Subclause reference	Value	Units
Signaling speed	70.7.1.3	1.25 ± 100 ppm	GBd
Differential peak-to-peak output voltage	70.7.1.5	800 to 1600	mV
Differential peak-to-peak output voltage (max.) with TX disabled	70.6.5	30	mV
DC common-mode voltage limits	70.7.1.5	–0.4 to 1.9	V
Common-mode voltage deviation (max) during LPI	70.7.1.5	150	mV
Differential output return loss (min.)	70.7.1.6	[See Equation (70–1) and Equation (70–2)]	dB
Transition time[a] (20%–80%)	70.7.1.7	60 to 320	ps
Output jitter (max. peak-to-peak) Deterministic jitter[b] Random jitter Total jitter[c]	70.7.1.8	 0.10 0.15 0.25	 UI UI UI

[a]Transition time parameters are recommended values, not compliance values.
[b]Deterministic jitter is already incorporated into the differential output template.
[c]At BER 10^{-12}.

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70.7.1.1 Test fixtures

The test fixture of Figure 70–2, or its functional equivalent, is required for measuring the transmitter specifications described in 70.7.1, with the exception of return loss.

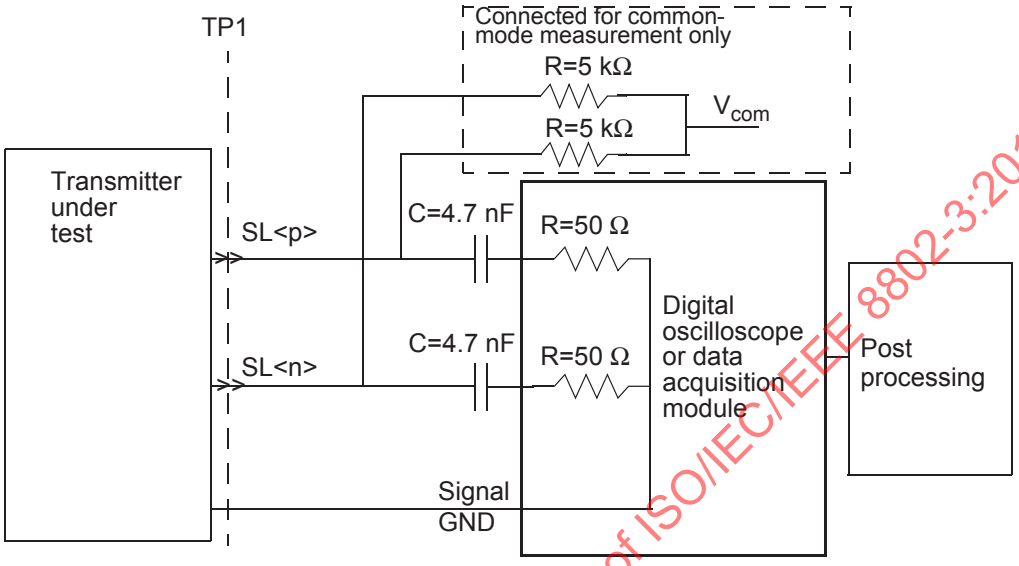

Figure 70–2—Transmit test fixture for 1000BASE-KX

70.7.1.2 Test fixture impedance

The differential load impedance applied to the transmitter output by the test fixture depicted in Figure 70–2 shall be 100 Ω with a return loss greater than 20 dB from 50 MHz to 625 MHz.

70.7.1.3 Signaling speed

The 1000BASE-KX signaling speed shall be 1.25 GBd ± 100 ppm.

70.7.1.4 Differential output eye mask

The transmitter differential output signal is defined at TP1, as shown in Figure 70–2. The transmitter output waveform shall fall within the eye mask shown in Figure 70–3 for the jitter test frame defined in 59.7.1. Voltage and time coordinates for mask points on Figure 70–3 are given in Table 70–5.

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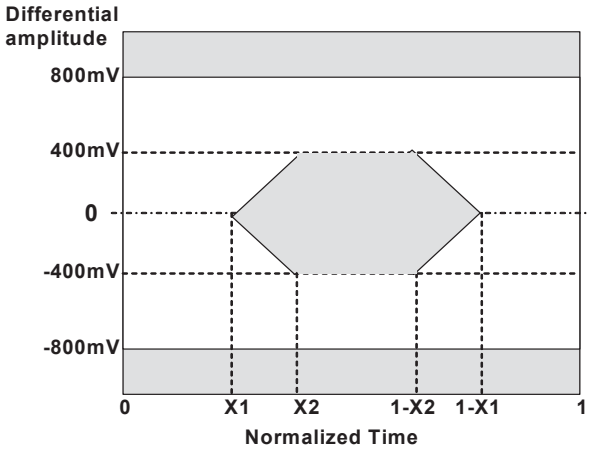

Figure 70–3—Absolute eye diagram mask at TP1 for 1000BASE-KX

Table 70–5—Transmitted eye mask at TP1 for 1000BASE-KX

Symbol	Value	Units
X1	0.125	Unit intervals (UI)
X2	0.325	Unit intervals (UI)

70.7.1.5 Output amplitude

While transmitting the test pattern specified in 36A.2, the transmitter differential peak-to-peak output voltage shall be between 800 mV and 1600 mV. See Figure 70–4 for an illustration of the definition of differential peak-to-peak output voltage. DC-referenced voltage levels are not defined since the receiver is AC-coupled. The common-mode voltage of SL<p> and SL<n> shall be between –0.4 V and 1.9 V with respect to signal ground as measured at V_{com} in Figure 70–2.

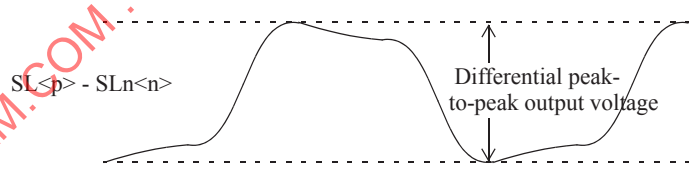

Figure 70–4—Transmitter differential peak-to-peak output voltage definition

NOTE—SL<p> and SL<n> are the positive and negative sides of the differential signal pair respectively.

For EEE capability, the transmitter's differential peak-to-peak output voltage shall be less than 30 mV within 500 ns of tx_quiet being asserted. Furthermore, the transmitters differential peak-to-peak output voltage shall be greater than 720 mV within 500 ns of tx_quiet being de-asserted. The transmitter output shall be fully compliant within 5 µs after tx_quiet is set to FALSE. During LPI, the common-mode shall be maintained to within ±150 mV of the pre-LPI value.

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70.7.1.6 Differential output return loss

For frequencies from 50 MHz to 1250 MHz, the differential return loss, in dB with f in MHz, of the transmitter shall meet the requirements of Equation (70–1) and Equation (70–2). This output impedance requirement applies to all valid output levels. The reference impedance for differential return loss measurements shall be 100 Ω.

$$\mathrm{ReturnLoss}(f) \geq 10 \tag{70–1}$$

for 50 MHz ≤ f < 625 MHz and

$$\mathrm{ReturnLoss}(f) \geq 10 - 10 \times \log\left(\frac{f}{625}\right) \tag{70–2}$$

for 625 MHz ≤ f ≤ 1250 MHz.

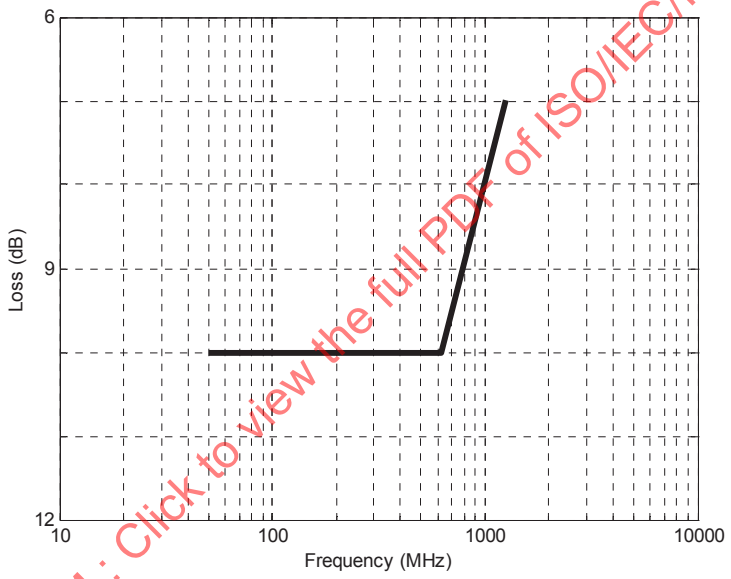

Figure 70–5—Differential return loss

70.7.1.7 Transition time

The rising edge transition time is recommended to be no less than 60 ps as measured at the 20% and 80% levels of the peak-to-peak differential value of the waveform using the high-frequency test pattern of 36A.1.

The falling edge transition time is recommended to be no less than 60 ps as measured at the 80% and 20% levels of the peak-to-peak differential value of the waveform using the high-frequency test pattern of 36A.1.

The maximum transition time is recommended to be no more than 320 ps.

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70.7.1.8 Transmit jitter

The transmitter shall have a maximum total jitter of 0.25 UI peak-to-peak and a maximum deterministic component of 0.10 UI peak-to-peak. Jitter specifications include all but 10^{-12} of the jitter population. Transmit jitter test requirements are specified in 70.7.1.9.

70.7.1.9 Transmit jitter test requirements

Transmit jitter is defined with respect to a test procedure resulting in a BER bathtub curve such as that described in Annex 48B. For the purpose of jitter measurement, the effect of a single-pole high-pass filter with a 3 dB point at 750 kHz is applied to the jitter. The data pattern for jitter measurements shall be the jitter test frame described in 59.7.1. Crossing times are defined with respect to the mid-point (0 V) of the AC-coupled differential signal.

70.7.2 Receiver characteristics

Receiver characteristics at TP4 are summarized in Table 70–6 and detailed in 70.7.2.1 through 70.7.2.5.

Table 70–6—Receiver characteristics for 1000BASE-KX

Parameter	Subclause reference	Value	Units
Bit error ratio	70.7.2.1	10^{-12}	
Signaling speed	70.7.2.2	1.25 ± 100 ppm	GBd
Receiver coupling	70.7.2.3	AC	
Differential input peak-to-peak amplitude (max.)	70.7.2.4	1600	mV
Differential input return loss (min.)	70.7.2.5	[See Equation (70–1) and Equation (70–2)]	dB

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70.7.2.1 Receiver interference tolerance

The receiver interference tolerance shall be measured as described in Annex 69A with the parameters specified in Table 70–7. The data pattern for the interference tolerance test shall be the jitter pattern test frame as defined in 59.7.1. The receiver shall satisfy the requirements for interference tolerance specified in Annex 69A.

Table 70–7—1000BASE-KX interference tolerance parameters

Parameter	Value	Units
Target BER	10^{-12}	
m_{TC}[a] (min.)	1.0	
Amplitude of broadband noise (min. RMS)	8.6	mV
Applied transition time (20%–80%, min.)	320	ps
Applied sinusoidal jitter (min. peak-to-peak)	0.10	UI
Applied random jitter (min. peak-to-peak)[b]	0.15	UI
Applied duty cycle distortion (min. peak-to-peak)	0.0	UI

[a]m_{TC} is defined in Equation (69A–6) of Annex 69A.
[b]Applied random jitter is specified at a BER of 10^{-12}.

70.7.2.2 Signaling speed range

A 1000BASE-KX receiver shall comply with the requirements of Table 70–7 for any signaling speed in the range 1.25 GBd ± 100 ppm. The corresponding unit interval is nominally 800 ps.

70.7.2.3 AC-coupling

The receiver shall be AC-coupled to the backplane to allow for maximum interoperability between various PMD components. AC-coupling is considered to be part of the receiver for the purposes of this specification unless explicitly stated otherwise. It should be noted that there may be various methods for AC-coupling in actual implementations.

NOTE—It is recommended that the maximum value of the coupling capacitors be limited to 4.7 nF. This will limit the inrush currents to the receiver that could damage the receiver circuits when repeatedly connected to transmit modules with a higher voltage level.

70.7.2.4 Input signal amplitude

Receivers shall accept differential input signal peak-to-peak amplitudes produced by compliant transmitters connected without attenuation to the receiver, and still meet the BER requirement specified in 70.7.2.1. Note that this may be larger than the 1600 mV differential maximum of 70.7.1.5 due to the actual transmitter output and receiver input impedances. The input impedance of a receiver can cause the minimum signal into a receiver to differ from that measured when the receiver is replaced with a 100 Ω test load. Since the receiver is AC-coupled, the absolute voltage levels with respect to the receiver ground are dependent on the receiver implementation.

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70.7.2.5 Differential input return loss

For frequencies from 50 MHz to 1250 MHz, the differential return loss, in dB with f in MHz, of the receiver shall meet the requirements of Equation (70–1) and Equation (70–2). This return loss requirement applies to all valid input levels. The reference impedance for differential return loss measurements shall be 100 Ω.

70.8 Interconnect characteristics

Informative interconnect characteristics for 1000BASE-KX are provided in Annex 69B.

70.9 Environmental specifications

70.9.1 General safety

All equipment that meets the requirements of this standard shall conform to applicable sections (including isolation requirements) of IEC 60950-1.

70.9.2 Network safety

The designer is urged to consult the relevant local, national, and international safety regulations to ensure compliance with the appropriate requirements.

70.9.3 Installation and maintenance guidelines

It is recommended that sound installation practice, as defined by applicable local codes and regulations, be followed in every instance in which such practice is applicable.

70.9.4 Electromagnetic compatibility

A system integrating the 1000BASE-KX PHY shall comply with applicable local and national codes for the limitation of electromagnetic interference.

70.9.5 Temperature and humidity

A system integrating the 1000BASE-KX PHY is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

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70.10 Protocol implementation conformance statement (PICS) proforma for Clause 70, Physical Medium Dependent (PMD) sublayer and baseband medium, type 1000BASE-KX[26]

70.10.1 Introduction

The supplier of a protocol implementation that is claimed to conform to IEEE Std 802.3, Clause 70, Physical Medium Dependent (PMD) sublayer and baseband medium type 1000BASE-KX, shall complete the following protocol implementation conformance statement (PICS) proforma. A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

70.10.2 Identification

70.10.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

70.10.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 70, Physical Medium Dependent (PMD) sublayer and baseband medium type 1000BASE-KX
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	
Date of Statement	

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[26]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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70.10.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
GMII	GMII	70.1, 35	Interface is supported	O	Yes [ ] No [ ]
PCS	Support of 1000BASE-X PCS/PMA	70.1, 36		M	Yes [ ] No [ ]
AN	Auto-Negotiation for Backplane Ethernet	70.1, 73	Device implements Auto-Negotiation for Backplane Ethernet	M	Yes [ ]
FD	Full duplex operation	70.1	Clause 36 PCS/PMA when used with 1000GBASE-KX supports full-duplex operation only	M	Yes [ ]
DC	Delay Constraints	70.4	Device conforms to delay constraints	M	Yes [ ]
LPI	LPI	70.6.10	Capable of LPI	O	Yes [ ] No [ ]
*MD	MDIO interface	70.5	Device implements MDIO	O	Yes [ ] No [ ]
*SD	Signal Detect Generation	70.6.4	Signal detect implemented	O	Yes [ ] No [ ]
*TD	PMD_transmit_disable	70.6.5		O	Yes [ ] No [ ]

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70.10.4 PICS proforma tables for Clause 70, Physical Medium Dependent (PMD) sublayer and baseband medium, type 1000BASE-KX

70.10.4.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FS1	Transmit function	70.6.2	Conveys bits from PMD service interface to MDI	M	Yes [ ]
FS2	Transmitter signal	70.6.2	A positive differential voltage corresponds to tx_bit = ONE	M	Yes [ ]
FS3	Receive function	70.6.3	Conveys bits from MDI to PMD service interface	M	Yes [ ]
FS4	Receiver signal	70.6.3	A positive differential voltage corresponds to rx_bit = ONE	M	Yes [ ]
FS5	PMD Signal Detect function	70.6.4	Continuously reported OK via PMD_SIGNAL.indication (SIGNAL_DETECT)	!SD:M	Yes [ ] No [ ]
FS6	PMD Signal Detect during LPI	70.6.4	Indicate signal energy during LPI	LPI:M	Yes [ ] N/A [ ]
FS7	Transmit Disable during LPI	70.6.5	Disable transmitter during tx_quiet	LPI:M	Yes [ ] N/A [ ]
FS8	Signal Detect for EEE	70.6.4	Transition timing to set SIGNAL_DETECT	LPI:M	Yes[ ] N/A [ ]
FS9	Transmit Disable	70.6.5	Disables Transmitter when PMD_Transmit_disable set to ONE	TD:M	Yes [ ] N/A [ ]
FS10	PMD_fault	70.6.5	Transmit disabled if detected	TD:O	Yes [ ] No [ ] N/A [ ]
FS11	PMD_transmit_disable	70.6.5	Loopback function not affected	TD:M	Yes [ ] N/A [ ]
FS12	tx_quiet disabled transmitter	70.7.1	Disables Transmitter when tx_quiet is asserted as specified in 70.7.1.5	LPI:M	Yes [ ] N/A [ ]
FS13	Loopback Function	70.6.6	Loopback function provided	M	Yes [ ]
FS14	Loopback affect on Transmitter	70.6.6	Loopback function does not disable transmitter	M	Yes [ ]

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70.10.4.2 Management functions

Item	Feature	Subclause	Value/Comment	Status	Support
MF1	MDIO Variable Mapping	70.5	Per Table 70–2 and Table 70–3	MD:M	Yes [ ] N/A [ ]
MF2	PMD_fault function	70.6.7	Sets PMD_fault to a logical 1 if any local fault is detected; otherwise, set to 0	MD:M	Yes [ ] N/A [ ]
MF3	PMD_transmit_fault function	70.6.8	Sets PMD_transmit_fault to a logical 1 if any local fault is detected on the transmit path; otherwise, set to 0	MD:M	Yes [ ] N/A [ ]
MF4	PMD_receive_fault function	70.6.9	Sets PMD_receive_fault to a logical 1 if any local fault is detected on the receive path; otherwise, set to 0	MD:M	Yes [ ] N/A [ ]

70.10.4.3 Transmitter electrical characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
TC1	100 Ω differential test fixture	70.7.1.2	With return loss > 20 dB from 50 MHz to 625 MHz	M	Yes [ ]
TC2	Signaling speed	70.7.1.3	1.25 GBd ± 100ppm	M	Yes [ ]
TC3	Output waveform within template per Figure 70–3	70.7.1.4		M	Yes [ ]
TC4	Differential peak-to-peak output voltage	70.7.1.5	Between 800 mV and 1600 mV while transmitting test pattern specified in 36A.2	M	Yes [ ]
TC5	Common-mode output voltage	70.7.1.5	Between –0.4 V and 1.9 V	M	Yes [ ]
TC6	Output Return Loss	70.7.1.6	Per Equation (70–1) and Equation (70–2)	M	Yes [ ]
TC7	Reference Impedance	70.7.1.6	100 Ω for differential return loss measurements	M	Yes [ ]
TC8	Transmit jitter, peak-to-peak	70.7.1.8	Max TJ of 0.25 UI. Max DJ of 0.10 UI	M	Yes [ ]
TC9	Output Amplitude LPI voltage	70.7.1.5	Less than 30 mV within 500 ns of tx_quiet	LPI:M	Yes [ ] N/A [ ]
TC10	Output Amplitude ON voltage	70.7.1.5	Greater than 720 mV within 500 ns of tx_quiet de-asserted	LPI:M	Yes [ ] N/A [ ]
TC11	Jitter test patterns	70.7.1.9	Jitter test frame per 59.7.1	M	Yes [ ]

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70.10.4.4 Receiver electrical characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
RC1	Receiver interference tolerance measurement method	70.7.2.1	Per Annex 69A with parameters specified in Table 70–7	M	Yes [ ]
RC2	Receiver interference tolerance test pattern	70.7.2.1	Per 70.7.2.1	M	Yes [ ]
RC3	Receiver interference tolerance requirements	70.7.2.1	Satisfy requirements per Annex 69A	M	Yes [ ]
RC4	Input signaling speed in the range of 1.25 GBd ± 100ppm	70.7.2.2	Receiver meets requirements of Table 70–7	M	Yes [ ]
RC5	Receiver AC-coupled	70.7.2.3		M	Yes [ ]
RC6	Input signal amplitude	70.7.2.4	BER still met when compliant transmitter is connected with no attenuation	M	Yes [ ]
RC7	Differential input return loss	70.7.2.5	Per Equation (70–1) and Equation (70–2)	M	Yes [ ]
RC8	Reference Impedance	70.7.2.5	100 Ω for differential return loss measurements	M	Yes [ ]

70.10.4.5 Environmental and safety specifications

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	General safety	70.9.1	Conforms to IEC 60950-1	M	Yes [ ]
ES2	Electromagnetic compatibility	70.9.4	Comply with applicable local and national codes	M	Yes [ ]

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71. Physical Medium Dependent sublayer and baseband medium, type 10GBASE-KX4

71.1 Overview

This clause specifies the 10GBASE-KX4 PMD and the baseband medium. When forming a complete PHY, a PMD shall be connected to the appropriate sublayers (see Table 71–1), and with the management functions that are optionally accessible through the management interface defined in Clause 45, or equivalent.

The XAUI, defined by Clause 47, is intended for chip-to-chip applications for lengths up to approximately 0.5 m. 10GBASE-KX4 is intended for backplane applications up to 1 m in length.

Table 71–1—Physical Layer clauses associated with the 10GBASE-KX4 PMD

Associated clause	10GBASE-KX4
46—XGMII[a]	Optional
47—XGXS and XAUI	Optional
48—10GBASE-X PCS/PMA	Required
73—Auto-Negotiation for Backplane Ethernet	Required
78—EEE	Optional

[a]The XGMII is an optional interface. However, if the XGMII is not implemented, a conforming implementation must behave functionally as though the RS and XGMII were present.

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A 10GBASE-KX4 PHY with the optional Energy-Efficient Ethernet (EEE) capability may optionally enter the Low Power Idle (LPI) mode to conserve energy during periods of low link utilization. The “Assert LPI” request at the XGMII is encoded in the transmitted symbols. Detection of LPI signaling in the received symbols is indicated as “Assert LPI” at the XGMII. Upon the detection of “Assert LPI” at the XGMII, an energy-efficient 10GBASE-KX4 PHY continues transmitting for a predefined period, then ceases transmission and deactivates transmit functions to conserve energy. The PHY periodically transmits during this quiet period to allow the remote PHY to refresh its receiver state (e.g., timing recovery, adaptive filter coefficients) and thereby track long-term variations in the timing of the link or the underlying channel characteristics. If, during the quiet or refresh periods, normal interframes resume at the XGMII, the PHY reactivates transmit functions and initiates transmission. This transmission will be detected by the remote PHY, causing it to also exit the LPI mode.

71.2 Physical Medium Dependent (PMD) service interface

The 10GBASE-KX4 PMD utilizes the PMD service interface defined in 53.1.1.

The following primitives are defined on the PMD Service Interface when EEE is supported:

PMD_RXQUIET.request(rx_quiet)
PMD_TXQUIET.request(tx_quiet)

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These messages are defined for the PCS in 48.2.6.1.7.

71.2.1 PMD_RXQUIET.request

This primitive is generated by the PCS Receive Process when EEE is supported to indicate that the input signal is quiet and the PMA and PMD receiver may go into a low power mode. When EEE is not supported, the primitive is never invoked and the PMD behaves as if rx_quiet = FALSE.

71.2.1.1 Semantics of the service primitive

PMD_RXQUIET.request (rx_quiet)

The rx_quiet parameter takes on one of two values: TRUE or FALSE.

71.2.1.2 When generated

The PCS generates this primitive to request the appropriate PMD receive LPI state.

71.2.1.3 Effect of receipt

This variable is from the Receive process of the PCS to control the power-saving function of the local receiver. The 10GBASE-KX4 PHY receiver should put unused functional blocks into a low power state to save energy.

71.2.2 PMD_TXQUIET.request

This primitive is generated by the PCS Transmit Process when EEE is supported to indicate that the PMA and PMD transmit functions may go into a low power mode and to disable the PMD transmitter. When EEE is not supported, the primitive is never invoked and the PMD behaves as if tx_quiet = FALSE.

71.2.2.1 Semantics of the service primitive

PMD_TXQUIET.request (tx_quiet)

The tx_quiet parameter takes on one of two values: TRUE or FALSE.

71.2.2.2 When generated

The PCS generates this primitive to request the appropriate PMD transmit LPI state.

71.2.2.3 Effect of receipt

This primitive affects operation of the PMD Transmit disable function as described in 71.6.6. The 10GBASE-KX4 PHY transmitter should put unused functional blocks into a lower power state to save energy.

71.3 PCS requirements for Auto-Negotiation (AN) service interface

The PCS associated with this PMD shall support the AN service interface primitive AN_LINK.indication defined in 73.9. (See 48.2.7.)

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71.4 Delay constraints

Predictable operation of the MAC Control PAUSE operation (Clause 31, Annex 31B) demands that there be an upper bound on the propagation delays through the network. This implies that MAC, MAC Control sublayer, and PHY implementers must consider the delay maxima, and that network planners and administrators consider the delay constraints regarding the physical topology and concatenation of devices. A description of overall system delay constraints and the definitions for bit-times and pause_quanta can be found in 69.3.

The sum of transmit and receive delays contributed by the 10GBASE-KX4 PMD and medium shall be no more than 512 bit times or 1 pause_quanta. It is assumed that the round-trip delay through the medium is 160 bit times.

71.5 PMD MDIO function mapping

The optional MDIO capability described in Clause 45 defines several variables that provide control and status information for and about the PMD. If the MDIO is implemented, it shall map MDIO control variables to PMD control variables as shown in Table 71–2 and MDIO status variables to PMD status variables as shown in Table 71–3.

Table 71–2—MDIO/PMD control variable mapping

MDIO control variable	PMA/PMD register name	Register/ bit number	PMD control variable
Reset	Control register 1	1.0.15	PMD_reset
Global Transmit Disable	Transmit disable register	1.9.0	Global_PMD_transmit_disable
Transmit disable 3	Transmit disable register	1.9.4	PMD_transmit_disable_3
Transmit disable 2	Transmit disable register	1.9.3	PMD_transmit_disable_2
Transmit disable 1	Transmit disable register	1.9.2	PMD_transmit_disable_1
Transmit disable 0	Transmit disable register	1.9.1	PMD_transmit_disable_0

71.6 PMD functional specifications

The 10GBASE-KX4 PMD performs the transmit and receive functions that convey data between the PMD service interface and the MDI, and provides various management functions if the optional MDIO is implemented.

71.6.1 Link block diagram

For purposes of system conformance, the PMD sublayer is standardized at test points TP1 and TP4 as shown in Figure 71–1. The transmitter and receiver blocks include all off-chip components associated with the respective block. For example, external AC-coupling capacitors, if required, are to be included in the receiver block.

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Table 71–3—MDIO/PMD status variable mapping

MDIO status variable	PMA/PMD register name	Register/ bit number	PMD status variable
Fault	Status register 1	1.1.7	PMD_fault
Transmit fault	Status register 2	1.8.11	PMD_transmit_fault
Receive fault	Status register 2	1.8.10	PMD_receive_fault
Global PMD Receive signal detect	Receive signal detect register	1.10.0	Global_PMD_signal_detect
PMD signal detect 3	Receive signal detect register	1.10.4	PMD_signal_detect_3
PMD signal detect 2	Receive signal detect register	1.10.3	PMD_signal_detect_2
PMD signal detect 1	Receive signal detect register	1.10.2	PMD_signal_detect_1
PMD signal detect 0	Receive signal detect register	1.10.1	PMD_signal_detect_0

The electrical path from the transmitter block to TP1, and from TP4 to the receiver block, will affect link performance and the measured values of electrical parameters used to verify conformance to this specification. It is therefore recommended that this path be carefully designed.

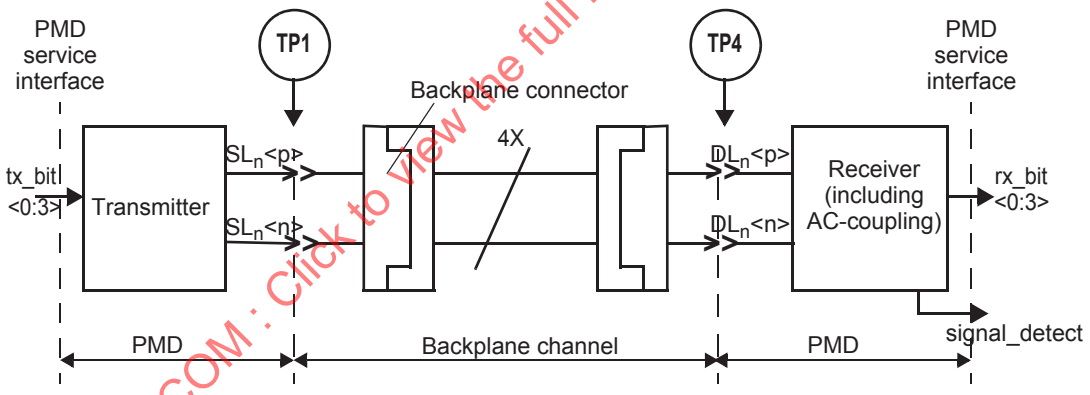

Figure 71–1—Link block diagram

71.6.2 PMD Transmit function

The PMD Transmit function shall convert the four logical bit streams requested by the PMD service interface message PMD_UNITDATA.request (tx_bit<0:3>) into four separate electrical signal streams. The four electrical signal streams shall then be delivered to the MDI, all according to the specifications in 71.7.1. A positive output voltage of SLn<p> minus SLn<n> (differential voltage) shall correspond to tx_bit = ONE.

The PMD shall convey the bits received from the PMD service interface using the message PMD_UNITDATA.request(tx_bit<0:3>) to the MDI lanes, where SL0<p>/<n> corresponds to tx_bit<0>, SL1<p>/<n> to tx_bit<1>, SL2<p>/<n> to tx_bit<2>, and SL3<p>/<n>) = tx_bit<3>.

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71.6.3 PMD Receive function

The PMD Receive function shall convert the four electrical signal streams from the MDI into four logical bit streams for delivery to the PMD service interface using the message PMD_UNITDATA.indication(rx_bit<0:3>), all according to the receive electrical specifications in 71.7.2. A positive input voltage level in each signal stream of DLn<p> minus DLn<n> (differential voltage) shall correspond to a rx_bit = ONE.

The PMD shall convey the bits received from the MDI lanes to the PMD service interface using the message PMD_UNITDATA.indication(rx_bit<0:3>), where rx_bit<0:3> = (DL0<p>/<n>, DL1<p>/<n>, DL2<p>/<n>, DL3<p>/<n>).

71.6.4 Global PMD signal detect function

For 10GBASE-KX4 operation Global PMD signal detect is mandatory if EEE is supported. When EEE is not implemented, the PMD signal detect is optional for 10GBASE-KX4 and its definition is beyond the scope of this standard. When Global PMD signal detect is not implemented, the value of SIGNAL_DETECT shall be set to OK for purposes of management and signaling of the primitive.

If EEE is supported, a local PMD signal detect function shall report to the PMD service interface using the message PMD_SIGNAL.indication(SIGNAL_DETECT). This message is signaled continuously. For EEE, the SIGNAL_DETECT parameter can take on one of two values, OK or FAIL, indicating whether the PMD is detecting electrical energy at the receiver (OK) or not (FAIL). When SIGNAL_DETECT = FAIL, PMD_UNITDATA.indication(rx_lane<3:0>) is undefined. The signal energy from a compliant transmitter shall set SIGNAL_DETECT to OK within 750 ns when transitioning from LPI quiet to active and set SIGNAL_DETECT to FAIL within 750 ns when transitioning from active to LPI quiet.

71.6.5 PMD lane-by-lane signal detect function

When the MDIO is implemented, each PMD_signal_detect_n value, where n represents the lane number in the range 0:3, shall report the value of SIGNAL_DETECT for the corresponding lane when signal detect is implemented, or OK otherwise.

71.6.6 Global PMD transmit disable function

The Global_PMD_transmit_disable function is mandatory if EEE is supported and is otherwise optional. When implemented, it allows all of the transmitters to be disabled with a single variable.

a) When the Global_PMD_transmit_disable variable is set to ONE, this function shall turn off all of the transmitters such that each transmitter drives a constant level (i.e., no transitions) and does not exceed the maximum differential peak-to-peak output voltage specified in Table 71–4.
b) If a PMD_fault (71.6.9) is detected, then the PMD may turn off the electrical transmitter in all lanes.
c) Loopback, as defined in 71.6.8, shall not be affected by Global_PMD_transmit_disable.
d) For EEE capability, the PMD_transmit_disable function shall turn off all transmitter lanes after tx_quiet is asserted within a time and voltage level specified in 71.7.1.4. The PMD_transmit_disable function shall turn on all transmitter lanes after tx_quiet is de-asserted within a time and voltage level specified in 71.7.1.4.

71.6.7 PMD lane-by-lane transmit disable function

The PMD_transmit_disable_n function shall be implemented. It allows the electrical transmitters in each lane to be selectively disabled.

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a) When a PMD_transmit_disable_n variable is set to ONE, this function shall turn off the transmitter associated with that variable such that the corresponding transmitter drives a constant level (i.e., no transitions) and does not exceed the maximum differential peak-to-peak output voltage specified in Table 71–4.
b) If a PMD_fault (71.6.9) is detected, then the PMD may turn off the electrical transmitter in all lanes.
c) Loopback, as defined in 71.6.8, shall not be affected by PMD_transmit_disable_n.

NOTE—Turning off a transmitter can be disruptive to a network.

71.6.8 Loopback mode

Loopback mode shall be provided for the 1000BASE-KX4 PMA/PMD by the transmitter and receiver of a device as a test function to the device. When loopback mode is selected, transmission requests passed to the transmitter are shunted directly to the receiver, overriding any signal detected by the receiver on its attached link. Transmitter operation shall be independent of loopback mode. A device must be explicitly placed in loopback mode because loopback mode is not the normal mode of operation of a device. The method of implementing loopback mode is not defined by this standard.

Control of the loopback function is specified in 45.2.1.1.5.

NOTE 1—The signal path that is exercised in the loopback mode is implementation specific, but it is recommended that this signal path encompass as much of the circuitry as is practical. The intention of providing this loopback mode of operation is to permit diagnostic or self-test functions to test the transmit and receive data paths using actual data. Other loopback signal paths may also be enabled independently using loopback controls within other devices or sublayers.

NOTE 2—Placing a network port into loopback mode can be disruptive to a network.

71.6.9 PMD fault function

If the MDIO is implemented, and the PMD has detected a local fault on any of the transmit or receive paths, the PMD shall set PMD_fault to ONE; otherwise, the PMD shall set PMD_fault to ZERO.

71.6.10 PMD transmit fault function

If the MDIO is implemented, and the PMD has detected a local fault on any transmit lane, the PMD shall set the PMD_transmit_fault variable to ONE; otherwise, the PMD shall set PMD_transmit_fault to ZERO.

71.6.11 PMD receive fault function

If the MDIO is implemented, and the PMD has detected a local fault on any receive lane, the PMD shall set the PMD_receive_fault variable to ONE; otherwise, the PMD shall set PMD_receive_fault to ZERO.

71.6.12 PMD LPI function

The PMD LPI function responds to transitions between Active, Sleep, Quiet, Refresh, and Wake states via the PMD_TXQUIET and PMD_RXQUIET requests. Implementation of the function is optional. EEE capabilities and parameters, as described in 45.2.7, is advertised during the Backplane Auto-negotiation. The transmitter on the local device will inform the link partner's receiver when to sleep, refresh, and wake. The local receiver transitions are controlled by the link partner's transmitter and can change independent of the local transmitter states and transitions.

The transmitter sends /LI/ ordered sets during the sleep and refresh states, disables the transmitter during quiet, and forwards ||I|| during the wake phase.

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If EEE is supported, the PMD transmit function enters into a low power mode when tx_quiet is set to TRUE and exits when tx_quiet is set to FALSE. While tx_quiet is TRUE the PMD transmitter functional blocks should be deactivated to conserve energy. The PMD receive function enters into a low power mode when rx_quiet is set to TRUE and exits when rx_quiet is set to FALSE. While rx_quiet is TRUE, the PMD receiver functional blocks should be deactivated to conserve energy.

71.7 Electrical characteristics for 10GBASE-KX4

71.7.1 Transmitter characteristics

Transmitter characteristics at TP1 are summarized in Table 71–4.

Table 71–4—Transmitter characteristics for 10GBASE-KX4

Parameter	Subclause reference	Value	Units
Signaling speed, per lane	71.7.1.3	3.125 ± 100 ppm	GBd
Differential peak-to-peak output voltage	71.7.1.4	800 to 1200	mV
Differential peak-to-peak output voltage (max.) with TX disabled	71.6.6 71.6.7	30	mV
Common-mode voltage limits	71.7.1.4	–0.4 to 1.9	V
Common-mode voltage deviation (max) during LPI	71.7.1.4	150	mV
Differential output return loss (min.)	71.7.1.5	[See Equation (71–1) and Equation (71–2)]	dB
Differential output template	71.7.1.6	[See Figure 71–5 and Table 71–5]	V
Transition time[a] (20%–80%)	71.7.1.7	60 to 130	ps
Output jitter (max. peak-to-peak) Random jitter Deterministic jitter Total jitter[b]	71.7.1.8	 0.27 0.17 0.35	 UI UI UI

[a]Transition time parameters are recommended values, not compliance values.
[b]At BER 10^{-12}.

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71.7.1.1 Test fixtures

The test fixture of Figure 71–2, or its functional equivalent, is required for measuring the transmitter specifications described in 71.7.1, with the exception of return loss.

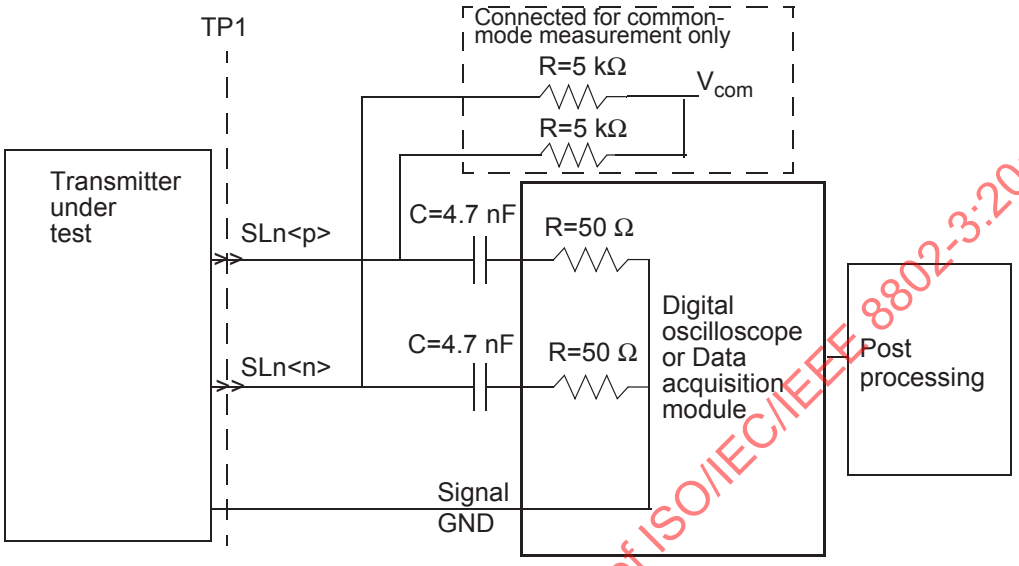

Figure 71–2—Transmit test fixture for 10GBASE-KX4

71.7.1.2 Test fixture impedance

The differential load impedance applied to the transmitter output by the test fixture depicted in Figure 71–2 shall be 100 Ω with a return loss greater than 20 dB from 100 MHz to 2000 MHz.

71.7.1.3 Signaling speed

The 10GBASE-KX4 signaling speed shall be 3.125 GBd ±100 ppm. The corresponding unit interval is nominally 320 ps.

71.7.1.4 Output amplitude

While transmitting the test pattern specified in 48A.2,

1) The transmitter maximum differential peak-to-peak output voltage shall be less than 1200 mV.
2) The minimum differential peak-to-peak output voltage shall be greater than 800 mV.
3) The maximum difference between any two lanes' differential peak-to-peak output voltage shall be less than or equal to 150 mV.

See Figure 71–3 for an illustration of the definition of differential peak-to-peak output voltage.

DC-referenced voltage levels are not defined since the receiver is AC-coupled. The common-mode voltage of SLn<p> and SLn<n> shall be between –0.4 V and 1.9 V with respect to signal ground as measured at V_{com} in Figure 71–2.

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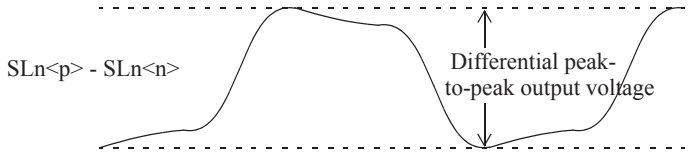

Figure 71–3—Transmitter differential peak-to-peak output voltage definition

NOTE—SLn<p> and SLn<n> are the positive and negative sides of the differential signal pair for Lane n (n = 0,1,2,3).

For EEE capability, the transmitter lane's differential peak-to-peak output voltage shall be less than 30 mV within 500 ns of tx_quiet being asserted. Furthermore, the transmitter lane's differential peak-to-peak output voltage shall be greater than 720 mV within 500 ns of tx_quiet being de-asserted. The transmitter output shall be fully compliant within 5 µs after tx_quiet is set to FALSE. During LPI, the common-mode shall be maintained to within ± 150 mV of the pre-LPI value.

71.7.1.5 Output return loss

For frequencies from 100 MHz to 2000 MHz, the differential return loss, in dB with f in MHz, of the transmitter shall meet the requirements of Equation (71–1) and Equation (71–2). This output impedance requirement applies to all valid output levels. The reference impedance for differential return loss measurements shall be 100 Ω.

$$\mathrm{ReturnLoss}(f) \geq 10 \qquad (71\text{–}1)$$

for 100 MHz ≤ f < 625 MHz and

$$\mathrm{ReturnLoss}(f) \geq 10 - 10 \times \log_{10}\left(\frac{f}{625}\right) \qquad (71\text{–}2)$$

for 625 MHz ≤ f ≤ 2000 MHz

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The minimum differential output return loss is shown in Figure 71–4.

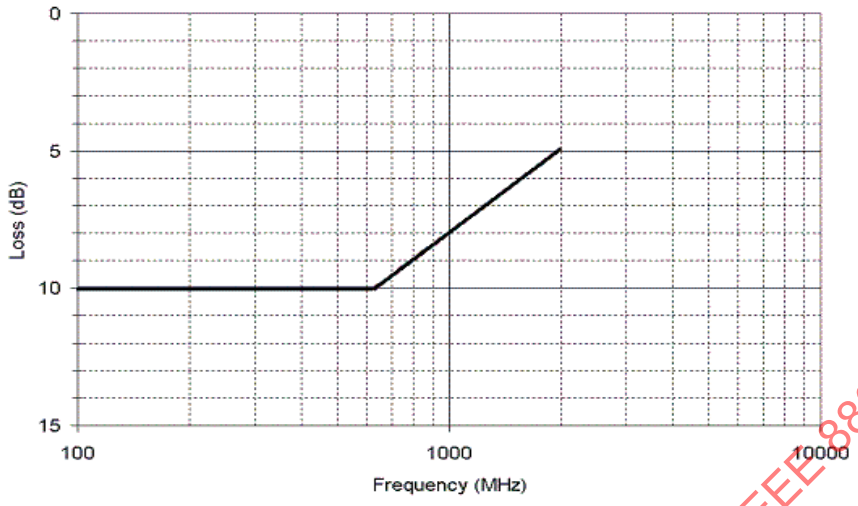

Figure 71–4—Minimum differential output return loss

71.7.1.6 Differential output template

The transmitter differential output signal is defined at TP1, as shown in Figure 71–2 and Figure 71–3. The transmitter shall provide equalization such that the output waveform falls within the template shown in Figure 71–5 for the test pattern specified in 48A.2, with all other transmitters active. All other transmitters shall be terminated with a load meeting the requirements described in 71.7.1.2. Voltage and time coordinates for inflection points on Figure 71–5 are given in Table 71–5. The waveform under test shall be normalized by using the following procedure:

a) Align the output waveform under test, to achieve the best fit along the horizontal time axis.
b) Calculate the +1 low frequency level as V_{lowp} = average of any two successive unit intervals (2UI) between 2.5 UI and 5.5 UI.
c) Calculate the 0 low frequency level as V_{lowm} = average of any two successive unit intervals (2UI) between 7.5 UI and 10.5 UI.
d) Calculate the vertical offset to be subtracted from the waveform as $V_{off} = (V_{lowp} + V_{lowm}) / 2$.
e) Calculate the vertical normalization factor for the waveform as $V_{norm} = (V_{lowp} - V_{lowm}) / 2$.
f) Calculate the normalized waveform as:
Normalized_Waveform = (Original_Waveform – V_{off}) × (0.69/V_{norm}).
g) Align the Normalized_Waveform under test, to achieve the best fit along the horizontal time axis.

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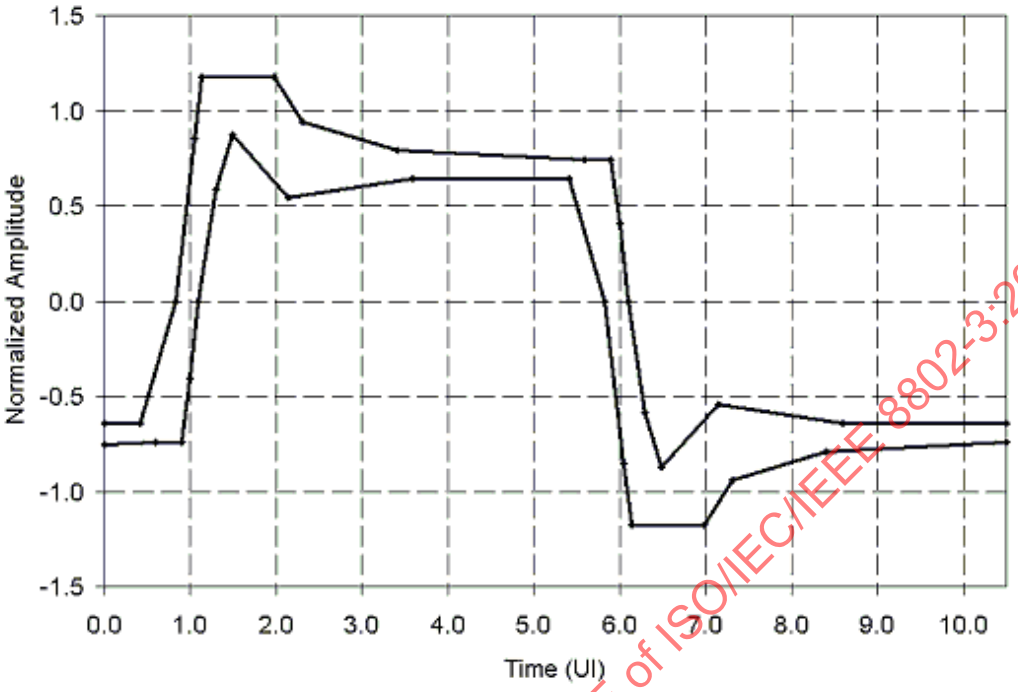

Figure 71–5—Normalized transmit template

Table 71–5—Normalized transmit time domain template

Upper limit				Lower limit			
Time (UI)	Amplitude	Time (UI)	Amplitude	Time (UI)	Amplitude	Time (UI)	Amplitude
0.000	–0.640	5.897	0.740	0.000	–0.754	5.409	0.640
0.409	–0.640	5.997	0.406	0.591	–0.740	5.828	0.000
0.828	0.000	6.094	0.000	0.897	–0.740	6.050	–0.856
1.050	0.856	6.294	–0.586	0.997	–0.406	6.134	–1.175
1.134	1.175	6.491	–0.870	1.094	0.000	6.975	–1.175
1.975	1.175	7.141	–0.546	1.294	0.586	7.309	–0.940
2.309	0.940	8.591	–0.640	1.491	0.870	8.500	–0.790
3.409	0.790	10.500	–0.640	2.141	0.546	10.500	–0.742
5.591	0.740			3.591	0.640		

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71.7.1.7 Transition time

The rising edge transition time is recommended to be between 60 ps and 130 ps as measured at the 20% and 80% levels of the peak-to-peak differential value of the waveform using the high-frequency test pattern of 48A.1. The falling edge transition time is recommended to be between 60 ps and 130 ps as measured at the 80% and 20% levels of the peak-to-peak differential value of the waveform using the high-frequency test pattern of 48A.1.

71.7.1.8 Transmit jitter

The transmitter shall have a maximum total jitter of 0.350 UI peak-to-peak, a maximum deterministic component of 0.170 UI peak-to-peak, and a maximum random component of 0.270 UI peak-to-peak. Jitter specifications include all but 10^{-12} of the jitter population. Transmit jitter test requirements are specified in 71.7.1.9.

71.7.1.9 Transmit jitter test requirements

Transmit jitter is defined with respect to the transmitter differential output signal at TP1, as shown in Figure 71–2 and Figure 71–5, and the test procedure resulting in a BER bathtub curve such as that described in Annex 48B. For the purpose of jitter measurement, the effect of a single-pole high-pass filter with a 3 dB point at 1.875 MHz is applied to the jitter. The data pattern for jitter measurements shall be the jitter tolerance test pattern defined in Annex 48A.5. For this test, all other transmitters shall be active and terminated with a load meeting the requirements described in 71.7.1.2. Crossing times are defined with respect to the mid-point (0 V) of the AC-coupled differential signal.

71.7.2 Receiver characteristics

Receiver characteristics at TP4 are summarized in Table 71–6 and detailed in 71.7.2.1 through 71.7.2.5.

Table 71–6—Receiver characteristics

Parameter	Subclause reference	Value	Units
Bit error ratio	71.7.2.1	10^{-12}	
Signaling speed, per lane	71.7.2.2	3.125 ± 100 ppm	GBd
Unit interval (UI) nominal	71.7.2.2	320	ps
Receiver coupling	71.7.2.3	AC	
Differential input peak-to-peak amplitude (maximum)	71.7.2.4	1600	mV
EEE Signal Detect deactivation time (T_{SD}) from active to LPI quiet	71.6.4	750	ns
EEE Signal Detect activation time (T_{SA}) from LPI quiet to active	71.6.4	750	ns
Differential input return loss[a] (minimum)	71.7.2.5	[See Equation (71–1) and Equation (71–2)]	dB

[a]Relative to 100 Ω differential.

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71.7.2.1 Receiver interference tolerance

The receiver interference tolerance shall be measured as described in Annex 69A with the parameters specified in Table 71–7. The data pattern for the interference tolerance test shall be the continuous jitter test pattern as defined in Annex 48A.5. The receiver shall satisfy the requirements for interference tolerance specified in Annex 69A.

Table 71–7—10GBASE-KX4 interference tolerance parameters

Parameter	Value	Units
Target BER	10^{-12}	
m_{TC}[a] (min.)	1.0	
Amplitude of broadband noise (min. RMS)	8.1	mV
Applied transition time (20%–80%, min.)	130	ps
Applied sinusoidal jitter (min. peak-to-peak)	0.17	UI
Applied random jitter (min. peak-to-peak)[b]	0.18	UI
Applied duty cycle distortion (min. peak-to-peak)	0.0	UI

[a]m_{TC} is defined in Equation (69A–6) of Annex 69A.
[b]Applied random jitter is specified at a BER of 10^{-12}.

71.7.2.2 Signaling speed

The 10GBASE-KX4 signaling speed shall be 3.125 GBd ± 100 ppm. The corresponding unit interval is nominally 320 ps.

71.7.2.3 AC-coupling

The 10GBASE-KX4 receiver shall be AC-coupled to the backplane to allow for maximum interoperability between various 10 Gb/s components. AC-coupling is considered to be part of the receiver for the purposes of this specification unless explicitly stated otherwise. It should be noted that there may be various methods for AC-coupling in actual implementations.

NOTE—It is recommended that the maximum value of the coupling capacitors be limited to 4.7 nF. This will limit the inrush currents to the receiver that could damage the receiver circuits when repeatedly connected to transmit modules with a higher voltage level.

71.7.2.4 Input signal amplitude

10GBASE-KX4 receivers shall accept differential input signal peak-to-peak amplitudes produced by compliant transmitters connected without attenuation to the receiver, and still meet the BER requirement specified in 71.7.2.1. Note that this may be larger than the 1200 mV differential maximum of 71.7.1.4 due to the actual transmitter output and receiver input impedances. The input impedance of a receiver can cause the minimum signal into a receiver to differ from that measured when the receiver is replaced with a 100 Ω test load. Since the channel is AC-coupled, the absolute voltage levels with respect to the receiver ground are dependent on the receiver implementation.

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71.7.2.5 Differential input return loss

For frequencies from 100 MHz to 2000 MHz, the differential return loss, in dB with *f* in MHz, of the receiver shall be greater than or equal to Equation (71–1) and Equation (71–1). This return loss requirement applies to all valid input levels. The reference impedance for differential return loss measurements is 100 Ω.

71.8 Interconnect characteristics

Informative interconnect characteristics for 10GBASE-KX4 are provided in Annex 69B.

71.9 Environmental specifications

71.9.1 General safety

All equipment that meets the requirements of this standard shall conform to applicable sections (including isolation requirements) of IEC 60950-1.

71.9.2 Network safety

The designer is urged to consult the relevant local, national, and international safety regulations to ensure compliance with the appropriate requirements.

71.9.3 Installation and maintenance guidelines

It is recommended that sound installation practice, as defined by applicable local codes and regulations, be followed in every instance in which such practice is applicable.

71.9.4 Electromagnetic compatibility

A system integrating the 10GBASE-KX4 PHY shall comply with applicable local and national codes for the limitation of electromagnetic interference.

71.9.5 Temperature and humidity

A system integrating the 10GBASE-KX4 PHY is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

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71.10 Protocol implementation conformance statement (PICS) proforma for Clause 71, Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-KX4[27]

71.10.1 Introduction

The supplier of a protocol implementation that is claimed to conform to IEEE Std 802.3, Clause 71, Physical Medium Dependent (PMD) sublayer and baseband medium type 10GBASE-KX4, shall complete the following protocol implementation conformance statement (PICS) proforma. A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

71.10.2 Identification

71.10.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

71.10.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 71, Physical Medium Dependent (PMD) sublayer and baseband medium type 10GBASE-KX4
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	
Date of Statement	

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71.10.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
XGE	XGMII	71.1, 46	Interface is supported	O	Yes [ ] No [ ]
XGXS	XGXS and XAUI	71.1, 47		O	Yes [ ] No [ ]
PCS	Support of 10GBASE-X PCS/PMA	71.1, 48		M	Yes [ ]
AN	Auto-Negotiation for Backplane Ethernet	71.1, 73	Device implements Auto-Negotiation for Backplane Ethernet	M	Yes [ ]
DC	Delay Constraints	71.4	Device conforms to delay constraints	M	Yes [ ]
LPI	LPI function	71.6.12	LPI supported	O	Yes [ ] No [ ]
*MD	MDIO interface	71.5	Device implements MDIO	O	Yes [ ] No [ ]
*SD	Signal Detect Generation	71.6.4	Signal detect implemented	O	Yes [ ] No [ ]
*TD	Global_PMD_transmit_disable	71.6.6		O	Yes [ ] No [ ]

71.10.4 PICS proforma tables for Clause 71, Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-KX4

71.10.4.1 PCS requirements for AN service interface

Item	Feature	Subclause	Value/Comment	Status	Support
PR1	AN service interface primitive	71.3	The PCS associated with this PMD supports the AN service interface primitive AN_LINK.indication defined in 73.9	M	Yes [ ]

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71.10.4.2 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FS1	Transmit function	71.6.2	Convert the 4 logical signals requested by PMD_UNITDATA.request (tx_bit<0:3>) to 4 electrical signals	M	Yes [ ]
FS2	Delivery to the MDI	71.6.2	Supplies 4 electrical signal streams for delivery to the MDI per 71.7.1	M	Yes [ ]
FS3	Transmitter signal	71.6.2	A positive differential voltage corresponds to tx_bit = ONE	M	Yes [ ]
FS4	Transmit Signal order	71.6.2	PMD_UNITDATA.request(tx_bit<0:3>) = (SL0<p>/<n>, SL1<p>/<n>, SL2<p>/<n>, SL3<p>/<n>)	M	Yes [ ]
FS5	Receive function	71.6.3	Convert the 4 electrical signals received from the MDI to 4 logical signals PMD_UNITDATA.indication (rx_bit<0:3>) per 71.7.2	M	Yes [ ]
FS6	Receiver signal	71.6.3	A positive differential voltage corresponds to rx_bit = ONE	M	Yes [ ]
FS7	Receive Signal order	71.6.3	PMD_UNITDATA.request(rx_bit<0:3>) = (DL0<p>/<n>, DL1<p>/<n>, DL2<p>/<n>, DL3<p>/<n>)	M	Yes [ ]
FS8	Behavior when Global_PMD_signal_detect is not implemented	71.6.4	SIGNAL_DETECT = OK continuously	!SD:M	Yes [ ] N/A [ ]
FS9	Global_PMD_signal_detect function	71.6.4	Reported via PMD_SIGNAL.indication (SIGNAL_DETECT)	SD:M	Yes [ ] N/A [ ]
FS10	Global_PMD_signal_detect during LPI	71.6.4	Detect signal energy during LPI	LPI:M	Yes [ ] N/A [ ]
FS11	Signal Detect for EEE	71.6.4	Transition timing to set SIGNAL_DETECT	LPI:M	Yes [ ] N/A [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
FS12	Global_PMD_transmit_disable function	71.6.6	Disables all transmitters by forcing a constant level.	TD:M	Yes [ ] N/A [ ]
FS13	PMD_fault global effect	71.6.6	All transmitters disabled if detected	TD:O	Yes [ ] No [ ] N/A [ ]
FS14	Global_PMD_transmit_disable affect on loopback	71.6.6	Loopback function not affected	TD:M	Yes [ ] N/A [ ]
FS15	Global_PMD_transmit_disable during LPI	71.6.6	Disable transmitters during tx_quiet	LPI:M	Yes [ ] N/A [ ]
FS16	PMD_transmit_disable_n function implemented	71.6.7		M	Yes [ ]
FS17	PMD_transmit_disable_n action when enabled	71.6.7	Disables transmitter by forcing a constant level	M	Yes [ ]
FS18	PMD_transmit_disable_n affect on loopback	71.6.7	Loopback function not affected	M	Yes [ ]
FS19	Loopback Function	71.6.8	Loopback function provided	M	Yes [ ]
FS20	Loopback affect on transmitters	71.6.8	Loopback function does not disable transmitters	M	Yes [ ]
FS21	LPI function	71.6.12	PMD_RXQUIET.request and PMD_TXQUIET.request supported	LPI:M	Yes [ ] No [ ] N/A [ ]

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71.10.4.3 Management functions

Item	Feature	Subclause	Value/Comment	Status	Support
MF1	MDIO Variable Mapping	71.5	Per Table 71–2 and Table 71–3	MD:M	Yes [ ] N/A [ ]
MF2	Lane-by-Lane Signal Detect function	71.6.5	Sets PMD_signal_detect_n values on a lane-by-lane basis per requirements of 71.6.5	MD*SD:M	Yes [ ] N/A [ ]
MF3	Lane-by-Lane Signal Detect function not implemented	71.6.5	PMD_signal_detect_n continuously indicated as OK	MD*!SD:M	Yes [ ] N/A [ ]
MF4	PMD_fault function	71.6.9	Sets PMD_fault to a logical 1 if any local fault is detected; otherwise, set to 0	MD:M	Yes [ ] N/A [ ]
MF5	PMD_transmit_fault function	71.6.10	Sets PMD_transmit_fault to a logical 1 if any local fault is detected on the transmit path; otherwise, set to 0	MD:M	Yes [ ] N/A [ ]
MF6	PMD_receive_fault function	71.6.11	Sets PMD_receive_fault to a logical 1 if any local fault is detected on the receive path; otherwise, set to 0	MD:M	Yes [ ] N/A [ ]

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71.10.4.4 Transmitter electrical characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
TC1	100 Ω differential test fixture	71.7.1.2	With return loss > 20 dB from 100 MHz to 2000 MHz	M	Yes [ ]
TC2	Signaling speed	71.7.1.3	3.125 GBd ± 100 ppm	M	Yes [ ]
TC3	Maximum transmitter differential peak-to-peak voltage	71.7.1.4	Less than 1200 mV	M	Yes [ ]
TC4	Minimum transmitter differential peak-to-peak voltage	71.7.1.4	Greater than 800 mV	M	Yes [ ]
TC5	Maximum transmitter differential peak-to-peak voltage difference	71.7.1.4	Less than or equal to 150 mV	M	Yes [ ]
TC6	Common-mode output voltage	71.7.1.4	Between –0.4 V and 1.9 V	M	Yes [ ]
TC7	Output Amplitude LPI voltage	71.7.1.4	Less than 30 mV within 500 ns of tx_quiet	LPI:M	Yes [ ] N/A [ ]
TC8	Output Amplitude ON voltage	71.7.1.4	Greater than 720 mV within 500 ns of tx_quiet de-asserted	LPI:M	Yes [ ] N/A [ ]
TC9	Output Return Loss	71.7.1.5	Per Equation (71–1) and Equation (71–2)	M	Yes [ ]
TC10	Reference Impedance	71.7.1.5	100 Ω for differential return loss measurements	M	Yes [ ]
TC11	Output within transmit template per Figure 71–5	71.7.1.6	While sending pattern specified in 48A.2, with all other transmitters active	M	Yes [ ]
TC12	Other transmitters terminated	71.7.1.6	Per 71.7.1.2	M	Yes [ ]
TC13	Transmitter output normalization	71.7.1.6	Per defined process	M	Yes [ ]
TC14	Transmit jitter, peak-to-peak	71.7.1.8	See 71.7.1.9. Max TJ of 0.35 UI. Max DJ of 0.17 UI. Max RJ of 0.27 UI	M	Yes [ ]
TC15	Jitter test patterns	71.7.1.9	Per 48A.5	M	Yes [ ]
TC16	Other transmitters during jitter test	71.7.1.9	Other transmitters active and terminated per 71.7.1.2	M	Yes [ ]

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71.10.4.5 Receiver electrical characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
RC1	Receiver interference tolerance	71.7.2.1	Per Annex 69A with parameters specified in Table 71–6	M	Yes [ ]
RC2	Receiver interference tolerance test pattern	71.7.2.1	Per 71.7.2.1	M	Yes [ ]
RC3	Receiver interference tolerance requirements	71.7.2.1	Satisfy requirements per Annex 69A	M	Yes [ ]
RC4	Signaling speed	71.7.2.2	3.125 GBd ±100 ppm	M	Yes [ ]
RC5	Receiver AC-coupled	71.7.2.3		M	Yes [ ]
RC6	Input signal amplitude	71.7.2.4	BER still met when compliant transmitter is connected with no attenuation	M	Yes [ ]
RC7	Differential return loss	71.7.2.5	Per Equation (71–1) and Equation (71–2)	M	Yes [ ]

71.10.4.6 Environmental and safety specifications

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	General safety	71.9.1	Conforms to IEC 60950-1	M	Yes [ ]
ES2	Electromagnetic compatibility	71.9.4	Comply with applicable local and national codes	M	Yes [ ]

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72. Physical Medium Dependent sublayer and baseband medium, type 10GBASE-KR

72.1 Overview

This clause specifies the 10GBASE-KR PMD and the baseband medium. When forming a complete PHY, a PMD shall be connected to the appropriate sublayers (see Table 72–1), and with the management functions that are optionally accessible through the management interface defined in Clause 45, or equivalent.

Table 72–1—Physical Layer clauses associated with the 10GBASE-KR PMD

Associated clause	10GBASE-KR
46—XGMII[a]	Optional
47—XGXS and XAUI	Optional
49—10GBASE-R PCS	Required
51—10-Gigabit Serial PMA	Required
73—Auto-Negotiation for Backplane Ethernet	Required
74—BASE-R FEC	Optional
78—Energy-Efficient Ethernet	Optional

[a]The XGMII is an optional interface. However, if the XGMII is not implemented, a conforming implementation must behave functionally as though the RS and XGMII were present.

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A 10GBASE-KR PHY with the optional Energy-Efficient Ethernet (EEE) capability may optionally enter the Low Power Idle (LPI) mode to conserve energy during periods of low link utilization. The “Assert LPI” request at the XGMII is encoded in the transmitted symbols. Detection of LPI signaling in the received symbols is indicated as “Assert LPI” at the XGMII. Upon the detection of “Assert LPI” at the XGMII, an energy-efficient 10GBASE-KR PHY continues transmitting for a predefined period, then ceases transmission and deactivates transmit functions to conserve energy. The PHY periodically transmits during this quiet period to allow the remote PHY to refresh its receiver state (e.g., timing recovery, adaptive filter coefficients) and thereby track long-term variations in the timing of the link or the underlying channel characteristics. If, during the quiet or refresh periods, normal interframes resume at the XGMII, the PHY reactivates transmit functions and initiates transmission. This transmission will be detected by the remote PHY, causing it to also exit the LPI mode.

72.2 Physical Medium Dependent (PMD) service interface

The 10GBASE-KR PMD utilizes the PMD service interface defined in 52.1.1. The PMD service interface is summarized as follows:

a) PMD_UNITDATA.request (as defined in 52.1.1)
b) PMD_UNITDATA.indication (as defined in 52.1.1)
c) PMD_SIGNAL.indication

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If EEE is supported, the following primitives are also defined on the PMD Service Interface:

PMD_RX_MODE.request(rx_mode)
PMD_TX_MODE.request(tx_mode)

These messages affect the PCS variables as described in 49.2.13.2.2.

72.2.1 PMD_RX_MODE.request

This primitive is generated by the PCS Receive Process when EEE is supported to indicate that the input signal is quiet and the PMA and PMD receiver may go into a low power mode. When EEE is not supported, the primitive is never invoked and the PMD behaves as if rx_mode = DATA.

72.2.1.1 Semantics of the service primitive

PMD_RX_MODE.request (rx_mode)

The rx_mode parameter takes on one of two values: QUIET or DATA.

72.2.1.2 When generated

The PCS generates this primitive to request the appropriate PMD receive LPI state.

72.2.1.3 Effect of receipt

When rx_mode is QUIET, the PMD receive function may deactivate functional blocks to conserve energy. When rx_mode is DATA, the PMD receive function operates normally.

72.2.2 PMD_TX_MODE.request

This primitive is generated by the PCS Transmit Process when EEE is supported to indicate that the PMA and PMD transmit functions may go into a low power mode and to disable the PMD transmitter. See subclause 72.6.5. When EEE is not supported, the primitive is never invoked and the PMD behaves as if tx_mode = DATA.

72.2.2.1 Semantics of the service primitive

PMD_TX_MODE.request (tx_mode)

The tx_mode parameter takes on one of three values: QUIET, ALERT, or DATA.

72.2.2.2 When generated

The PCS generates this primitive to request appropriate PMD transmit LPI state.

72.2.2.3 Effect of receipt

When tx_mode is QUIET, the PMD Transmit function may deactivate functional blocks to conserve energy. When tx_mode is ALERT, the PMD Transmit function transmits the alert pattern. And when it is DATA, the PMD Transmit function operates normally.

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72.3 PCS requirements for Auto-Negotiation (AN) service interface

The PCS associated with this PMD shall support the AN service interface primitive AN_LINK.indication defined in 73.9. (See 49.2.16.)

72.4 Delay constraints

Predictable operation of the MAC Control PAUSE operation (Clause 31, Annex 31B) demands that there be an upper bound on the propagation delays through the network. This implies that MAC, MAC Control sublayer, and PHY implementers must consider the delay maxima, and that network planners and administrators consider the delay constraints regarding concatenation of devices. A description of overall system delay constraints and the definitions for bit-times and pause_quanta can be found in 69.3.

The sum of the transmit and the receive delays contributed by the 10GBASE-KR PMD and medium shall be no more than 1024 bit times. It is assumed that the round-trip delay through the medium is 160 bit times.

72.5 PMD MDIO function mapping

The optional MDIO capability described in Clause 45 defines several variables that provide control and status information for and about the PMD. If MDIO is implemented, it shall map MDIO control variables to PMD control variables as shown in Table 72–2, and MDIO status variables to PMD status variables as shown in Table 72–3.

Table 72–2—MDIO/PMD control variable mapping

MDIO control variable	PMA/PMD register name	Register/ bit number	PMD control variable
Reset	Control register 1	1.0.15	PMD_reset
Global PMD Transmit Disable	Transmit disable register	1.9.0	Global_PMD_transmit_disable
Restart training	BASE-R PMD control register	1.150.0	mr_restart_training
Training enable	BASE-R PMD control register	1.150.1	mr_training_enable

72.6 PMD functional specifications

72.6.1 Link block diagram

For purposes of system conformance, the PMD sublayer is standardized at test points TP1 and TP4 as shown in Figure 72–1. The transmitter and receiver blocks include all off-chip components associated with the respective block. For example, external AC-coupling capacitors, if required, are to be included in the receiver block.

The electrical path from the transmitter block to TP1, and from TP4 to the receiver block, will affect link performance and the measured values of electrical parameters used to verify conformance to this standard. Therefore, it is recommended that this path be carefully designed.

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Table 72–3—MDIO/PMD status variable mapping

MDIO status variable	PMA/PMD register name	Register/ bit number	PMD status variable
Fault	Status register 1	1.1.7	PMD_fault
Transmit fault	Status register 2	1.8.11	PMD_transmit_fault
Receive fault	Status register 2	1.8.10	PMD_receive_fault
Global PMD Receive signal detect	Receive signal detect register	1.10.0	Global_PMD_signal_detect
Receiver status	BASE-R PMD status register	1.151.0	rx_trained
Frame lock	BASE-R PMD status register	1.151.1	frame_lock
Start-up protocol status	BASE-R PMD status register	1.151.2	training
Training failure	BASE-R PMD status register	1.151.3	training_failure

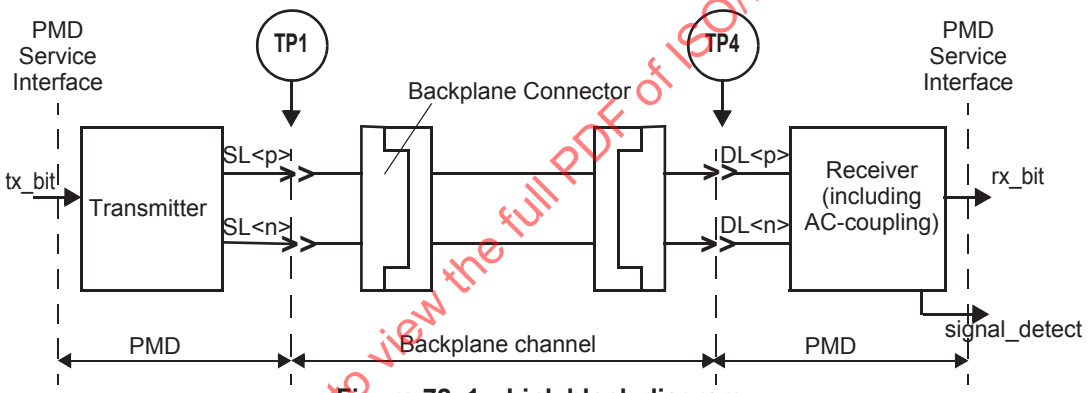

Figure 72–1—Link block diagram

72.6.2 PMD transmit function

The PMD Transmit function shall convey the bits requested by the PMD service interface message PMD_UNITDATA.request(tx_bit) to the MDI according to the specifications in this clause. A positive output voltage of SL<p> minus SL<n> (differential voltage) shall correspond to tx_bit = ONE.

If the optional Energy-Efficient Ethernet (EEE) capability is supported (see Clause 78) then when tx_mode is set to ALERT, the PMD will transmit a repeating 16-bit pattern, hexadecimal 0xFF00. When tx_mode is ALERT, the transmitter equalizer taps are set to the preset state specified in 72.6.10.2.3.1. When tx_mode is DATA, the driver coeffcients are restored to their states resolved during training.

72.6.3 PMD receive function

The PMD Receive function shall convey the bits received from the MDI according to the electrical specifications in this clause to the PMD service interface using the message PMD_UNITDATA.indication(rx_bit). A positive input voltage of DL<p> minus DL<n> (differential voltage) shall correspond to rx_bit = ONE.

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72.6.4 PMD signal detect function

The Global PMD signal detect function shall report to the PMD service interface, using the message PMD_SIGNAL.indication(SIGNAL_DETECT), which is signaled continuously. PMD_SIGNAL.indication is used by 10GBASE-KR to indicate the successful completion of the start-up protocol. When the PHY supports the optional EEE capability, PMD_SIGNAL.indication is also used to indicate when the ALERT signal is detected, which corresponds to the beginning of a refresh or a wake. If the MDIO interface is implemented, then Global_PMD_signal_detect (1.10.0) shall be continuously set to the value of SIGNAL_DETECT as described in 45.2.1.9.7.

The value of the SIGNAL_DETECT is defined by the training state diagram shown in Figure 72–5 when the PHY does not support the EEE capability or if the PHY supports the EEE capability and rx_mode is set to DATA. When the PHY supports the EEE capability, SIGNAL_DETECT is set to FAIL following a transition from rx_mode = DATA to rx_mode = QUIET. When rx_mode = QUIET, SIGNAL_DETECT shall be set to OK within 500 ns following the application of a signal at the receiver input that is the output of a channel that satisfies the requirements of all the parameters of both interference tolerance test channels defined in 72.7.2.1 when driven by a square wave pattern with a period of 16 unit intervals and peak-to-peak differential output amplitude of 720 mV. While rx_mode = QUIET, SIGNAL_DETECT changes from FAIL to OK only after a valid ALERT signal is applied to the channel.

SIGNAL_DETECT shall be set to FAIL following system reset or the manual reset of the training state diagram. Upon completion of training, SIGNAL_DETECT shall be set to OK.

If training is disabled by management and EEE is not implemented, SIGNAL_DETECT shall be set to OK.

72.6.5 PMD transmit disable function

The Global_PMD_transmit_disable function is mandatory if EEE is supported and is otherwise optional. When this function is supported, it shall meet the requirements of this subclause.

a) When the Global_PMD_transmit_disable variable is set to ONE, this function shall turn off the transmitter such that it drives a constant level (i.e., no transitions) and does not exceed the maximum differential peak-to-peak output voltage specified in Table 72–6.
b) If a PMD_fault (72.6.7) is detected, then the PMD may turn off the electrical transmitter.
c) Loopback, as defined in 72.6.6, shall not be affected by Global_PMD_transmit_disable.
d) For EEE capability, the PMD_transmit_disable function shall turn off the transmitter after tx_mode is set to QUIET within a time and voltage level specified in 72.7.1.4. The PMD_transmit_disable function shall turn on the transmitter after tx_mode is set to DATA or ALERT within the time and voltage level specified in 72.7.1.4.

If the MDIO interface is implemented, then this function shall map to the Global_PMD_transmit_disable bit as specified in 45.2.1.8.7.

72.6.6 Loopback mode

Loopback mode shall be provided for the 10GBASE-KR PMD by the transmitter and receiver of a device as a test function to the device. When loopback mode is selected, transmission requests passed to the transmitter are shunted directly to the receiver, overriding any signal detected by the receiver on its attached link. Note, this bit does not affect the state of the transmitter. The method of implementing loopback mode is not defined by this standard.

Control of the loopback function is specified in 45.2.1.1.5.

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NOTE 1—The signal path that is exercised in the loopback mode is implementation specific, but it is recommended that this signal path encompass as much of the circuitry as is practical. The intention of providing this loopback mode of operation is to permit diagnostic or self-test functions to test the transmit and receive data paths using actual data. Other loopback signal paths may also be enabled independently using loopback controls within other devices or sublayers.

NOTE 2—Placing a network port into loopback mode can be disruptive to a network.

72.6.7 PMD_fault function

If the MDIO is implemented, PMD_fault is the logical OR of PMD_receive_fault, PMD_transmit_fault, and any other implementation specific fault.

72.6.8 PMD transmit fault function

The PMD_transmit_fault function is optional. The faults detected by this function are implementation specific, but should not include the assertion of the Global_PMD_transmit_disable function.

If a PMD_transmit_fault (optional) is detected, then the Global_PMD_transmit_disable function should also be asserted.

If the MDIO interface is implemented, then this function shall be mapped to the PMD_transmit_fault bit as specified in 45.2.1.7.4.

72.6.9 PMD receive fault function

The PMD_receive_fault function is optional. The faults detected by this function are implementation specific.

If the MDIO interface is implemented, then this function shall contribute to PMA/PMD receive fault bit as specified in 45.2.1.7.5.

72.6.10 PMD control function

72.6.10.1 Overview

The PMD control function generates the control actions required to bring the PMD from initialization to a mode in which data may be exchanged with the link partner.

The PMD control function implements the 10GBASE-KR start-up protocol. This protocol facilitates timing recovery and equalization while also providing a mechanism through which the receiver can tune the transmit equalizer to optimize performance over the backplane interconnect. The protocol supports these mechanisms through the continuous exchange of fixed-length training frames.

If EEE is supported, the PMD control function responds to PCS requests to transition in and out of quiet states.

72.6.10.2 Training frame structure

The training frame is a fixed length structure that is sent continuously during training. The training frame, shown in Figure 72–2, is 548 octets in length and contains a control channel and training pattern.

The control channel is signaled using differential Manchester encoding (DME) at a signaling rate equal to one quarter of the 10GBASE-KR signaling rate. Since each DME symbol contains two DME transition positions and each transition position is four 10GBASE-KR UI, one control channel bit is transmitted every eight 10GBASE-KR UI.

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Differential Manchester encoding guarantees transition density and DC balance while the reduced rate of transmission facilitates reception over non-optimally equalized channels.[28]

Training frames are delimited by a fixed 4 octet frame marker.

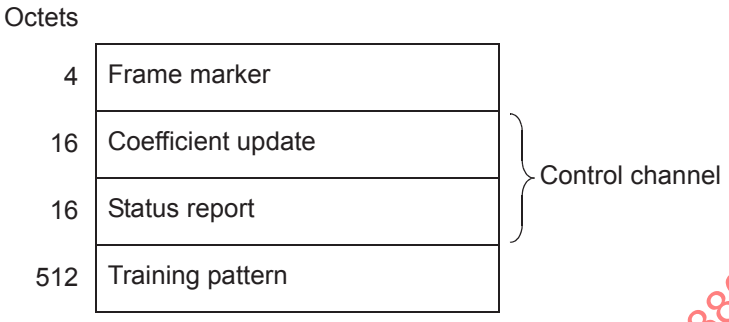

Figure 72–2—Training frame structure

72.6.10.2.1 Frame marker

Frames are delimited by the 32-bit pattern, hexadecimal 0xFFFF0000 (ones transmitted first), as expressed in 10.3125 Gbd symbols. This pattern does not appear in the control channel or the training pattern and therefore serves as a unique indicator of the start of a training frame.

72.6.10.2.2 Control channel encoding

The control channel shall be transmitted using differential Manchester encoding (DME). The rules of differential Manchester encoding are as follows:

a) A data transition shall occur at each cell boundary.
b) A mid-cell data transition shall be used to signal a logical one.
c) The absence of a mid-cell data transition shall be used to signal a logical zero.

If a coding violation is detected within the bounds of the control channel in a given training frame, the contents of the control channel for that frame shall be ignored.

The data cell length shall be 8 10GBASE-KR UI. Therefore, the total length of the control channel is 256 10GBASE-KR UI.

72.6.10.2.3 Coefficient update field

The coefficient update field carries correction information from the local receiver to the link partner transmit equalizer. The field consists of preset controls, initialization controls, and coefficient updates for three transmit equalizer taps. The format of the coefficient update field shall be as shown in Table 72–4. Cell 15 of the coefficient update field sent shall be transmitted first. The preset, initialize, and coefficient updates are set by the receiver adaptation process. The algorithm employed by the receiver adaptation process is beyond the scope of this standard.

[28]The differential Manchester encoding defined for Backplane Ethernet is different from that defined in IEEE Std 802.5™.

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Table 72–4—Coefficient update field

Cell(s)	Name	Description
15:14	Reserved	Transmitted as 0, ignored on reception.
13	Preset	1 = Preset coefficients 0 = Normal operation
12	Initialize	1 = Initialize coefficients 0 = Normal operation
11:6	Reserved	Transmitted as 0, ignored on reception.
5:4	Coefficient (+1) update	5 4 1 1 = reserved 0 1 = increment 1 0 = decrement 0 0 = hold
3:2	Coefficient (0) update	3 2 1 1 = reserved 0 1 = increment 1 0 = decrement 0 0 = hold
1:0	Coefficient (–1) update	1 0 1 1 = reserved 0 1 = increment 1 0 = decrement 0 0 = hold

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72.6.10.2.3.1 Preset

The preset control is sent to request that the coefficients be set to a state where equalization is turned off. When received, the pre-cursor ($k = -1$) and post-cursor ($k = +1$) coefficients shall be set to a zero value and the main ($k = 0$) coefficient shall be set to its maximum value. The preset control shall only be initially sent when all coefficient status fields indicate not_updated, and will then continue to be sent until the status for all coefficients indicates updated or maximum. At that point, the outgoing preset control shall be set to zero. Maximum status shall be returned when the main coefficient is updated. Maximum status shall be returned for the pre-cursor and/or post-cursor coefficients when the coefficient is updated and zero is its maximum supported value. Updated status shall be returned for the pre-cursor and/or post-cursor coefficients when the coefficient is updated and it supports additional settings above the value zero.

A new request to preset or initialize shall not be sent until the incoming status messages for all coefficients revert to not_updated. Preset shall not be sent in combination with initialize or coefficient increment/decrement requests.

72.6.10.2.3.2 Initialize

The initialize control is sent to request that the coefficients be set to configure the transmit equalizer to its INITIALIZE state. When received, the taps shall be set such that the transmit output meets the conditions defined in 72.6.10.4.2. The initialize control shall only be initially sent when all coefficient status fields indicate not_updated, and will then continue to be sent until no coefficient status field indicates not_updated.

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Updated status shall be returned for each coefficient when the coefficient update is completed. At that point, the outgoing initialize control shall be set to zero.

A new request to preset or initialize shall not be sent until the incoming status messages for all coefficients revert to not_updated. Initialize shall not be sent in combination with coefficient increment/decrement requests or preset.

72.6.10.2.3.3 Coefficient (*k*) update

Each coefficient, *k*, is assigned a 2-bit field describing a requested update. Three request encodings are defined: increment, decrement, and hold. The default state for a given tap is hold, which corresponds to no change in the coefficient. The increment or decrement encodings are transmitted to request that the corresponding coefficient be increased or decreased. The amount of change implemented by the transmitter in response to the coefficient update request shall meet the requirements of Table 72–7 and 72.7.1.10. An increment or decrement request shall continue to be transmitted until the update status for that tap (as defined in 72.6.10.2.4.5) indicates updated, maximum, or minimum. At that point, the outgoing requests for that tap shall be set to hold.

A new request to increment or decrement shall not be sent before the incoming status messages for that tap revert to not_updated. Coefficient increment/decrement shall not be sent in combination with initialize or preset.

The valid range for *k* is –1 to +1 where *k* = 0 denotes the main tap. The encoding of the coefficient update shall be as shown in Table 72–4.

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72.6.10.2.4 Status report field

The status report field is used to signal state information from the local PMD to the link partner. The format of the status report field shall be as shown in Table 72–5. Cell 15 of the status report field shall be transmitted first.

Table 72–5—Status report field

Cell(s)	Name	Description
15	Receiver ready	1 = The local receiver has determined that training is complete and is prepared to receive data. 0 = The local receiver is requesting that training continue.
14:6	Reserved	Transmitted as 0, ignored on reception
5:4	Coefficient (+1) status	5 4 1 1 = maximum 1 0 = minimum 0 1 = updated 0 0 = not_updated
3:2	Coefficient (0) status	3 2 1 1 = maximum 1 0 = minimum 0 1 = updated 0 0 = not_updated
1:0	Coefficient (–1) status	1 0 1 1 = maximum 1 0 = minimum 0 1 = updated 0 0 = not_updated

72.6.10.2.4.4 Receiver ready

The receiver ready bit is used to signal the local receiver state to the link partner. When asserted, the receiver ready bit indicates that the local receiver has concluded training and is prepared to receive data. When de-asserted, the receiver ready bit indicates that the local receiver is requesting that training continue. The format of the receiver ready bit shall be as shown in Table 72–5.

72.6.10.2.4.5 Coefficient (*k*) status

Each coefficient, *k*, is assigned a 2-bit field describing the status of pending updates to the coefficient. Four status encodings are defined: not updated, updated, maximum, and minimum.

These status encodings indicate the corresponding state of the coefficient update state diagram for coefficient *k*.

The valid range for *k* is –1 to +1 where *k* = 0 denotes the main tap. The encoding of the coefficient update shall be as shown in Table 72–5.

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72.6.10.2.5 Coefficient update process

Each coefficient, k, has an associated coefficient update state diagram that controls updates of the coefficient and generates the tap update status field.

The default state for a given tap is not_updated. An increment or decrement request will only be acted upon when the state of the tap is not_updated. Upon execution of a received increment or decrement request, the status is reported as updated, maximum, or minimum. Maximum is reported if a received increment request causes the tap value to reach its maximum limit, or if it is already at that limit. Minimum is reported if a received decrement request causes the tap value to reach its minimum limit, or if it is already at that limit.

Once the updated, maximum, or minimum state is reported it continues to be reported until a hold request is received, after which the status reverts to not_updated.

The coefficient update process responds to coefficient requests as specified in the state diagram shown in Figure 72–6.

72.6.10.2.6 Training pattern

The training pattern shall be a 512 octet pattern consisting of 4094 bits from the output of a pseudo-random bit sequence of order 11 (PRBS11) generator followed by two zeros. The PRBS11 pattern generator shall produce the same result as the implementation shown in Figure 72–3. This implements the generator polynomial shown in Equation (72–1).

$$G(x) = 1 + x^9 + x^{11} \tag{72–1}$$

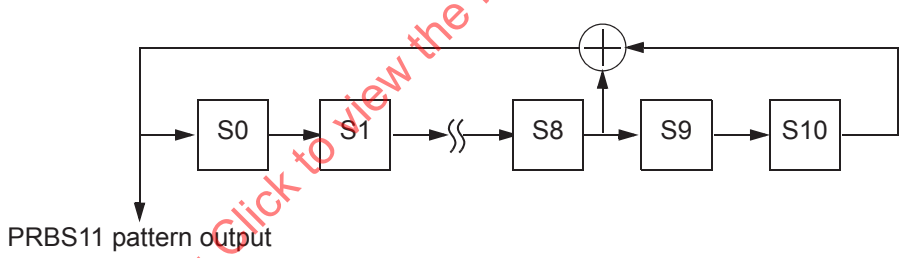

Figure 72–3—PRBS11 pattern generator

The pseudo-random generator shall have a random seed at the start of the training pattern. Each bit of the training pattern is transmitted as a single 10.3125 GBd symbol.

72.6.10.3 State variables

The notation used in the state diagrams follows the conventions of 21.5. State diagram timers follow the conventions of 14.2.3.2. The notation ++ after a counter or integer variable indicates that its value is to be incremented.

72.6.10.3.1 Variables

coefficient
: Integer variable containing a value that should be used as the tap coefficient.

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dec
: Boolean variable that is set to TRUE when a training frame has been completely received and the coefficient update field of that frame for this coefficient is decrement, and is set to FALSE on reception of any other value.

frame_lock
: Boolean variable that is set to TRUE when the receiver acquires training frame delineation and is set to FALSE otherwise.

frame_offset
: Boolean variable that is set to TRUE after receiving one full training frame (548 octets) from the current frame start position. The Boolean variable is set to FALSE when the GET_NEW_MARKER state is entered. The current frame start position is indicated by a transition into the GET_NEW_MARKER state when the Boolean variable is set to FALSE.

hold
: Boolean variable that is set to TRUE when a training frame has been completely received and the coefficient update field of that frame for this coefficient is hold, and neither preset or initialize are activated, and is set to FALSE on reception of any other value.

inc
: Boolean variable that is set to TRUE when a training frame has been completely received and the coefficient update field of that frame for this coefficient is increment, and set to FALSE on reception of any other value.

initialize
: Boolean variable that is set to TRUE when a training frame has been completely received and the initialize field of that frame is set to one and the preset field is set to zero, and is set to FALSE otherwise.

local_rx_ready
: Boolean variable that is set to TRUE by the training state diagram when rx_trained is asserted and is set to FALSE otherwise. This value is transmitted as the receiver ready bit on all outgoing training frames.

marker_valid
: Boolean variable that is set to TRUE when the candidate frame marker matches the specified frame marker pattern and is set to FALSE when the candidate frame marker does not match the specified frame marker pattern.

max_limit
: Integer variable containing the maximum tap coefficient value, subject to the constraints detailed in 72.7.1.10.

min_limit
: Integer variable containing the minimum tap coefficient value, subject to the constraints detailed in 72.7.1.10.

mr_restart_training
: Boolean variable used by system management to restart the 10GBASE-KR start-up protocol. When set to TRUE, it forces the training state diagram to the INITIALIZE state.

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mr_training_enable
: Boolean variable used by system management to enable or disable the 10GBASE-KR start-up protocol. It is set to TRUE when the start-up protocol is enabled and set to FALSE when the start-up protocol is disabled.

new_coeff
: Integer variable containing the result of increment/decrement operations on the coefficient value

new_marker
: Boolean variable that is set to TRUE when a new candidate frame marker is available for testing and FALSE when the TEST_MARKER state is entered. A new marker is available for testing when the training frame lock process has accumulated one frame marker (4 octets) from a candidate frame start position.

preset
: Boolean variable that is set to TRUE when a training frame has been completely received and the preset field of that frame is set to one and is set to FALSE if set to zero.

remote_rx_ready
: Boolean variable that is set to FALSE upon entry into the SEND_TRAINING state. The value of remote_rx_ready shall not be set to TRUE until no fewer than three consecutive training frames have been received with the receiver ready bit asserted.

reset
: Boolean variable that controls the resetting of the PMA/PMD. It is set to TRUE whenever a reset is necessary including when reset is initiated from the MDIO, during power on, and when the MDIO has put the PMA/PMD into low-power mode.

rx_trained
: Boolean variable that is set to TRUE when the remote transmit and local receive equalizers have been optimized and normal data transmission may commence and set to FALSE otherwise.

signal_detect
: Boolean variable that is set to TRUE when the training process is complete and is set to FALSE otherwise. The value of signal_detect is reported to the PMA sublayer via the PMD_SIGNAL.indication primitive.

slip_done
: Boolean variable that is set to TRUE when the SLIP requested by the Frame Lock State Diagram has been completed indicating that the next candidate frame sync position can be tested.

training
: Boolean variable that is set to TRUE to indicate that the 10GBASE-KR start-up protocol is in progress and is set to FALSE when training has completed.

training_failure
: Boolean variable that is set to TRUE when the training state diagram has timed out due to expiration of the max_wait_timer while in the SEND_TRAINING, TRAIN_LOCAL, or TRAIN_REMOTE states and is set to FALSE otherwise.

update_status
: Value to be transmitted in the Coefficient Status field for this coefficient in the next transmitted training frame, as defined in Table 72–8.

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72.6.10.3.2 Timers

max_wait_timer
: This timer is started in the INITIALIZE state of the training state diagram. If the max_wait_timer expires the training state diagram will enter the TRAINING_FAILURE state. The value of max_wait_timer shall be 500 ms ± 1%.

wait_timer
: This timer is started when the local receiver is trained and detects that the remote receiver is ready to receive data. The local PMD will deliver wait_timer additional training frames to ensure that the link partner correctly detects the local receiver state. The value of wait_timer shall be between 100 and 300 training frames.

72.6.10.3.3 Counters

bad_markers
: Count of the number of consecutive frame marker mis-matches.

good_markers
: Count of the number of consecutive frame marker matches.

72.6.10.3.4 Functions

COEFF_UPDATE(coefficient, preset, initialize, inc, dec)
: Returns an updated coefficient based on the contents of the coefficient update field in the training frame. Sets a fixed coefficient value, or adds, or subtracts from the current coefficient value to create the updated coefficient. If multiple actions are requested in the coefficient update field, then the priority is:

  1) preset
  2) initialize
  3) inc/dec

  Values: preset; If preset is TRUE then the function returns the coefficient value equivalent to no equalization [$c(-1)$ and $c(1)$ coefficients are set to zero, $c(0)$ set to maximum].
  initialize; If initialize is TRUE, then the function returns the coefficient value such that the transmit output meets the conditions defined in 72.6.10.4.2.
  inc; If inc is TRUE then the function returns (coefficient + step).
  dec; If dec is TRUE then the function returns (coefficient – step).

  The requirements for the value of step are defined in 72.7.1.10 and Table 72–7.

SLIP
: Causes the next candidate frame sync position to be tested. The precise method for determining the next candidate frame sync position is not specified and is implementation dependent. However, an implementation shall ensure that all possible bit positions are evaluated.

TRANSMIT(TRAINING, DATA)
: Controls the output of the TRANSMIT functional block.

  Values: TRAINING; the transmit block output is a continuous stream of training frames as defined in 72.6.10.2.
  DATA; the transmit block output is determined by the value of the input tx_bit.

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72.6.10.4 State diagrams

72.6.10.4.1 Frame lock

The 10GBASE-KR PMD shall implement the Frame Lock state diagram as depicted in Figure 72–4 including compliance with the associated state variables as specified in 72.6.10.3. The frame lock state diagram determines when the PMD control function has detected the frame boundaries in the received data stream.

72.6.10.4.2 Training

The 10GBASE-KR PMD shall implement the Training state diagram as depicted in Figure 72–5 including compliance with the associated state variables as specified in 72.6.10.3. The training state diagram defines the operation of the 10GBASE-KR start-up protocol. When the training state diagram enters the INITIALIZE state, the transmitter equalizer shall be configured such that R_{pre} and R_{pst} are 1.29 ± 10% and 2.57 ± 10% respectively. R_{pre} and R_{pst} are defined in 72.7.1.11. At the start of training the initial value of c(0) shall be set such that the constraints of 72.7.1.11 are satisfied and the peak-to-peak differential output voltage shall be greater than or equal to 800 mV for a 1010 pattern.

72.6.10.4.3 Coefficient update

For each tap, the 10GBASE-KR PMD shall implement an instance of the coefficient update state diagram as depicted in Figure 72–6 including compliance with the associated state variables as specified in 72.6.10.3. The coefficient update state diagram defines the process for updating transmit equalizer coefficients in response to requests from the link partner, and also defines the coefficient update status to be reported in outgoing training frames.

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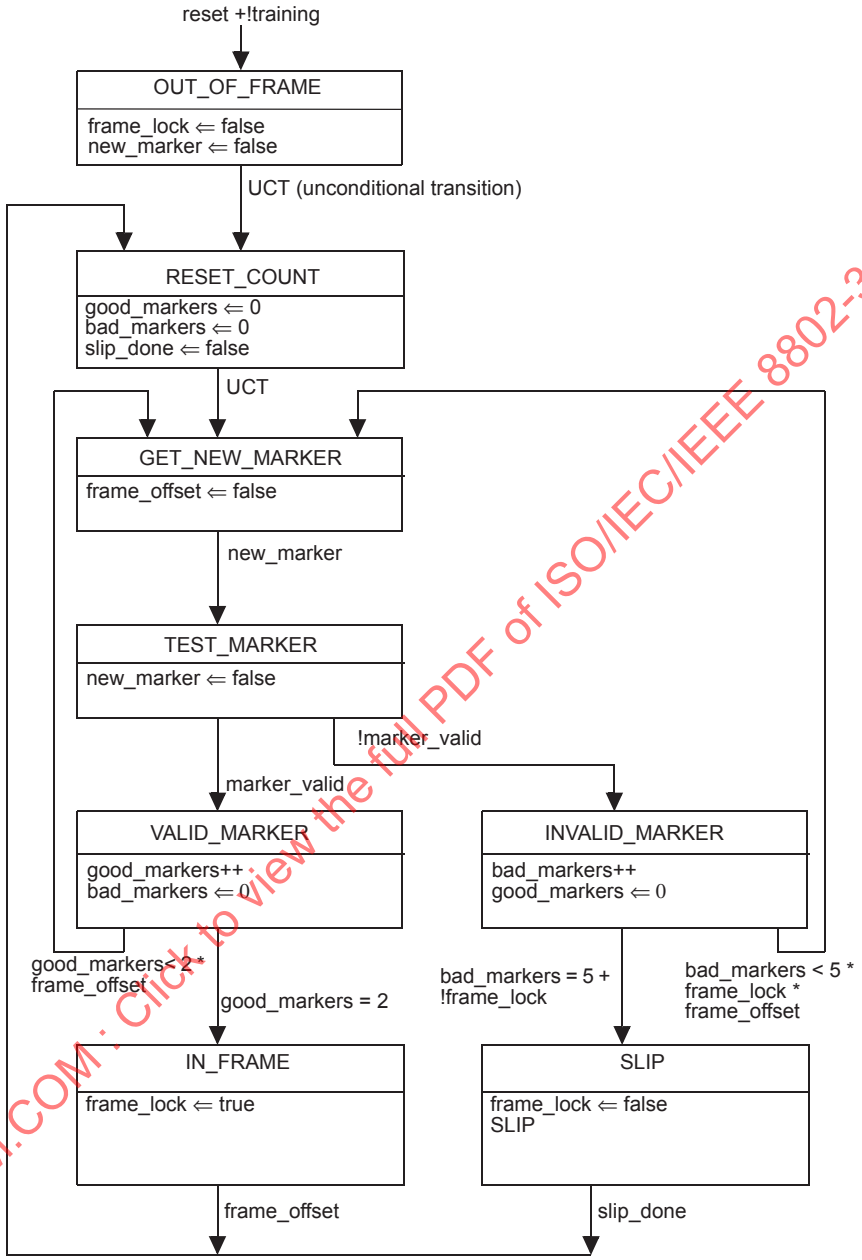

Figure 72–4—Frame lock state diagram

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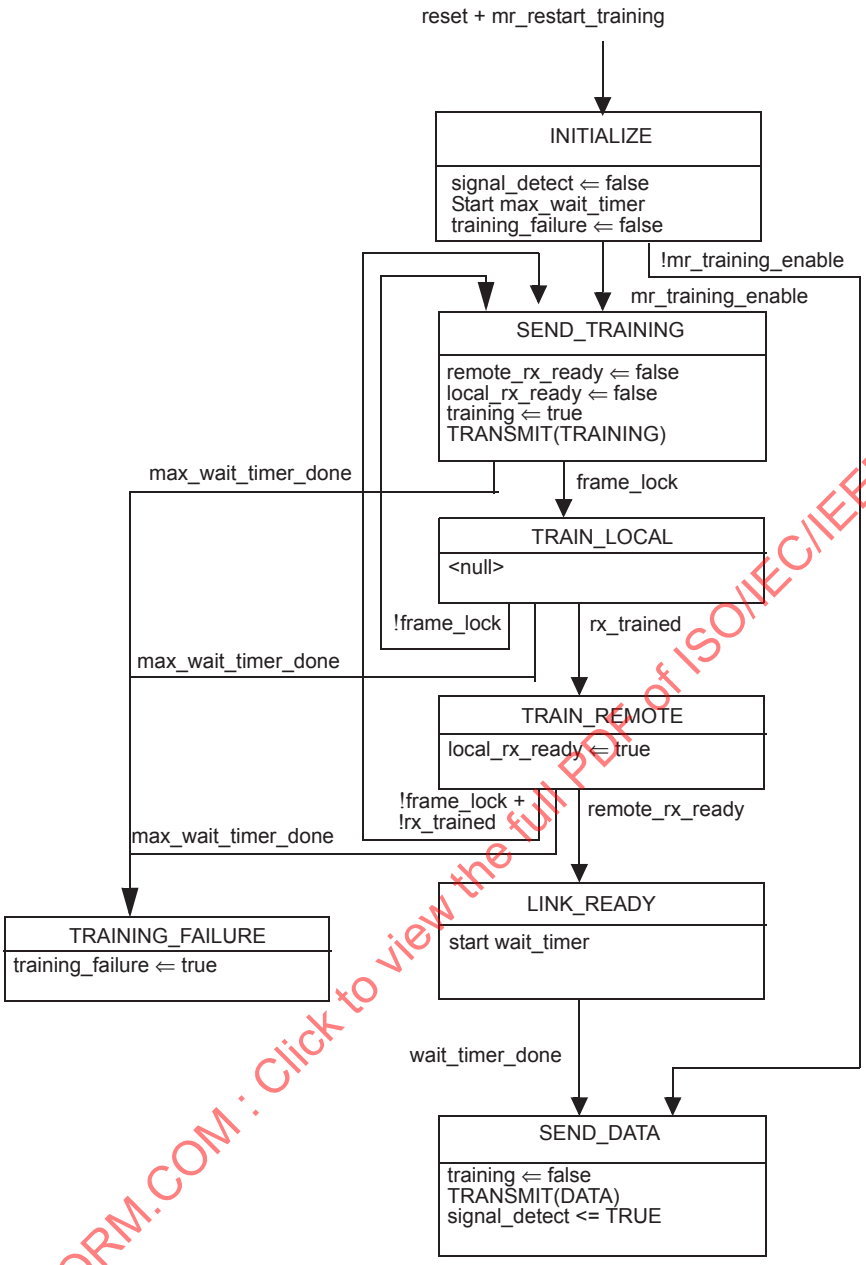

Figure 72–5—Training state diagram

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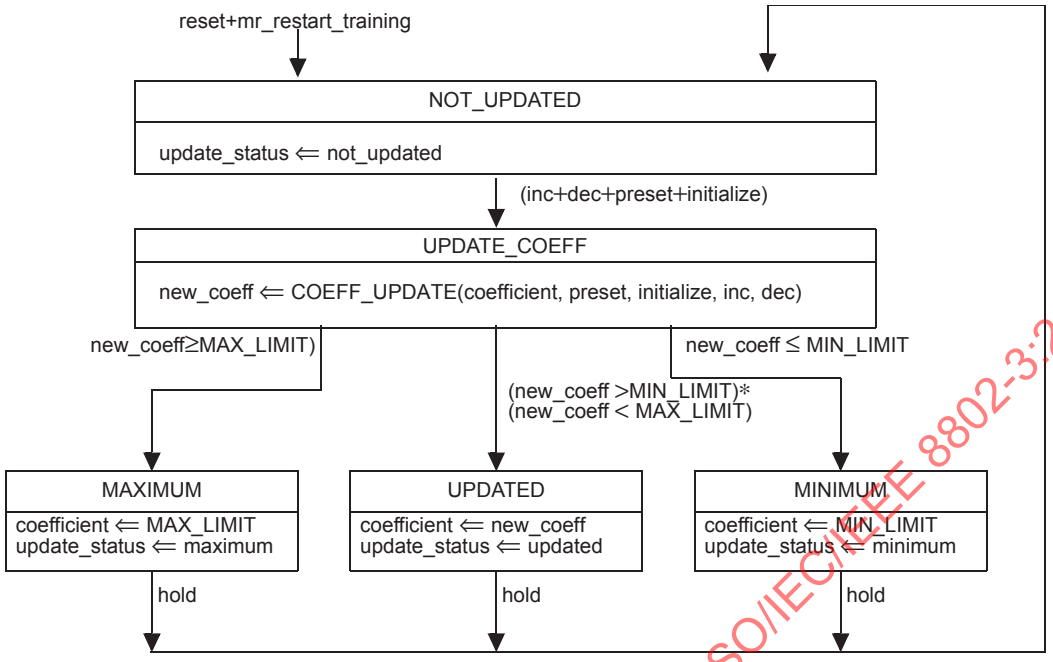

Figure 72–6—Coefficient update state diagram

72.6.11 PMD LPI function

The PMD LPI function responds to the transitions between Active, Sleep, Quiet, Refresh, and Wake states via the PMD_TX_MODE and PMD_RX_MODE requests. Implementation of the function is optional. EEE capabilities and parameters will be advertised during the Backplane Auto-negotiation, as described in 45.2.7.13. The transmitter on the local device will inform the link partner's receiver when to sleep, refresh and wake. The local receiver transitions are controlled by the link partner's transmitter and can change independent of the local transmitter states and transitions.

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72.7 10GBASE-KR electrical characteristics

72.7.1 Transmitter characteristics

Transmitter characteristics at TP1 are summarized in Table 72–6 and detailed in 72.7.1.1 through 72.7.1.11.

Table 72–6—Transmitter characteristics for 10GBASE-KR

Parameter	Subclause reference	Value	Units
Signaling speed	72.7.1.3	10.3125 ± 100 ppm	GBd
Differential peak-to-peak output voltage (max.)	72.7.1.4	1200	mV
Differential peak-to-peak output voltage (max.) with TX disabled	72.6.5	30	mV
Common-mode voltage limits	72.7.1.4	0 to 1.9	V
Common-mode voltage deviation (max) during LPI	72.7.1.4	150	mV
Differential output return loss (min.)	72.7.1.5	[See Equation (72–4) and Equation (72–5)]	dB
Common-mode output return loss (min.)	72.7.1.6	[See Equation (72–6) and Equation (72–7)]	dB
Transition time (20%–80%)	72.7.1.7	24 to 47	ps
Max output jitter (peak-to-peak) Random jitter[a] Deterministic jitter Duty Cycle Distortion[b] Total jitter	72.7.1.9	 0.15 0.15 0.035 0.28	 UI UI UI UI

[a]Jitter is specified at BER 10^{-12}.
[b]Duty Cycle Distortion is considered part of the deterministic jitter distribution.

72.7.1.1 Test fixture

The test fixture of Figure 72–7 or its functional equivalent, is required for measuring the transmitter specifications described in 72.7.1, with the exception of return loss.

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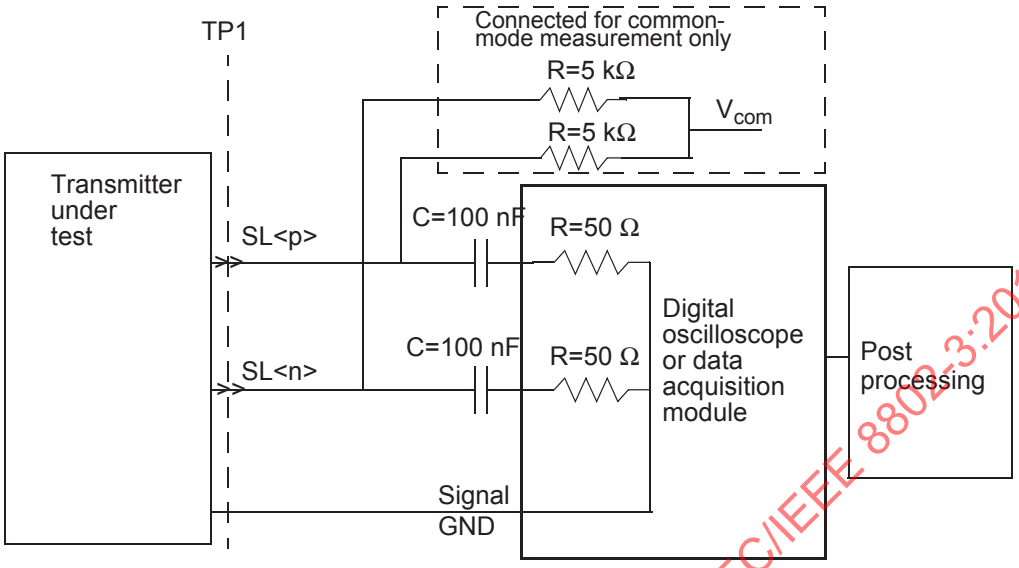

Figure 72–7—Transmit test fixture for 10GBASE-KR

72.7.1.2 Test fixture impedance

The differential load impedance applied to the transmitter output by the test fixture depicted in Figure 72–7 shall be 100 Ω. The differential return loss, in dB with f in MHz, of the test fixture shall meet the requirements of Equation (72–2) and Equation (72–3).

$$ReturnLoss(f) \geq 15 \tag{72–2}$$

for 100 MHz ≤ f < 5000 MHz

$$ReturnLoss(f) \geq 15 - 26.57\log_{10}\left(\frac{f}{5000\ \text{MHz}}\right) \tag{72–3}$$

for 5000 MHz ≤ f ≤ 10000 MHz

72.7.1.3 Signaling speed

The 10GBASE-KR signaling speed shall be 10.3125 GBd ± 100 ppm.

72.7.1.4 Output amplitude

The differential output voltage is constrained via the transmitter output waveform requirements specified in 72.7.1.10. For a 1010 pattern, the peak-to-peak differential output voltage shall be less than 1200 mV, regardless of equalization setting. The transmitter output voltage shall be less than 30 mV peak-to-peak when disabled. The differential output voltage test pattern shall consist of no fewer than eight symbols of alternating polarity.

NOTE 1—The required test patterns may be found in the training pattern field of the training frames or test patterns 2 or 3 as defined in 52.9.1.1.

NOTE 2—See Figure 72–8 for an illustration of the definition of differential peak-to-peak output voltage.

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DC-referenced voltage levels are not defined since the receiver is AC-coupled. The common-mode voltage of SL<p> and SL<n> shall be between 0 V and 1.9 V with respect to signal ground as measured at V_{com} in Figure 72–7.

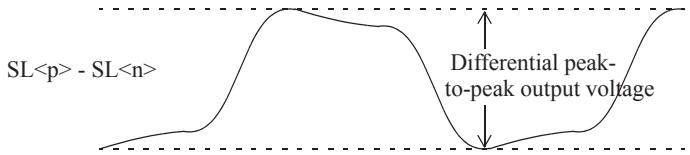

Figure 72–8—Transmitter differential peak-to-peak output voltage definition

NOTE—SL<p> and SL<n> are the positive and negative sides of the differential signal pair.

For EEE capability, the transmitter's differential peak-to-peak output voltage shall be less than 30 mV within 500 ns of tx_mode being set to QUIET and remain so while tx_mode is set to QUIET. Furthermore, the transmitter's differential peak-to-peak output voltage shall be greater than 720 mV within 500 ns of tx_mode being set to ALERT. The transmitter output shall be fully compliant within 5 µs after tx_mode is set to DATA. During LPI mode, the common-mode shall be maintained to within ± 150 mV of the pre-LPI value.

72.7.1.5 Differential output return loss

For frequencies from 50 MHz to 7500 MHz, the differential return loss, in dB with f in MHz, of the transmitter shall meet the requirements of Equation (72–4) and Equation (72–5). This output impedance requirement applies to all valid output levels. The reference impedance for differential return loss measurements shall be 100 Ω.

$$ReturnLoss(f) \geq 9 \tag{72–4}$$

for 50 MHz ≤ f < 2500 MHz

$$ReturnLoss(f) \geq 9 - 12\log_{10}\left(\frac{f}{2500\ \text{MHz}}\right) \tag{72–5}$$

for 2500 MHz ≤ f ≤ 7500 MHz

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The minimum differential output return loss is shown in Figure 72–9.

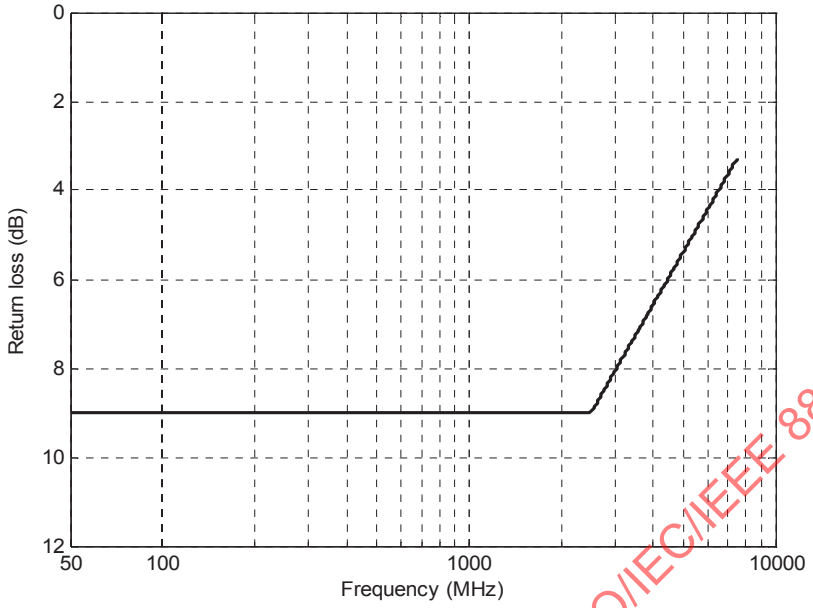

Figure 72–9—Minimum differential output return loss

72.7.1.6 Common-mode output return loss

The transmitter common-mode return loss shall meet the requirements of Equation (72–6) and Equation (72–7). The reference impedance for common-mode return loss measurements is 25 Ω.

$$ReturnLoss(f) \geq 6 \tag{72–6}$$

for 50 MHz ≤ f < 2500 MHz

$$ReturnLoss(f) \geq 6 - 12\log_{10}\left(\frac{f}{2500\ \text{MHz}}\right) \tag{72–7}$$

for 2500 MHz ≤ f ≤ 7500 MHz

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The minimum common-mode output return loss is shown in Figure 72–10.

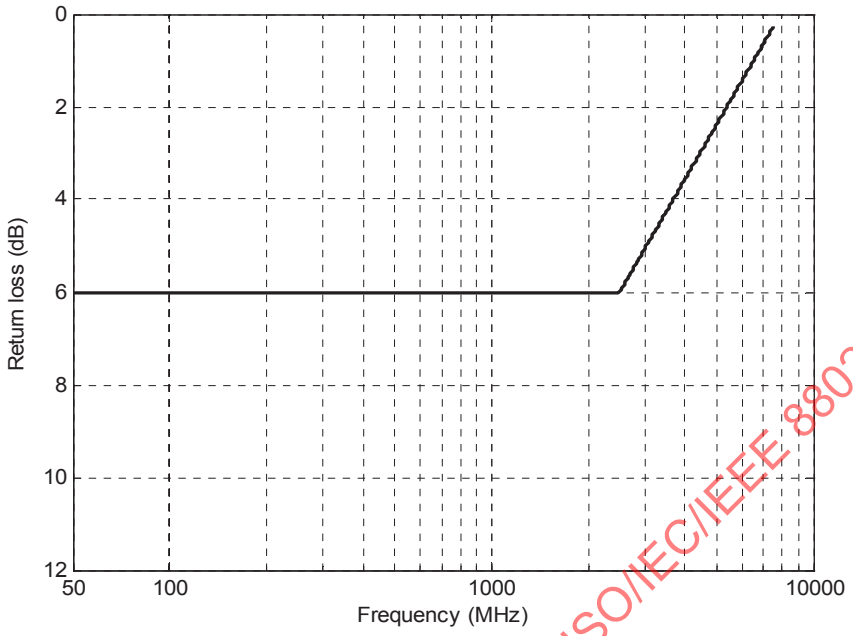

Figure 72–10—Minimum common-mode output return loss

72.7.1.7 Transition time

The rising and falling edge transition times shall be between 24 ps and 47 ps as measured at the 20% and 80% levels referenced to v_2 and v_5 as defined in 72.7.1.11. Measurement is done using the square wave test pattern defined in 52.9.1.2, with no equalization and a run of at least eight consecutive ones. Transmit equalization may be disabled by asserting the preset control defined in Table 45–62 and 45.2.1.82.3.

72.7.1.8 Transmit jitter test requirements

Transmit jitter is defined with respect to a test procedure resulting in a BER bathtub curve such as that described in Annex 48B.3. For the purpose of jitter measurement, the effect of a single-pole high-pass filter with a 3 dB point at 4 MHz is applied to the jitter. The data pattern for jitter measurements shall be test patterns 2 or 3 as defined in 52.9.1.1. Crossing times are defined with respect to the mid-point (0 V) of the AC-coupled differential signal. Equalization shall be off during jitter testing. Transmit equalization may be disabled by asserting the preset control defined in Table 45–62 and 45.2.1.82.3.

The duty cycle distortion test pattern shall consist of no fewer than eight symbols of alternating polarity.

NOTE—The required test patterns may be found in the training pattern field of the training frames or test patterns 2 or 3 as defined in 52.9.1.1.

72.7.1.9 Transmit jitter

The transmitter shall have a maximum total jitter of 0.28 UI peak-to-peak, composed of a maximum deterministic component of 0.15 UI peak-to-peak and a maximum random component of 0.15 UI peak-to-peak. Duty cycle distortion (DCD) is considered a component of deterministic jitter and shall not exceed 0.035 UI peak-to-peak. The peak-to-peak duty cycle distortion is defined as the absolute value of the difference in the mean pulse width of a 1 pulse or the mean pulse width of a 0 pulse (as measured at the mean of the high- and

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low-voltage levels in a clock-like repeating 0101 bit sequence) and the nominal pulse width. Jitter specifications are specified for BER 10^{-12}. Transmit jitter test requirements are specified in 72.7.1.8.

72.7.1.10 Transmitter output waveform

The 10GBASE-KR transmitter includes programmable equalization to compensate for frequency-dependent loss in the backplane channel and facilitate data recovery at the receiver. This equalization may be accomplished with a three-tap finite impulse response (FIR) structure as shown in Figure 72–11. The actual implementation of the transmit equalizer, including the incorporation of additional taps, is beyond the scope of this standard.

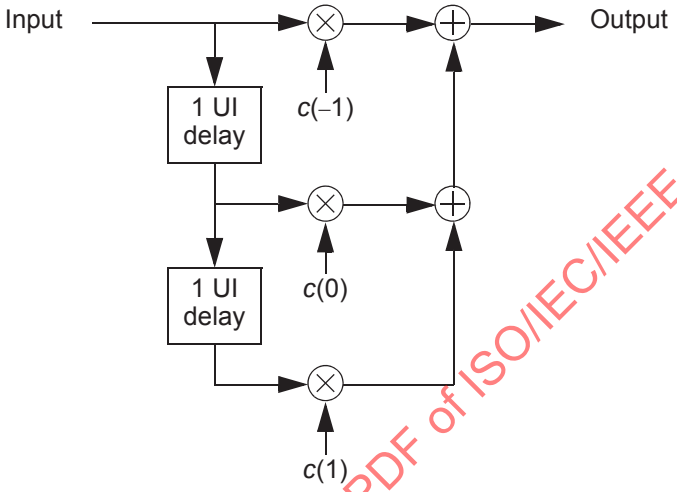

Figure 72–11—Transmit equalizer example

Transmit equalizer performance is specified in terms of the voltages defined in 72.7.1.11. It should be noted that the valid ranges of the $c(1)$ and $c(-1)$ coefficients may include positive and negative values. A value of zero is used to turn off equalization for the tap.

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72.7.1.11 Transmitter output waveform requirements

The test pattern for the transmitter output waveform is the square wave test pattern defined in 52.9.1.2, with a run of at least eight consecutive ones. The transmitter output waveform test is based on the voltages v_1 through v_6, Δv_2, and Δv_5, which shall be measured as shown in Figure 72–12 and described below.

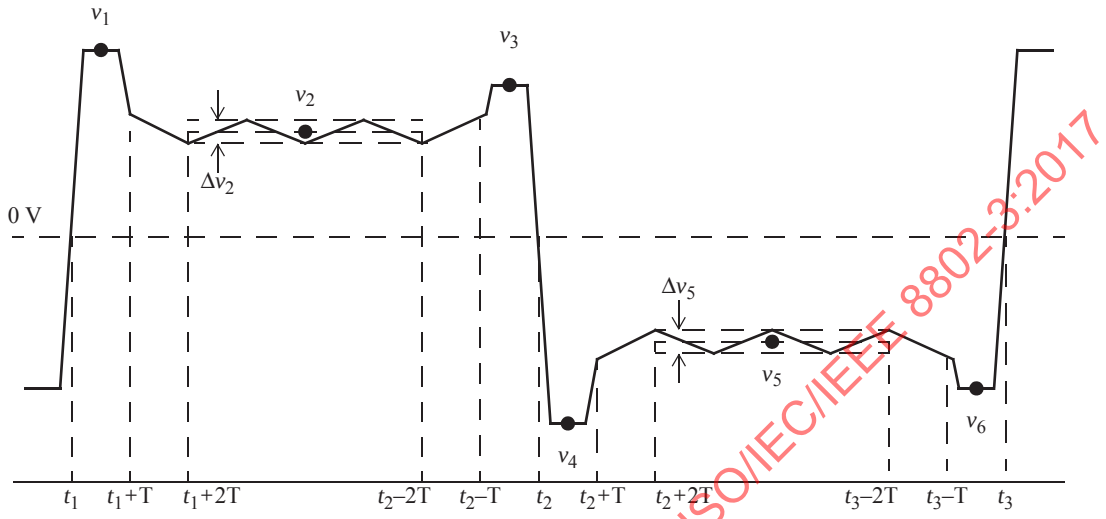

Figure 72–12—Transmitter output waveform

T	=	symbol period
t_1	=	zero-crossing point of the first rising edge of the AC-coupled signal
t_2	=	zero-crossing point of the falling edge of the AC-coupled signal
t_3	=	zero-crossing point of the second rising edge of the AC-coupled signal
v_1	=	maximum voltage measured in the interval t_1 to t_1 + T
v_2	=	positive steady-state voltage measured as the average voltage in the interval t_1 + 2T to t_2 – 2T
v_3	=	maximum voltage measured in the interval t_2 – T to t_2
v_4	=	minimum voltage measured in the interval t_2 to t_2 + T
v_5	=	negative steady-state voltage measured as the average voltage in the interval t_2 + 2T to t_3 – 2T
v_6	=	minimum voltage measured in the interval t_3 – T to t_3
Δv_2	=	positive voltage ripple measured as the peak-to-peak value of the difference between the voltage in the range t_1 + 2T to t_2 – 2T and v_2
Δv_5	=	negative voltage ripple measured as the peak-to-peak value of the difference between the voltage in the range t_2 + 2T to t_3 – 2T and v_5

From these voltages, the pre- and post-cursor equalization ratios R_{pre} and R_{pst} are derived from Equation (72–8) and Equation (72–9).

$$R_{pre} = \frac{v_3}{v_2} \tag{72–8}$$

$$R_{pst} = \frac{v_1}{v_2} \tag{72–9}$$

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The state of the transmitter equalizer and hence the transmitter output waveform is manipulated via the protocol defined in 72.6.10 or via management. The changes in the transmitter output waveform resulting from coefficient update requests shall meet the requirements stated in Table 72–7. The coefficient update requests in Table 72–7 are to be followed by a coefficient update equal to hold for all taps. The results shall be verified after the coefficient status for all taps is reported as not_updated.

Table 72–7—Transmitter output waveform requirements related to coefficient update

Coefficient update[a]			Requirements[b]		
$c(1)$	$c(0)$	$c(-1)$	$v_1(k) - v_1(k-1)$ (mV)	$v_2(k) - v_2(k-1)$ (mV)	$v_3(k) - v_3(k-1)$ (mV)
increment	hold	hold	–20 to –5	5 to 20	5 to 20
decrement	hold	hold	5 to 20	–20 to –5	–20 to –5
hold	increment	hold	5 to 20	5 to 20	5 to 20
hold	decrement	hold	–20 to –5	–20 to –5	–20 to –5
hold	hold	increment	5 to 20	5 to 20	–20 to –5
hold	hold	decrement	–20 to –5	–20 to –5	5 to 20

[a]Step size requirements for the tap under test apply regardless of the current value of the other taps.
[b]This difference is measured relative to the voltage prior to the assertion coefficient update k equal to hold.

For any coefficient update, the magnitudes of the changes in v_1, v_2, and v_3 shall be within 5 mV of each other. When sufficient increment or decrement updates have been applied to a given tap, it will reach a maximum or minimum limit governed by the coefficient range or by restrictions placed on minimum steady-state or maximum peak voltage, and the coefficient status is reported accordingly. The transmitter output waveform shall meet the requirements of Table 72–8 for all of the limiting cases represented in the table. Implementation of $c(-1)$ or $c(1)$ coefficient values greater than zero or less than the minimum defined by R_{pre} (min) and R_{pst} (min) is optional. A coefficient may be disabled by first asserting the preset control defined in Table 45–101 and 45.2.1.82, then manipulating the other coefficients as required by the test.

Table 72–8—Transmitter output waveform requirements related to coefficient status

Coefficient status			Requirements		
$c(1)$	$c(0)$	$c(-1)$	R_{pre}	R_{pst}	v_2 (mV)
disabled	minimum	disabled	0.90 to 1.10	0.90 to 1.10	220 to 330
disabled	maximum	disabled	0.95 to 1.05	0.95 to 1.05	400 to 600
minimum	minimum	disabled	—	4.00 (min)	—
disabled	minimum	minimum	1.54 (min)	—	—

In addition:

a) The quantities Δv_2 and Δv_5 shall not exceed 40 mV peak-to-peak.

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b) The positive and negative voltages shall match such that each of the quantities $(v_1 + v_4)/v_1$, $(v_2 + v_5)/v_2$, and $(v_3 + v_6)/v_3$ does not exceed 0.05.
c) The quantity v_2 shall be greater than or equal to 40 mV.
d) Any coefficient update equal to decrement applied to any tap that would result in v_2 less than 40 mV shall return a coefficient status value minimum.
e) Any coefficient update equal to decrement that would result in a violation of 72.7.1.4 shall return a coefficient status value minimum for that coefficient.
f) Any coefficient update equal to increment that would result in a violation of 72.7.1.4 shall return a coefficient status value maximum for that coefficient.

72.7.2 Receiver characteristics

Receiver characteristics at TP4 are summarized in Table 72–9 and detailed in 72.7.2.1 through 72.7.2.5.

Table 72–9—Receiver characteristics for 10GBASE-KR

Parameter	Subclause reference	Value	Units
Bit error ratio	72.7.2.1	10^{-12}	
Signaling speed	72.7.2.2	10.3125 ± 100 ppm	GBd
Receiver coupling	72.7.2.3	AC	
Differential input peak-to-peak amplitude (maximum)	72.7.2.4	1200[a]	mV
Differential input return loss (minimum)[b]	72.7.2.5	[See Equation (72–4) and Equation (72–5)]	dB

[a]The receiver shall tolerate amplitudes up to 1600 mV without permanent damage.
[b]Relative to 100 Ω differential.

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72.7.2.1 Receiver interference tolerance

The receiver interference tolerance shall consist of two separate tests as described in Annex 69A with the parameters specified in Table 72–10. The data pattern for the interference tolerance test shall be the test patterns 2 or 3 as defined in 52.9.1.1. The receiver shall satisfy the requirements for interference tolerance specified in Annex 69A for both tests.

Table 72–10—10GBASE-KR interference tolerance parameters

Parameter	Test 1 values	Test 2 values	Units
Target BER	10^{-12}	10^{-12}	
m_{TC} (min.)[a]	1.0	0.5	
Amplitude of broadband noise (min. RMS)	5.2	12	mV
Applied transition time (20%–80%, min.)	47	47	ps
Applied Sinusoidal jitter (min. peak-to-peak)	0.115	0.115	UI
Applied random jitter (min. peak-to-peak)[b]	0.130	0.130	UI
Applied Duty Cycle Distortion (min. peak-to-peak)	0.035	0.035	UI

[a] m_{TC} is defined in Equation (69A–6) of Annex 69A.
[b] Applied random jitter is specified at a BER of 10^{-12}.

72.7.2.2 Signaling speed range

A 10GBASE-KR receiver shall comply with the requirements of Table 72–9 for any signaling speed in the range 10.3125 GBd ± 100 ppm.

72.7.2.3 AC-coupling

The 10GBASE-KR receiver shall be AC-coupled to the backplane to allow for maximum interoperability between various 10 Gb/s components. AC-coupling is considered to be part of the receiver for the purposes of this specification unless explicitly stated otherwise. It should be noted that there may be various methods for AC-coupling in actual implementations.

NOTE—It is recommended that the maximum value of the coupling capacitors be limited to 100 nF. This will limit the inrush currents to the receiver that could damage the receiver circuits when repeatedly connected to transmit modules with a higher voltage level.

72.7.2.4 Input signal amplitude

10GBASE-KR receivers shall accept differential input signal peak-to-peak amplitudes produced by compliant transmitters connected without attenuation to the receiver, and still meet the BER requirement specified in 72.7.2.1. Note that this may be larger than the 1200 mV differential maximum of 72.7.1.4 due to the actual transmitter output and receiver input impedances. The input impedance of a receiver can cause the minimum signal into a receiver to differ from that measured when the receiver is replaced with a 100 Ω test load. Since the channel is AC-coupled, the absolute voltage levels with respect to the receiver ground are dependent on the receiver implementation.

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72.7.2.5 Differential input return loss

For frequencies from 100 MHz to 7500 MHz, the differential return loss, in dB with *f* in MHz, of the receiver shall be greater than or equal to Equation (72–4) and Equation (72–5). This return loss requirement applies at all valid input levels. The reference impedance for differential return loss measurements is 100 Ω.

72.8 Interconnect characteristics

Informative interconnect characteristics for 10GBASE-KR are provided in Annex 69B.

72.9 Environmental specifications

72.9.1 General safety

All equipment that meets the requirements of this standard shall conform to applicable sections (including isolation requirements) of IEC 60950-1.

72.9.2 Network safety

The designer is urged to consult the relevant local, national, and international safety regulations to ensure compliance with the appropriate requirements.

72.9.3 Installation and maintenance guidelines

It is recommended that sound installation practice, as defined by applicable local codes and regulations, be followed in every instance in which such practice is applicable.

72.9.4 Electromagnetic compatibility

A system integrating the 10GBASE-KR PHY shall comply with applicable local and national codes for the limitation of electromagnetic interference.

72.9.5 Temperature and humidity

A system integrating the 10GBASE-KR PHY is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling (such as shock and vibration). Specific requirements and values for these parameters are considered to be beyond the scope of this standard.

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72.10 Protocol implementation conformance statement (PICS) proforma for Clause 72, Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-KR[29]

72.10.1 Introduction

The supplier of a protocol implementation that is claimed to conform to IEEE Std 802.3, Clause 72, Physical Medium Dependent (PMD) sublayer and baseband medium type 10GBASE-KR, shall complete the following protocol implementation conformance statement (PICS) proforma. A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

72.10.2 Identification

72.10.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

72.10.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 72, Physical Medium Dependent (PMD) sublayer and baseband medium type 10GBASE-KR
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	
Date of Statement	

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[29]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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72.10.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
XGE	XGMII	72.1, 46	Interface is supported	O	Yes [ ] No [ ]
XGXS	XGXS and XAUI	72.1, 47		O	Yes [ ] No [ ]
PCS	Support of 10GBASE-R PCS	72.1, 49		M	Yes [ ]
PMA	Support of 10 Gigabit serial PMA	72.1, 51		M	Yes [ ]
AN	Auto-Negotiation for Backplane Ethernet	72.1, 73	Device implements Auto-Negotiation for Backplane Ethernet	M	Yes [ ]
FEC	Forward Error Correction	72.1, 74	Device implements 10GBASE-R Forward Error Correction	O	Yes [ ] No [ ]
DC	Delay Constraints	72.4	Device conforms to delay constraints	M	Yes [ ]
LPI	LPI	72.6.11	LPI	O	Yes [ ] No [ ]
*MD	MDIO interface	72.5	Device implements MDIO	O	Yes [ ] No [ ]
*TD	Global_PMD_transmit_disable	72.6.5		O	Yes [ ] No [ ]

72.10.4 PICS proforma tables for Clause 72, Physical Medium Dependent (PMD) sublayer and baseband medium, type 10GBASE-KR

72.10.4.1 PCS requirements for AN service interface

Item	Feature	Subclause	Value/Comment	Status	Support
PR1	AN service interface primitive	72.3	The PCS associated with this PMD supports the AN service interface primitive AN_LINK.indication defined in 73.9	M	Yes [ ]

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72.10.4.2 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FS1	Transmit function	72.6.2	Conveys bits from PMD service interface to MDI	M	Yes [ ]
FS2	Transmitter signal	72.6.2	A positive differential voltage corresponds to tx_bit = ONE	M	Yes [ ]
FS3	Receive function	72.6.3	Conveys bits from MDI to PMD service interface	M	Yes [ ]
FS4	Receiver signal	72.6.3	A positive differential voltage corresponds to rx_bit = ONE	M	Yes [ ]
FS5	Signal detect	72.6.4	Report to PMD service interface	M	Yes [ ]
FS6	Global signal detect	72.6.4	Value described in 45.2.1.9.7	M	Yes [ ]
FS7	SIGNAL_DETECT value	72.6.4	Set to FAIL	M	Yes [ ]
FS8	SIGNAL_DETECT value	72.6.4	Set to OK when traning is complete	M	Yes [ ]
FS9	SIGNAL_DETECT value	72.6.4	Set to OK when training disabled	M	Yes [ ]
FS10	Signal detect during LPI	72.6.4	Detect signal energy during LPI	LPI:M	Yes [ ] N/A[ ]
FS11	Signal detect for EEE	72.6.4	Transition timing to set SIGNAL_DETECT	LPI:M	Yes [ ] N/A [ ]
FS12	Transmit disable requirements	72.6.5	Requirements of 72.6.5 and Table 72–6	TD:M	Yes [ ] N/A[ ]
FS13	Transmit disable during LPI	72.6.5	Disable transmitter during tx_mode = QUIET	LPI:M	Yes [ ] N/A[ ]
FS14	Loopback support	72.6.6	Provided for 10GBASE-KR PMD by transmitter and receiver	M	Yes [ ]

72.10.4.3 Management functions

Item	Feature	Subclause	Value/Comment	Status	Support
MF1	MDIO Variable Mapping	72.5	Per Table 72–2 and Table 72–3	MD:M	Yes [ ] N/A [ ]
MF2	PMD_transmit_fault function	72.6.8	Sets PMD_transmit_fault as specified in 45.2.1.7.4	MD:M	Yes [ ] N/A [ ]
MF3	PMD_receive_fault function	72.6.9	Sets PMD_receive_fault as specified in 45.2.1.7.5	MD:M	Yes [ ] N/A [ ]

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72.10.4.4 PMD Control functions

Item	Feature	Subclause	Value/Comment	Status	Support
CF1	Control Channel Encoding	72.6.10.2.2	Control channel transmitted using differential Manchester encoding (DME)	M	Yes [ ]
CF2	Differential Manchester Encoding rules	72.6.10.2.2	Transitions at cell boundary.	M	Yes [ ]
CF3	Differential Manchester Encoding rules	72.6.10.2.2	Presence of a mid-cell transition to signal logic 1	M	Yes [ ]
CF4	Differential Manchester Encoding rules	72.6.10.2.2	Absence of a mid-cell transition to signal logic 0	M	Yes [ ]
CF5	Coding violation	72.6.10.2.2	Ignore contents of control channel if coding violation found	M	Yes [ ]
CF6	Coefficient update field format	72.6.10.2.3	Format of the coefficient update field per Table 72–4	M	Yes [ ]
CF7	Cell 15 of the coefficient update field	72.6.10.2.3	Transmitted first	M	Yes [ ]
CF8	Preset control	72.6.10.2.3.1	When received, pre-cursor and post-cursor coefficients set to zero	M	Yes [ ]
CF9	Preset control	72.6.10.2.3.1	When received, main coefficient set to maximum value	M	Yes [ ]
CF10	Preset control initially sent	72.6.10.2.3.1	Only when all coefficient status fields indicate not_updated and continues until all coefficients indicate updated or maximum	M	Yes [ ]
CF11	Outgoing initialize control	72.6.10.2.3.1	Set to zero when all coefficients indicate updated or maximum following preset	M	Yes [ ]
CF12	Maximum status	72.6.10.2.3.1	Returned when the main coefficient is updated	M	Yes [ ]
CF13	Maximum status	72.6.10.2.3.1	Returned for pre-cursor and/or post-cursor coefficients when coefficient updated and zero is its maximum value	M	Yes [ ]
CF14	Updated status	72.6.10.2.3.1	Returned for pre-cursor and/or post-cursor coefficients when the coefficient is updated and it supports additional settings above the value zero	M	Yes [ ]
CF15	New Preset or Initialize requests	72.6.10.2.3.1	Not sent until the incoming status for all coefficients revert to not_updated	M	Yes [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
CF16	Preset	72.6.10.2.3.1	Not sent in combination with initialize or ceofficient increment/decrement requests	M	Yes [ ]
CF17	Initalize control	72.6.10.2.3.2	When received, taps set to meet conditions of 72.6.10.4.2	M	Yes [ ]
CF18	Initalize control initially sent	72.6.10.2.3.2	Only when all coefficient status fields indicate not_updated and continues until all coefficients indicate updated	M	Yes [ ]
CF19	Updated status	72.6.10.2.3.2	Returned for each coefficient when the coefficient update is complete	M	Yes [ ]
CF20	Outgoing initalize field	72.6.10.2.3.2	Set to zero when all coefficients indicate update complete following initialize	M	Yes [ ]
CF21	New Preset or Initialize requests	72.6.10.2.3.2	Not sent until the incoming status for all coefficients revert to not_updated	M	Yes [ ]
CF22	Initialize	72.6.10.2.3.2	Not sent in combination with coefficient increment/decrement requests	M	Yes [ ]
CF23	Increment or decrement encodings transmitted	72.6.10.2.3.3	Transmitted until status indicates: updated, maximum, or minimum	M	Yes [ ]
CF24	Outgoing requests	72.6.10.2.3.3	Set to hold once update status for tap indicates updated, maximum or minimum	M	Yes [ ]
CF25	Increment or decrement request	72.6.10.2.3.3	Not sent before status reverts to not_updated	M	Yes [ ]
CF26	Encoding of coefficient update	72.6.10.2.3.3	Per Table 72–4	M	Yes [ ]
CF27	Format of status report field	72.6.10.2.4	Per Table 72–5	M	
CF28	Cell 15 of the status report field	72.6.10.2.4	Transmitted first	M	
CF29	Receiver ready indication	72.6.10.2.4.4	Per Table 72–5	M	Yes [ ]
CF30	Coefficient status	72.6.10.2.4.5	Per Table 72–5	M	Yes [ ]
CF31	Training pattern length	72.6.10.2.6	512 octets	M	Yes [ ]
CF32	Training pattern generator	72.6.10.2.6	Per Figure 72–3	M	Yes [ ]
CF33	Training pattern seed	72.6.10.2.6	The pseudo-random generator shall have a random seed at the start of the training pattern	M	Yes [ ]
CF34	Remote_rx_ready	72.6.10.3.1	TRUE after three or more consecutive training frames received with receiver ready indicated	M	Yes [ ]
CF35	Wait Timer	72.6.10.3.2	100 to 300 training frames	M	Yes [ ]
CF36	Max Wait Timer	72.6.10.3.2	500 ms ± 1%	M	Yes [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
CF37	Slip function to find framesync	72.6.10.3.2	Evaluates all possible positions	M	Yes [ ]
CF38	Frame Lock state diagram	72.6.10.4.1	Meets requirements of Figure 72–4	M	Yes [ ]
CF39	Training state diagram	72.6.10.4.2	Meets requirements of Figure 72–5	M	Yes [ ]
CF40	Entry to INITIALIZE state	72.6.10.4.2	Transmitter equalizer configured per 72.6.10.4.2	M	Yes [ ]
CF41	Initial value of c(0) at the start of training	72.6.10.4.2	Meets the requirements of 72.6.10.4.2	M	Yes [ ]
CF42	Coefficient Update state diagram	72.6.10.4.3	Meets requirements of Figure 72–6	M	Yes [ ]

72.10.4.5 Transmitter electrical characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
TC1	Test fixture impedance	72.7.1.2	100 Ω	M	Yes [ ]
TC2	Differential return loss of test fixture	72.7.1.2	Per Equation (72–2) and Equation (72–3)	M	Yes [ ]
TC3	Signaling speed	72.7.1.3	10.3125 GBd ± 100 ppm	M	Yes [ ]
TC4	Maximum transmitter differential peak-to-peak voltage	72.7.1.4	Less than 1200 mV for a 1010 pattern	M	Yes [ ]
TC5	Maximum transmitter differential peak-to-peak voltage when TX disabled	72.7.1.4	Less than 30 mV	M	Yes [ ]
TC6	Common-mode output voltage	72.7.1.4	Between 0 and 1.9 V	M	Yes [ ]
TC7	Output Amplitude LPI voltage	72.7.1.4	Less than 30 mV within 500 ns of tx_quiet	LPI:M	Yes [ ] N/A [ ]
TC8	Output Amplitude ON voltage	72.7.1.4	Greater than 90% of previous level within 500 ns of tx_quiet de-asserted	LPI:M	Yes [ ] N/A [ ]
TC9	Differential output return loss	72.7.1.5	Per Equation (72–4) and Equation (72–5)	M	Yes [ ]
TC10	Differential output reference impedance	72.7.1.5	100 Ω	M	Yes [ ]
TC11	Common-mode output return loss	72.7.1.6	Per Equation (72–6) and Equation (72–7)	M	Yes [ ]
TC12	Rising edge transition time	72.7.1.7	Between 24 ps and 47 ps measured at the 20% and 80% levels of the peak-to-peak differential value of the waveform	M	Yes [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
TC13	Falling edge transition time	72.7.1.7	Between 24 ps and 47 ps measured at the 80% and 20% levels of the peak-to-peak differential value of the waveform	M	Yes [ ]
TC14	Transmit jitter, peak-to-peak	72.7.1.9	See 72.7.1.8. Max TJ of 0.28 UI. Max DJ of 0.15 UI. Max RJ of 0.15 UI	M	Yes [ ]
TC15	Duty Cycle Distortion	72.7.1.9	Not to exceed 0.035 UI	M	Yes [ ]
TC16	Jitter test patterns	72.7.1.8	Test patterns 2 or 3 as defined in 52.9.1.1	M	Yes [ ]
TC17	During jitter testing	72.7.1.8	Equalization turned off	M	Yes [ ]
TC18	Changes in transmit output waveform resulting from coefficient updates	72.7.1.10	Meet requirements of Table 72–7	M	Yes [ ]
TC19	Verification of coefficient updates	72.7.1.10	After the coefficient status for all taps is reported as not_updated	M	Yes [ ]
TC20	Transmit output waveform	72.7.1.10	Meet requirements of Table 72–8	M	Yes [ ]
TC21	v_2	72.7.1.10	Greater than or equal to 40 mV for all transmit equalizer configurations	M	Yes [ ]
TC22	Coefficient status value minimum	72.7.1.10	Returned for any coefficient update equal to decrement applied to any tap that would result in Δv_2 or Δv_5 less than 40 mV	M	Yes [ ]
TC23	Coefficient status value maximum	72.7.1.10	Returned for any coefficient update equal to decrement applied to c(-1) or c(1) that would result in a violation of 72.7.1.4	M	Yes [ ]
TC24	Coefficient status value maximum	72.7.1.10	Returned for any coefficient update equal to increment applied to c(0) that would result in a violation of 72.7.1.4	M	Yes [ ]
TC25	Transmitter output waveform	72.7.1.11	Verified with test patterns 2 or 3 as defined in 52.9.1.1	M	Yes [ ]
TC26	v_1, v_2, Δv_2, v_3, v_4, v_5, Δv_5, v_6	72.7.1.11, 72.7.1.10	Measured per Figure 72–12. The absolute value of v_6 and v_3 must be within 5%. The absolute value of v_1 and v_4 must be within 5% and the absolute value of v_2 and v_5 must be within 5%. The maximum peak-to-peak value of Δv_2 and Δv_5 shall not exceed 40 mV	M	Yes [ ]

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72.10.4.6 Receiver electrical characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
RC1	Receiver amplitude tolerance	72.7.2	Amplitudes up to 1600 mV without permanent damage	M	Yes [ ]
RC2	Receiver interference tolerance	72.7.2.1	Measured as described in Annex 69A with parameters in Table 72–10	M	Yes [ ]
RC3	Receiver interference tolerance	72.7.2.1	Receiver interference tolerance test pattern per 72.7.2.1	M	Yes [ ]
RC4	Receiver interference tolerance	72.7.2.1	Satisfy the requirements specified in Annex 69A	M	Yes [ ]
RC5	Signaling speed	72.7.2.2	10.3125 GBd ±100 ppm	M	Yes [ ]
RC6	Receiver coupling	72.7.2.3	AC-coupled	M	Yes [ ]
RC7	Input signal amplitude	72.7.2.4	BER still met when compliant transmitter is connected with no attenuation	M	Yes [ ]
RC8	Differential return loss	72.7.2.5	Per Equation (72–4) and Equation (72–5)	M	Yes [ ]

72.10.4.7 Environmental specifications

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	General safety	72.9.1	Complies with applicable section of IEC 60950-1	M	Yes [ ]
ES2	Electromagnetic interference	72.9.4	Complies with applicable local and national codes	M	Yes [ ]

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73. Auto-Negotiation for backplane and copper cable assembly

Auto-Negotiation, as defined in this clause, is specified for use with Ethernet PHYs operating over a backplane and for use with certain Ethernet PHYs operating over a copper cable assembly.

73.1 Auto-Negotiation introduction

While implementation of Auto-Negotiation is mandatory for Backplane Ethernet PHYs, the use of Auto-Negotiation is optional. Parallel detection shall be provided for legacy devices that do not support Auto-Negotiation.

The Auto-Negotiation function allows an Ethernet device to advertise modes of operation it possesses to another device at the remote end of a Backplane Ethernet link and to detect corresponding operational modes the other device may be advertising.

The objective of this Auto-Negotiation function is to provide the means to exchange information between two devices that share a link across a backplane and to automatically configure both devices to take maximum advantage of their abilities. It has the additional objective of supporting a digital signal detect to ensure that the device is attached to a link partner rather than detecting signal due to crosstalk.

Auto-Negotiation is performed using differential Manchester encoding (DME) pages. DME provides a DC-balanced signal. DME does not add packet or upper layer overhead to the network devices.

Auto-Negotiation does not test the link segment characteristics.

This function allows the devices at both ends of a link segment to advertise abilities, acknowledge receipt and discover the common modes of operation that both devices share, and to reject the use of operational modes that are not shared by both devices. Where more than one common mode exists between the two devices, a mechanism is provided to allow the devices to resolve to a single mode of operation using a predetermined priority resolution function. The Auto-Negotiation function allows the devices to switch between the various operational modes in an orderly fashion, permits management to disable or enable the Auto-Negotiation function, and allows management to select a specific operational mode. The Auto-Negotiation function also provides a parallel detection function to allow Backplane Ethernet devices to connect to other Backplane Ethernet devices that have Auto-Negotiation disabled and interoperate with legacy devices that do not support Clause 73 Auto-Negotiation.

It is recommended that a device that has negotiated 1000BASE-KX operation through this clause not perform Clause 37 Auto-Negotiation. A device that performs Clause 37 Auto-Negotiation after having negotiated 1000BASE-KX operation through Clause 73 Auto-Negotiation will not interoperate with a device that does not perform Clause 37 Auto-Negotiation. Therefore, a device that intends to enable Clause 37 Auto-Negotiation after Clause 73 Auto-Negotiation has completed shall ensure through an implementation-specific mechanism that the link partner supports Clause 37 Auto-Negotiation and intends to enable it. If Clause 37 Auto-Negotiation is performed after Clause 73 Auto-Negotiation, then the advertised abilities used in the Clause 37 Auto-Negotiation shall match those advertised abilities used in the Clause 73 Auto-Negotiation.

The Auto-Negotiation functions are listed in 73.3.

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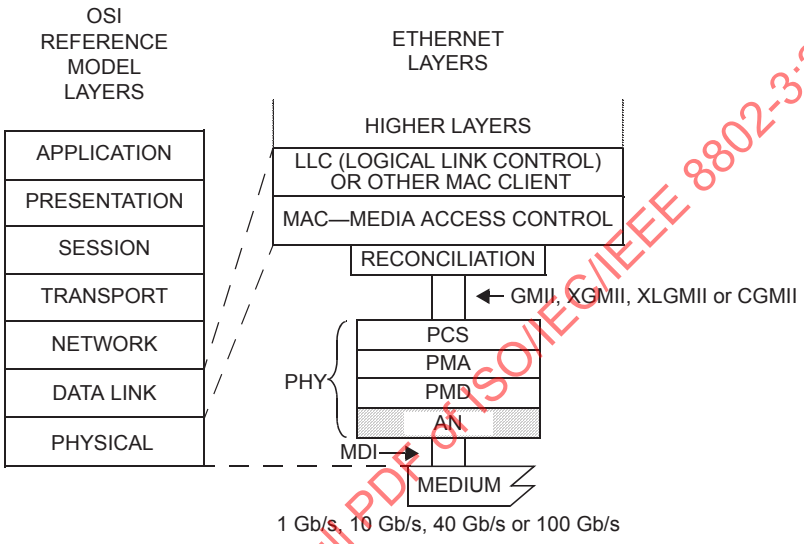
73.2 Relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model

The Auto-Negotiation function is provided at the Physical Layer of the ISO/IEC OSI reference model as shown in Figure 73–1. A device that supports multiple modes of operation may advertise its capabilities using the Auto-Negotiation function. The actual transfer of information is observed only at the MDI or on the backplane medium.



AN = AUTO-NEGOTIATION
CGMII = 100 Gb/s MEDIA INDEPENDENT INTERFACE
GMII = GIGABIT MEDIA INDEPENDENT INTERFACE
MDI = MEDIUM DEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT
XGMII = 10 Gb/s MEDIA INDEPENDENT INTERFACE
XLGMII = 40 Gb/s MEDIA INDEPENDENT INTERFACE

Figure 73–1—Location of Auto-Negotiation function within the ISO/IEC OSI reference model

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73.3 Functional specifications

The Auto-Negotiation function provides a mechanism to control connection of a single MDI to a single PHY type, where more than one PHY type may exist. A management interface provides control and status of Auto-Negotiation, but the presence of a management agent is not required.

The Auto-Negotiation function shall provide the following:

a) Auto-Negotiation transmit
b) Auto-Negotiation receive
c) Auto-Negotiation arbitration

These functions shall comply with the state diagrams from Figure 73–9 through Figure 73–11. The Auto-Negotiation functions shall interact with the technology-dependent PHYs through the Technology-Dependent interface (see 73.9). Technology-Dependent PHYs include 1000BASE-KX,

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10GBASE-KX4, 10GBASE-KR, 40GBASE-KR4, 40GBASE-CR4, 100GBASE-CR10, 100GBASE-KP4, 100GBASE-KR4, and 100GBASE-CR4.

When the MDI supports multiple lanes, then lane 0 of the MDI shall be used for Auto-Negotiation and for connection of any single-lane PHYs (e.g., 1000BASE-KX or 10GBASE-KR).

73.4 Transmit function requirements

The Transmit function provides the ability to transmit pages. The first pages exchanged by the local device and its link partner after Power-On, link restart, or renegotiation contain the base link codeword defined in Figure 73–6. The local device may modify the link codeword to disable an ability it possesses, but will not transmit an ability it does not possess. This makes possible the distinction between local abilities and advertised abilities so that multi-ability devices may Auto-Negotiate to a mode lower in priority than the highest common ability.

73.5 DME transmission

Auto-Negotiation's method of communication builds upon the encoding mechanism known as differential Manchester encoding (DME). The DME page encodes the data that is used to control the Auto-Negotiation function. DME pages shall not be transmitted when Auto-Negotiation is complete and the highest common denominator PHY has been enabled.

73.5.1 DME electrical specifications

Transmitter characteristics shall meet the specifications in Table 73–1 at TP1 while transmitting DME pages. Receiver characteristics shall meet the specifications in Table 73–1 at TP4 while receiving DME pages.

Table 73–1—DME electrical characteristics

Parameter	Value	Units
Transmit differential peak-to-peak output voltage	600 to 1200	mV
Receive differential peak-to-peak input voltage	200 to 1200	mV

For any multi-lane PHY, DME pages shall be transmitted only on lane 0. The transmitters on other lanes should be disabled as specified in 71.6.7, 84.7.7, 85.7.7, 92.7.7, 93.7.7, or 94.3.6.7.

73.5.2 DME page encoding

A DME page carries a 48-bit Auto-Negotiation page. It consists of 106 evenly spaced transition positions that contain a Manchester violation delimiter, the 48-bit page, and a single pseudo-random bit. The odd-numbered transition positions represent clock information. The even numbered transition positions represent data information. DME pages are transmitted continuously without any idle or gap.

The first eight transition positions contain the Manchester violation delimiter, which marks the beginning of the page. The Manchester violation contains a transition at position 1 and position 5 and no transitions at the remaining positions. The Manchester violation delimiter is the only place where four intervals occur between transitions. This allows the receiver to obtain page synchronization.

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Each of the remaining 49 odd-numbered transition positions shall contain a transition. The remaining 49 even-numbered transition positions shall represent data information as follows:

— A transition present in an even-numbered transition position represents a logical one
— A transition absent from an even-numbered transition position represents a logical zero

The first 48 of these positions shall carry the data of the Auto-Negotiation page. The final position carries the pseudo-random bit. The value of the pseudo-random bit shall be derived from a pseudo-random generator as shown in Figure 73–2.

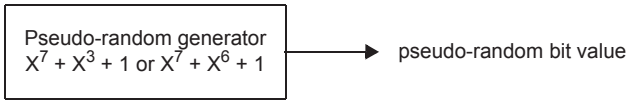

Figure 73–2—DME page bit 49 randomizer

The counter shall increment once per DME page.

The purpose of the 49th bit is to remove the spectral peaks that would otherwise occur when sending the same AN page repeatedly. Randomly choosing between 0 or 1 for one of the DME bits results in randomly inverting or not inverting the encoded page so that repetitions of the same page no longer produce a periodic signal.

Clock transition positions are differentiated from data transition positions by the spacing between them, as shown in Figure 73–3 and enumerated in Table 73–2.

The encoding of data using DME bits in an DME page is illustrated in Figure 73–3.

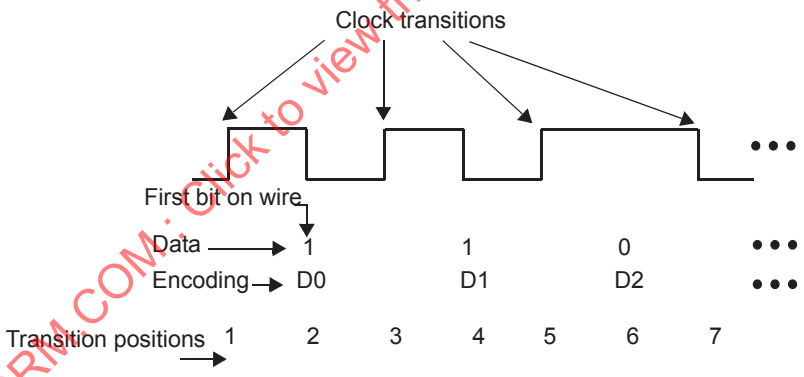

Figure 73–3—Data bit encoding within DME pages

73.5.3 DME page timing

The timing parameters for DME pages shall be followed as in Table 73–2. The transition positions within a DME page are spaced with a period of T1. T2 is the separation between clock transitions. T3 is the time from a clock transition to a data transition representing a one. The period, T1, shall be 3.2 ns ± 0.01%. Transitions shall occur within ± 0.2 ns of their ideal positions.

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T5 specifies the duration of a DME page. Since DME pages are sent continuously during Auto-Negotiation, T5 is also the time from the start of one DME page to the start of the next DME page.

The minimum number of transitions and maximum number of transitions in a page is represented by T4.

Table 73–2 summarizes the timing parameters. The transition timing parameters are illustrated in Figure 73–4.

Table 73–2— DME page timing summary

	Parameter	Min.	Typ.	Max.	Units
T1	Transition position spacing (period)	3.2 –0.01%	3.2	3.2 +0.01%	ns
T2	Clock transition to clock transition	6.2	6.4	6.6	ns
T3	Clock transition to data transition (data = 1)	3.0	3.2	3.4	ns
T4	Transitions in a DME page	51	—	100	—
T5	DME page width	338.8	339.2	339.6	ns
T6	DME Manchester violation delimiter width	12.6	12.8	13.0	ns

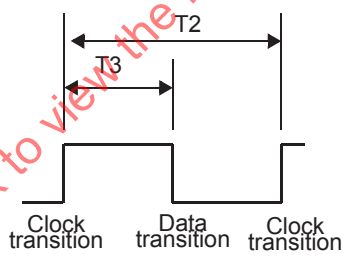

Figure 73–4—DME page transition timing

73.5.3.1 Manchester violation delimiter

A violation is signaled as shown in Figure 73–5.

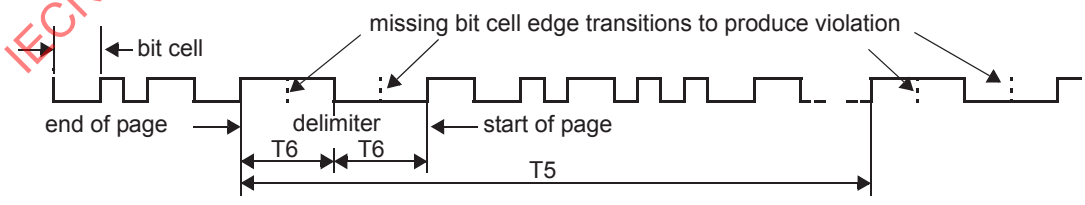

Figure 73–5—Manchester violation

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73.6 Link codeword encoding

The base link codeword (Base Page) transmitted within a DME page shall convey the encoding shown in Figure 73–6. The Auto-Negotiation function supports additional pages using the Next Page function. Encoding for the link codeword(s) used in the Next Page exchange are defined in 73.7.7. In a DME page, D0 shall be the first bit transmitted.

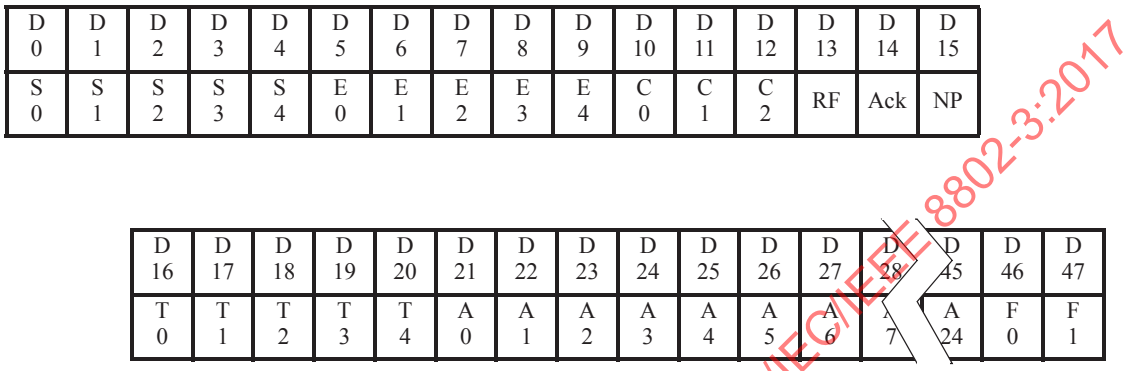

Figure 73–6—Link codeword Base Page

D[4:0] contains the Selector Field. D[9:5] contains the Echoed Nonce field. D[12:10] contains capability bits to advertise capabilities not related to the PHY. C[1:0] is used to advertise pause capability. The remaining capability bit C[2] is reserved. D[15:13] contains the RF, Ack, and NP bits. These bits shall function as specified in 28.2.1.2. D[20:16] contains the Transmitted Nonce field. D[45:21] contains the Technology Ability Field. D[47:46] contains FEC capability (see 73.6.5).

73.6.1 Selector Field

Selector Field (S[4:0]) is a five-bit wide field, encoding 32 possible messages. Selector Field encoding definitions are shown in Annex 28A. Combinations not specified are reserved for future use. Reserved combinations of the Selector Field shall not be transmitted.

The Selector Field for IEEE Std 802.3 is shown in Table 73–3.

Table 73–3—Selector Field Encoding

S4	S3	S2	S1	S0	Selector description
0	0	0	0	1	IEEE Std 802.3

73.6.2 Echoed Nonce Field

Echoed Nonce Field (E[4:0]) is a 5-bit wide field containing the nonce received from the link partner. When Acknowledge is set to logical zero, the bits in this field shall contain logical zeros. When Acknowledge is set to logical one, the bits in this field shall contain the value received in the Transmitted Nonce Field from the link partner.

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73.6.3 Transmitted Nonce Field

Transmitted Nonce Field (T[4:0]) is a 5-bit wide field containing a random or pseudo-random number. A new value shall be generated for each entry to the Ability Detect state. The method of generating the nonce is left to the implementer. The transmitted nonce should have a uniform distribution in the range from 0 to $2^5 - 1$. The method used to generate the value should be designed to minimize correlation to the values generated by other devices.

73.6.4 Technology Ability Field

Technology Ability Field (A[24:0]) is a 25-bit wide field containing information indicating supported technologies specific to the selector field value when used with the Auto-Negotiation for Backplane Ethernet. These bits are mapped to individual technologies such that abilities are advertised in parallel for a single selector field value. The Technology Ability Field encoding for the IEEE 802.3 selector with Auto-Negotiation for Backplane Ethernet is described in Table 73–4.

Table 73–4—Technology Ability Field encoding

Bit	Technology
A0	1000BASE-KX
A1	10GBASE-KX4
A2	10GBASE-KR
A3	40GBASE-KR4
A4	40GBASE-CR4
A5	100GBASE-CR10
A6	100GBASE-KP4
A7	100GBASE-KR4
A8	100GBASE-CR4
A9 through A24	Reserved for future technology

Multiple technologies may be advertised in the link codeword. A device shall support the data service ability for a technology it advertises. It is the responsibility of the Arbitration function to determine the common mode of operation shared by a link partner and to resolve multiple common modes.

A PHY for operation over an electrical backplane (e.g., 1000BASE-KX, 10GBASE-KX4, 10GBASE-KR, 40GBASE-KR4, 100GBASE-KP4, 100GBASE-KR4) shall not be advertised simultaneously with a PHY for operation over a copper cable assembly (e.g., 40GBASE-CR4, 100GBASE-CR10, 100GBASE-CR4) as the MDI and physical medium are different.

The fields A[24:9] are reserved for future use. Reserved fields shall be sent as zero and ignored on receive.

73.6.5 FEC capability

FEC (F0:F1) is encoded in bits D46:D47 of the base link codeword. The two FEC bits are used as follows:

a) F0 is FEC ability
b) F1 is FEC requested

When the FEC ability bit is set to logical one, it indicates that the PHY has FEC ability (see Clause 74). When the FEC requested bit is set to logical one, it indicates a request to enable FEC on the link.

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Since the local device and the link partner may have set the FEC capability bits differently, the priority resolution function is used to enable FEC in the respective PHYs. The FEC function shall be enabled on the link if 10GBASE-KR, 40GBASE-KR4, 40GBASE-CR4, or 100GBASE-CR10 is the HCD technology (see 73.7.6), both devices advertise FEC ability on the F0 bits, and at least one device requests FEC on the F1 bits; otherwise FEC shall not be enabled.

The variable an_baser_fec_control indicates that BASE-R FEC operation has been negotiated. If the value is false, then BASE-R FEC has not been negotiated. If the value is true, then BASE-R FEC has been negotiated. The mapping of this variable to an MDIO bit is defined in Table 73–6.

If mr_autoneg_enable (see 73.10.1) is false, the FEC function is controlled by implementation-dependent means.

73.6.6 Pause Ability

Pause (C0:C1) is encoded in bits D11:D10 of the base link codeword. The two-bit Pause is encoded as follows:

a) C0 is the same as PAUSE as defined in Annex 28B
b) C1 is the same as ASM_DIR as defined in Annex 28B

The Pause encoding is defined in Clause 28B.2, Table 28B–2. The PAUSE bit indicates that the device is capable of providing the symmetric PAUSE functions as defined in Annex 31B. The ASM_DIR bit indicates that asymmetric PAUSE is supported. The value of the PAUSE bit when the ASM_DIR bit is set indicates the direction the PAUSE frames are supported for flow across the link. Asymmetric PAUSE configuration results in independent enabling of the PAUSE receive and PAUSE transmit functions as defined by Annex 31B. See 28B.3 regarding PAUSE configuration resolution.

73.6.7 Remote Fault

Remote Fault (RF) is encoded in bit D13 of the base link codeword. The default value is logical zero. The Remote Fault bit provides a standard transport mechanism for the transmission of simple fault information. When the RF bit in the AN advertisement register (Register 7.16.13) is set to logical one, the RF bit in the transmitted base link codeword is set to logical one. When the RF bit in the received base link codeword is set to logical one, the Remote Fault bit in the AN LP Base Page ability register (Register 7.19.13) will be set to logical one, if the management function is present.

73.6.8 Acknowledge

Acknowledge (Ack) is used by the Auto-Negotiation function to indicate that a device has successfully received its link partner's link codeword. The Acknowledge Bit is encoded in bit D14 of link codeword. If no Next Page information is to be sent, this bit shall be set to logical one in the link codeword after the reception of at least three consecutive and consistent DME pages (ignoring the Acknowledge bit value). If Next Page information is to be sent, this bit shall be set to logical one after the device has successfully received at least three consecutive and matching DME pages (ignoring the Acknowledge bit value), and will remain set until the Next Page information has been loaded into the AN XNP transmit register (Registers 7.22, 7.23, 7.24). In order to save the current received link codeword, it must be read from the AN LP XNP ability register (Register 7.25, 7.26, 7.27) before the Next Page of transmit information is loaded into the AN XNP transmit register. After the COMPLETE ACKNOWLEDGE state has been entered, the link codeword will be transmitted at least six times.

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73.6.9 Next Page

Next Page (NP) is encoded in bit D15 of link codeword. Support of Next Pages is mandatory. If the device does not have any Next Pages to send, the NP bit shall be set to logical zero. If a device wishes to engage in Next Page exchange, it shall set the NP bit to logical one. If a device has no Next Pages to send and its link partner has set the NP bit to logical one, it shall transmit Next Pages with Null message codes and the NP bit set to logical zero while its link partner transmits valid Next Pages. Next page exchanges will occur if either the device or its link partner sets the Next Page bit to logical one. The Next Page function is defined in 73.7.7.

73.6.10 Transmit Switch function

During Auto-Negotiation and prior to entry into the AN_GOOD_CHECK state, the Transmit Switch function shall connect only the DME page generator controlled by the Transmit State Diagram to the MDI.

Upon entry into the AN_GOOD_CHECK state, the Transmit Switch function shall connect the transmit path from a single technology-dependent (highest common denominator) PHY to the MDI.

When a PHY is connected to the MDI through the Transmit Switch function, the signals at the MDI shall conform to all of the PHY's specifications within 20 ms.

73.7 Receive function requirements

The receive function detects the DME page sequence, decodes the information contained within, and stores the data in rx_link_code_word[48:1]. The receive function incorporates a receive switch to control connection of the DME page receiver or a PHY to the MDI.

73.7.1 DME page reception

To be able to detect the DME bits, the receiver should have the capability to receive DME signals sent with the electrical specifications of the PHY (1000BASE-KX, 10GBASE-KX4, 10GBASE-KR, 40GBASE-KR4, 40GBASE-CR4, 100GBASE-CR10, 100GBASE-KP4, 100GBASE-KR4, or 100GBASE-CR4). The DME transmit signal level and receive sensitivity are specified in 73.5.1.

73.7.2 Receive Switch function

During Auto-Negotiation and prior to entry into the AN_GOOD_CHECK state, the Receive Switch function shall connect the DME page receiver to the MDI. For the Parallel Detection function, the Receive Switch function shall also connect the receive path of the 1000BASE-KX and 10GBASE-KX4 PHY to the MDI when those PHYs are present.

Upon entry into the AN_GOOD_CHECK state, the Receive Switch function shall connect the receive path from a single technology-dependent (highest common denominator) PHY to the MDI.

73.7.3 Link codeword matching

The Receive function shall generate ability_match, acknowledge_match, and consistency_match variables as defined in Arbitration state diagram Figure 73–11.

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73.7.4 Arbitration function requirements

The Arbitration function is described in Figure 73–11 and ensures proper sequencing of the Auto-Negotiation function using the Transmit function and Receive function. The Arbitration function enables the Transmit function to advertise and acknowledge abilities. Upon indication of acknowledgement, the Arbitration function determines the highest common denominator using the priority resolution function and enables the appropriate technology-dependent PHY via the link_control_[x] variables.

If mr_autoneg_enable (see 73.10.1) is false, enabling the desired technology-dependent PHY is controlled by implementation-dependent means.

73.7.4.1 Parallel Detection function

The local device detects a link partner that supports Auto-Negotiation by DME page detection. The Parallel Detection function allows detection of link partners that support 1000BASE-KX and 10GBASE-KX4 but have disabled Auto-Negotiation, and detection of legacy devices that can interoperate with 1000BASE-KX and 10GBASE-KX4 devices, but do not provide Clause 73 Auto-Negotiation.

A local device shall provide Parallel Detection for 1000BASE-KX and 10GBASE-KX4 if it supports those PHYs. Additionally, parallel detection may be used for 10GBASE-CX4. Parallel detection of 10GBASE-CX4 will be indicated by the setting of the Negotiated Port Type to "10GBASE-KX4 or 10GBASE-CX4" in the management register bit 7.48.2. The means to distinguish between 10GBASE-KX4 and 10GBASE-CX4 is implementation dependent. Parallel Detection shall be performed by directing the MDI receive activity to the PHY. This detection may be done in sequence between detection of DME pages and detection of each supported PHY. If at least one of the 1000BASE-KX, or 10GBASE-KX4 establishes link_status=OK, the LINK STATUS CHECK state is entered and the autoneg_wait_timer is started. If exactly one link_status=OK indication is present when the autoneg_wait_timer expires, then Auto-Negotiation shall set link_control=ENABLE for the PHY indicating link_status=OK. If a PHY is enabled, the Arbitration function shall set link_control=DISABLE to all other PHYs and indicate that Auto-Negotiation has completed. On transition to the AN GOOD CHECK state from the LINK STATUS CHECK state, the Parallel Detection function shall set the bit in the AN LP Base Page ability registers (see 45.2.7.7) corresponding to the technology detected by the Parallel Detection function.

If Auto-Negotiation detects link_status=OK from any of the technology-dependent PHYs prior to DME page detection, the autoneg_wait_timer shall start. If more than one technology-dependent PHYs indicate link_status=OK when the autoneg_wait_timer expires, Auto-Negotiation will not allow any data service to be enabled and may signal this as a remote fault to the link partner using the Base Page and will flag this in the local device by setting the Parallel Detection fault bit (45.2.7.2) in the AN Status register.

73.7.5 Renegotiation function

A renegotiation request from any entity, such as a management agent, shall cause the Arbitration function to disable all technology-dependent PHYs and halt any transmit data and link transition activity until the break_link_timer expires. Consequently, the link partner will go into link fail and normal Auto-Negotiation resumes. The local device shall resume Auto-Negotiation after the break_link_timer has expired by issuing DME pages with the Base Page valid in tx_link_code_word[48:1]. Once Auto-Negotiation has completed, renegotiation will take place if the Highest Common Denominator technology that receives link_control=ENABLE returns link_status=FAIL. To allow the PHY an opportunity to determine link integrity using its own link integrity test function, the link_fail_inhibit_timer qualifies the link_status=FAIL indication such that renegotiation takes place if the link_fail_inhibit_timer has expired and the PHY still indicates link_status=FAIL.

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73.7.6 Priority Resolution function

Since a local device and a link partner may have multiple common abilities, a mechanism to resolve which mode to configure is required. The mechanism used by Auto-Negotiation is a Priority Resolution function that predefines the hierarchy of supported technologies. The single PHY enabled to connect to the MDI by Auto-Negotiation shall be the technology corresponding to the bit in the Technology Ability Field common to the local device and link partner that has the highest priority as defined in Table 73–5 (listed from highest priority to lowest priority).

Table 73–5—Priority Resolution

Priority	Technology	Capability
1	100GBASE-CR4	100 Gb/s 4 lane, highest priority
2	100GBASE-KR4	100 Gb/s 4 lane
3	100GBASE-KP4	100 Gb/s 4 lane
4	100GBASE-CR10	100 Gb/s 10 lane
5	40GBASE-CR4	40 Gb/s 4 lane
6	40GBASE-KR4	40 Gb/s 4 lane
7	10GBASE-KR	10 Gb/s 1 lane
8	10GBASE-KX4	10 Gb/s 4 lane
9	1000BASE-KX	1 Gb/s 1 lane, lowest priority

The common technology is referred to as the highest common denominator, or HCD, technology. If the local device receives a Technology Ability Field with a bit set that is reserved, the local device shall ignore that bit for priority resolution. Determination of the HCD technology occurs on entrance to the AN GOOD CHECK state. In the event that a technology is chosen through the parallel detection function, that technology shall be considered the highest common denominator (HCD) technology. In the event that there is no common technology, HCD shall have a value of “NULL”, indicating that no PHY receives link_control=ENABLE and link_status[HCD]=FAIL.

NOTE—If both local device and link partner are Backplane Ethernet compliant PHYs, then both ends use abilities exchanged through Clause 73 Auto-Negotiation function. If the Link partner is a legacy device (or has disabled Auto-Negotiation) as indicated by the parallel detect function, then the peer 1 Gb/s devices can opt to use abilities exchanged through Clause 37. This will ensure there are no interoperability issues when connected to a Backplane Ethernet PHY.

73.7.7 Next Page function

The Next Page function uses the Auto-Negotiation arbitration mechanisms to allow exchange of Next Pages of information, which may follow the transmission and acknowledgment procedures used for the base link codeword. The Next Page has both Message code field and Unformatted code fields.

A dual acknowledgment system is used. Acknowledge (Ack) is used to acknowledge receipt of the information; Acknowledge 2 (Ack2) is used to indicate that the receiver is able to act on the information (or perform the task) defined in the message.

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The Toggle bit is used to ensure proper synchronization between the local device and the link partner.

Next page exchange occurs after the base link codewords have been exchanged if either end of the link segment set the Next Page bit to logical one indicating that it had at least one Next Page to send. Next page exchange consists of using the normal Auto-Negotiation arbitration process to send Next Page messages.

The Next Page contains two message encodings. The message encodings are defined as follows: message code, which contain predefined 11-bit codes, and unformatted code contains 32 bit codes. Multiple Next Pages with appropriate message codes and unformatted codes can be transmitted to send extended messages. Each series of Next Pages shall have a Message code that defines how the Unformatted codes will be interpreted. Any number of Next Pages may be sent in any order; however, it is recommended that the total number of Next Pages sent be kept small to minimize the link startup time.

Next page transmission ends when both ends of a link segment set their Next Page bits to logical zero, indicating that neither has anything additional to transmit. It is possible for one device to have more pages to transmit than the other device. Once a device has completed transmission of its Next Page information, it shall transmit Next Pages with Null message codes and the NP bit set to logical zero while its link partner continues to transmit valid Next Pages. An Auto-Negotiation able device shall recognize reception of Message Pages with Null message codes as the end of its link partner's Next Page information.

73.7.7.1 Next page encodings

The Next Page shall use the encoding shown in Figure 73–7 and Figure 73–8 for the NP, Ack, MP, Ack2, and T bits. These bits shall function as specified in 28.2.3.4. There are two types of Next Page encodings—message and unformatted. For message Next Pages, the MP bit shall be set to logical one, the 11-bit field D[10:0] shall be encoded as a Message Code Field and D[47:16] shall be encoded as Unformatted Code Field. For Unformatted Next Pages, the MP bit shall be set to logical zero; D[10:0] and D[47:16] shall be encoded as the Unformatted Code Field.

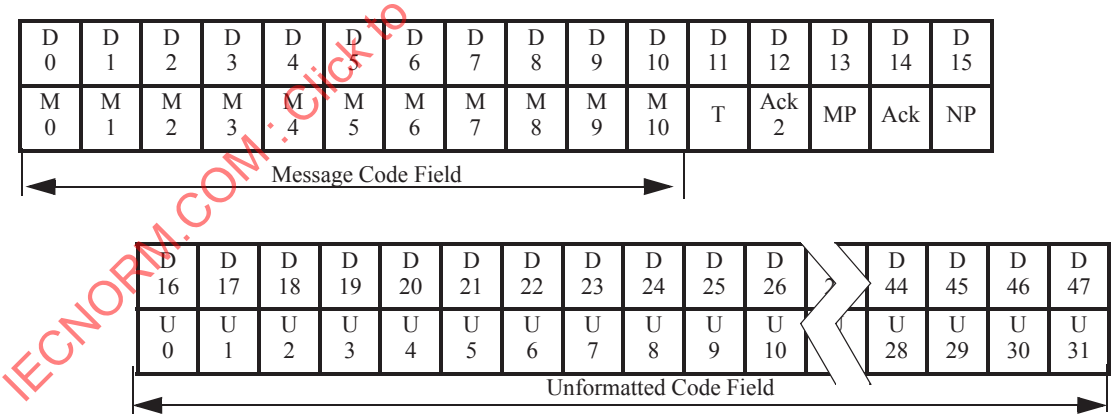

Figure 73–7—Message Next Page

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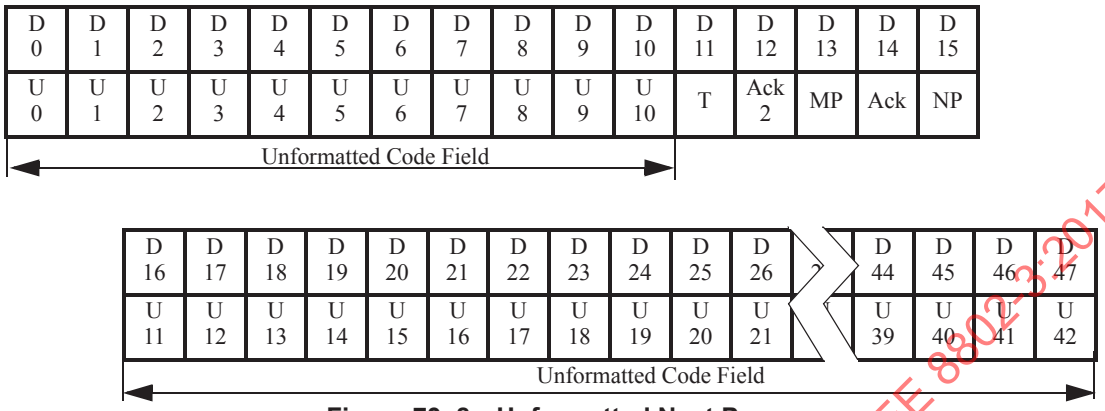

Figure 73–8—Unformatted Next Page

73.7.7.2 Use of Next Pages

Next page exchange will commence after the Base Page exchange if either device requests it by setting the NP bit to logical one.

Next page exchange shall continue until neither device on a link has more pages to transmit as indicated by the NP bit. A Next Page with a Null Message Code Field value shall be sent if the device has no other information to transmit.

A message code can carry either a specific message or information that defines how the corresponding unformatted codes should be interpreted.

73.8 Management register requirements

The management interface is used to communicate Auto-Negotiation information to the management entity. MMD7 of the Clause 45 Management Data Input/Output (MDIO) interface shall be provided as the logical interface to access the device registers for Auto-Negotiation and other management purposes. The Clause 45 MDIO electrical interface is optional. Where no physical embodiment of the MDIO exists, provision of an equivalent mechanism to access the registers is recommended. Table 73–6 provides the mapping of Backplane Ethernet Auto-Negotiation variables to management registers.

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Table 73–6—Backplane Ethernet Auto-Negotiation variable to MDIO register mapping

Variable	Description
mr_adv_ability[48:1]	{7.18.15:0, 7.17.15:0, 7.16.15:0} AN advertisement registers
mr_autoneg_complete	7.1.5 Auto-Negotiation Complete
mr_autoneg_enable	7.0.12 Auto-Negotiation Enable
mr_lp_adv_ability[48:1]	For Base Page: {7.21.15:0, 7.20.15:0, 7.19.15:0} AN LP Base Page ability registers For Next Page(s): {7.27.15:0, 7.26.15:0, 7.25.15:0} AN LP XNP ability registers
mr_lp_autoneg_able	7.1.0 LP Auto-Negotiation Able
mr_main_reset	7.0.15 Reset
mr_next_page_loaded	Set on write to AN XNP Transmit registers; cleared by Arbitration state diagram
mr_np_tx[48:1]	{7.24.15:0, 7.23.15:0, 7.22.15:0} AN XNP Transmit registers
mr_page_rx	7.1.6 Page Received
mr_parallel_detection_fault	7.1.9 Parallel detection Fault
mr_restart_negotiation	7.0.9 Auto-Negotiation Restart
set to 1	7.1.3 Auto-Negotiation Ability
link_control_[x]	{7.48.11:8, 7.48.6:5, 7.48.3:1} Negotiated Port Type
an_baser_fec_control	7.48.4 BASE-R FEC negotiated

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73.9 Technology-Dependent interface

The Technology-Dependent interface is the communication mechanism between each technology's PCS and the Auto-Negotiation function. Auto-Negotiation can support multiple technologies, all of which need not be implemented in a given device. Each of these technologies may utilize its own technology-dependent link integrity test function.

73.9.1 AN_LINK.indication

This primitive is generated by the PCS to indicate the status of the underlying medium. The purpose of this primitive is to give the Auto-Negotiation function a means of determining the validity of received code elements.

73.9.1.1 Semantics of the service primitive

AN_LINK.indication(link_status)

The link_status parameter shall assume one of two values: OK or FAIL, indicating whether the underlying receive channel is intact and enabled (OK) or not intact (FAIL).

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73.9.1.2 When generated

A technology-dependent PCS generates this primitive to indicate a change in the value of link_status.

73.9.1.3 Effect of receipt

The effect of receipt of this primitive shall be governed by the state diagram of Figure 73–11.

73.10 State diagrams and variable definitions

The notation used in state diagrams follows the conventions in Clause 28. Variables in a state diagram with default values evaluate to the variable default in each state where the variable value is not explicitly set.

Auto-Negotiation shall implement the Transmit state diagram, Receive state diagram and Arbitration state diagram. Additional requirements to these state diagrams are made in the respective functional requirements sections. Options to these state diagrams clearly stated as such in the functional requirements sections or state diagrams shall be allowed. In the case of any ambiguity between stated requirements and the state diagrams, the state diagrams shall take precedence.

73.10.1 State diagram variables

A variable with "_[x]" appended to the end of the variable name indicates a variable or set of variables as defined by "x". "x" may be as follows:

all;	represents all specific technology-dependent PMDs supported in the local device.
1GKX;	represents the 1000BASE-KX PMD.
10GKR;	represents the 10GBASE-KR PMD.
10GKX4;	represents the 10GBASE-KX4 or 10GBASE-CX4 PMD.
40GKR4;	represents the 40GBASE-KR4 PMD.
40GCR4;	represents the 40GBASE-CR4 PMD.
100GCR10;	represents the 100GBASE-CR10 PMD.
100GKP4;	represents the 100GBASE-KP4 PMD.
100GKR4;	represents the 100GBASE-KR4 PMD.
100GCR4;	represents the 100GBASE-CR4 PMD.
HCD;	represents the single technology-dependent PMD chosen by Auto-Negotiation as the highest common denominator technology through the Priority Resolution or parallel detection function.
notHCD;	represents all technology-dependent PMDs not chosen by Auto-Negotiation as the highest common denominator technology through the Priority Resolution or parallel detection function.
PD;	represents all of the following that are present: 1000BASE-KX PMD and 10GBASE-KX4 (or 10GBASE-CX4) PMD.

Variables with [48:1] appended to the end of the variable name indicate arrays that can be directly mapped to 48-bit registers. For these variables, "[x]" indexes an element or set of elements in the array, where "[x]" may be as follows:

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a) Any integer
b) Any range of integers
c) Any variable that takes on integer values
d) NP; represents the index of the Next Page bit
e) ACK; represents the index of the Acknowledge bit
f) RF; represents the index of the Remote Fault bit

Variables of the form "mr_x", where x is a label, comprise a management interface that is intended to be connected to the Management function. However, an implementation-specific management interface may provide the control and status function of these bits.

ability_match

Indicates that three consecutive link codewords match, ignoring the Acknowledge bit. Three consecutive words are any three words received one after the other, regardless of whether the word has already been used in a word-match comparison or not.

Values: false; three matching consecutive link codewords have not been received, ignoring the Acknowledge bit (default).
true; three matching consecutive link codewords have been received, ignoring the Acknowledge bit.

NOTE—This variable is set by this variable definition; it is not set explicitly in the state diagrams.

ability_match_word [48:1]

A 48-bit array that is loaded upon transition to Acknowledge Detect state with the value of the link codeword that caused ability_match = true for that transition. For each element in the array transmitted.

Values: zero; data bit is logical zero.
one; data bit is logical one.

NOTE—This variable is set by this variable definition; it is not set explicitly in the state diagrams.

ack_finished

Status indicating that the final remaining_ack_cnt link codewords with the Ack bit set have been transmitted.

Values: false; more link codewords with the Ack bit set to logical one must be transmitted.
true; all remaining link codewords with the Ack bit set to logical one have been transmitted.

ack_nonce_match

Indicates whether the echoed nonce received from the link partner matches the transmitted nonce field sent by the local device. The echoed nonce value from the DME page that caused acknowledge_match to be set is used for this test.

Values false; link partner echoed nonce does not equal local device transmitted nonce.
true; link partner echoed nonce equals local device transmitted nonce.

acknowledge_match

Indicates that three consecutive link codewords match and have the Acknowledge bit set. Three consecutive words are any three words received one after the other, regardless of whether the word has already been used in a word match comparison or not.

Values: false; three matching and consecutive link codewords have not been received with the

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Acknowledge bit set (default).
true; three matching and consecutive link codewords have been received with the Acknowledge bit set.

NOTE—This variable is set by this variable definition; it is not set explicitly in the state diagrams.

an_link_good

Indicates that Auto-Negotiation has completed.

Values: false; negotiation is in progress (default).
true; negotiation is complete, forcing the Transmit and Receive functions to IDLE.

an_receive_idle

Indicates that the Receive state diagram is in the IDLE or DELIMITER DETECT state.

Values: false; the Receive state diagram is not in the IDLE or DELIMITER DETECT state (default).
true; the Receive state diagram is in the IDLE or DELIMITER DETECT state.

base_page

Status indicating that the page currently being transmitted by Auto-Negotiation is the initial link codeword encoding used to communicate the device's abilities.

Values: false; a page other than base link codeword is being transmitted.
true; the base link codeword is being transmitted.

code_sel

A Boolean random or pseudo-random value uniformly distributed. A new value is generated each time the variable code_sel is used.

Values: zero; a zero has been assigned.
one; a one has been assigned.

complete_ack

Controls the counting of transmitted link codewords that have their Acknowledge bit set.

Values: false; transmitted link codewords with the Acknowledge bit set are not counted (default).
true; transmitted link codewords with the Acknowledge bit set are counted.

consistency_match

Indicates that the ability_match_word same as the link codeword that caused acknowledge_match to be set.

Values: false; the link codeword that caused ability_match to be set is not the same as the link codeword that caused acknowledge_match to be set, ignoring the Acknowledge bit value and the echoed nonce value.
true; the link codeword that caused ability_match to be set is the same as the link codeword that caused acknowledge_match to be set, ignoring the Acknowledge bit value and the echoed nonce value.

NOTE—This variable is set by this variable definition; it is not set explicitly in the state diagrams.

detect_mv_pair

Status indicating that the receiver has detected the pair of Manchester violations forming a Manchester Violation delimiter—a sequence of three consecutive transitions with 12.8 ns ± 200 ps between each pair of transitions.

Values: false; set to false after any Receive State Diagram state transition (default).

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true; Manchester violation pair has been detected.

detect_transition

Status indicating that the receiver has detected a transtion.

Values: false; set to false after any Receive State Diagram state transition (default).
true; set to true when a transition is received.

incompatible_link

Parameter used following Priority Resolution to indicate the resolved link is incompatible with the local device settings. A device's ability to set this variable to true is optional.

Values: false; A compatible link exists between the local device and link partner (default).
true; Optional indication that Priority Resolution has determined no highest common denominator exists following the most recent negotiation.

NOTE—This variable is set by this variable definition; it is not set explicitly in the state diagrams.

link_control_[x]

Controls the connection of each PMD to the MDI. When all PMD transmitters are isolated from the MDI, the AN transmitter is connected to the MDI.

Values: DISABLE; isolates the PMD from the MDI.
SCAN_FOR_CARRIER; connects the PMD receiver to the MDI and isolates the PMD transmitter from the link.
ENABLE; connects the PMD (both transmit and receive) to the MDI.

link_status_[x]

This variable is defined in 73.9.1.

mr_autoneg_complete

Status indicating whether Auto-Negotiation has completed or not.

Values: false; Auto-Negotiation has not completed.
true; Auto-Negotiation has completed.

mr_autoneg_enable

Controls the enabling and disabling of the Auto-Negotiation function.

Values: false; Auto-Negotiation is disabled.
true; Auto-Negotiation is enabled.

mr_adv_ability[48:1]

A 48-bit array that contains the Advertised Abilities link codeword.
For each element within the array:

Values: zero; data bit is logical zero.
one; data bit is logical one.

mr_lp_adv_ability[48:1]

A 48-bit array that contains the link partner's Advertised Abilities link codeword.
For each element within the array:

Values: zero; data bit is logical zero.
one; data bit is logical one.

mr_lp_autoneg_able

Status indicating whether the link partner supports Auto-Negotiation.

Values: false; the link partner does not support Auto-Negotiation.

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true; the link partner supports Auto-Negotiation.

mr_main_reset

Controls the resetting of the Auto-Negotiation state diagrams.

Values: false; do not reset the Auto-Negotiation state diagrams.
true; reset the Auto-Negotiation state diagrams.

mr_next_page_loaded

Status indicating whether a new page has been loaded into the AN XNP transmit register (45.2.7.8).

Values: false; a New Page has not been loaded.
true; a New Page has been loaded.

mr_np_tx[48:1]

A 48-bit array that contains the new Next Page to transmit.
For each element within the array:

Values: zero; data bit is logical zero.
one; data bit is logical one.

mr_page_rx

Status indicating whether a New Page has been received. A New Page has been successfully received when acknowledge_match=true and consistency_match=true and the link codeword has been written to mr_lp_adv_ability[48:1].

Values: false; a New Page has not been received.
true; a New Page has been received.

mr_parallel_detection_fault

Error condition indicating that while performing parallel detection, either an_receive_idle = false, or zero or more than one of the following indications were present when the autoneg_wait_timer expired. This signal is cleared on read of the AN status register (Register 7.1).

1) link_status_ [1GKX] = OK
2) link_status_[10GKX4] = OK

Values: false; Exactly one of the above two indications was true when the autoneg_wait_timer expired, and an_receive_idle = true.
true; either zero or more than one of the above two indications was true when the autoneg_wait_timer expired, or an_receive_idle = false.

mr_restart_negotiation

Controls the entrance to the TRANSMIT DISABLE state to break the link before Auto-Negotiation is allowed to renegotiate via management control.

Values: false; renegotiation is not taking place.
true; renegotiation is started.

nonce_match

Indicates whether the transmitted nonce received from the link partner matches the transmitted nonce field sent by the local device.

Values false; link partner transmitted nonce does not equal local device transmitted nonce.
true; link partner transmitted nonce equals local device transmitted nonce.

np_rx

Flag to hold the value of rx_link_code_word[NP] upon entry to the COMPLETE

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ACKNOWLEDGE state. This value is associated with the value of rx_link_code_word[NP] when acknowledge_match was last set.

Values zero; local device np_rx bit equals a logical zero.
one; local device np_rx bit equals a logical one.

power_on

Condition that is true until such time as the power supply for the device that contains the Auto-Negotiation state diagrams has reached the operating region or the device has low-power mode set via MMD control register bit 1.120.12.

Values: false; the device is completely powered (default).
true; the device has not been completely powered.

pulse_too_long

Indicates that the receiver has detected successive transitions spaced too far apart for a valid DME page. Transitions separated by more than 20 ns shall cause this indication to be true. Valid Manchester violation delimiters shall not cause this indication to be true.

Values: false; excessively long pulses have not been detected.
true; excessively long pulses have been detected.

pulse_too_short

Indicates that the receiver has detected successive transitions spaced too closely for a valid DME page. Transitions separated by less than 1.6 ns shall cause this indication to be true. Valid Manchester transitions shall not cause this indication to be true.

Values: false; excessively short pulses have not been detected.
true; excessively short pulses have been detected.

rx_link_code_word[48:1]

A 48-bit array that contains the data bits to be received from a DME page.
For each element within the array:

Values: zero; data bit is a logical zero.
one; data bit is a logical one.

rx_nonce[4:0]

A 5-bit array that contains the transmitted nonce received from the DME page that caused ability_match=true.
For each element within the array:

Values: zero; data bit is a logical zero.
one; data bit is a logical one.

single_link_ready

Status indicating that an_receive_idle = true and only one the of the following indications is being received:

1) link_status_[1GKX] = OK
2) link_status_[10GKX4] = OK
3) link_status_[10GKR] = OK
4) link_status_[40GKR4] = OK
5) link_status_[40GCR4] = OK
6) link_status_[100GCR10] = OK
7) link_status_[100GKP4] = OK
8) link_status_[100GKR4] = OK
9) link_status_[100GCR4] = OK

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Values: false; either zero or more than one of the above indications are true or an_receive_idle = false.
true; Exactly one of the above indications is true and an_receive_idle = true.

NOTE—This variable is set by this variable definition; it is not set explicitly in the state diagrams.

TD_AUTONEG

Controls the signal sent by Auto-Negotiation on the TD_AUTONEG circuit.

Values: disable; transmission of Auto-Negotiation signals is disabled
idle; Auto-Negotiation maintains the current signal level on the MDI.
mv_delimiter; Auto-Negotiation causes the transmission of the Manchester violation delimiter on the MDI.
transition; Auto-Negotiation causes a transition in the level on the MDI.

toggle_rx

Flag to keep track of the state of the link partner's Toggle bit.

Values: zero; link partner's Toggle bit equals logical zero.
one; link partner's Toggle bit equals logical one.

toggle_tx

Flag to keep track of the state of the local device's Toggle bit.

Values: zero; local device's Toggle bit equals logical zero.
one; local device's Toggle bit equals logical one.

transmit_ability

Controls the transmission of the link codeword containing tx_link_code_word[48:1].

Values: false; any transmission of tx_link_code_word[48:1] is halted (default).
true; the transmit state diagram begins sending tx_link_code_word[48:1].

transmit_ack

Controls the setting of the Acknowledge bit in the tx_link_code_word[48:1] to be transmitted.

Values: false; sets the Acknowledge bit in the transmitted tx_link_code_word[48:1] to a logical zero (default).
true; sets the Acknowledge bit in the transmitted tx_link_code_word[48:1] to a logical one.

transmit_disable

Controls the transmission of tx_link_code_word[48:1].

Values: false; tx_link_code_word[48:1] transmission is allowed (default).
true; tx_link_code_word[48:1] transmission is halted.

transmit_mv_done

Status indicating that the transmission of the Manchester violation delimiter has been completed.

Values: false; transmission of the Manchester violation is in progress.
true; transmission of the Manchester violation has been completed.

tx_link_code_word[49:1]

A 49-bit array that contains the data bits to be transmitted in an DME page.
tx_link_code_word[48:1] contains the Auto-Negotiation page to be transmitted.
tx_link_code_word[49] contains the pseudo-random bit. This array may be loaded from mr_adv_ability or mr_np_tx.

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For each element within the array:

Values: zero; data bit is logical zero.
one; data bit is logical one.

73.10.2 State diagram timers

All timers operate in the manner described in 14.2.3.2.

autoneg_wait_timer
: Timer for the amount of time to wait before evaluating the number of link integrity test functions with link_status=OK asserted. The autoneg_wait_timer shall expire 25 ms to 50 ms from the assertion of link_status=OK from the PCS.

break_link_timer
: Timer for the amount of time to wait in order to assure that the link partner enters a Link Fail state. The timer shall expire 60 ms to 75 ms after being started.

clock_detect_min_timer
: Timer for the minimum time between detection of differential Manchester clock transitions. The clock_detect_min_timer shall expire 4.8 ns to 6.2 ns after being started or restarted.

clock_detect_max_timer
: Timer for the maximum time between detection of differential Manchester clock transitions. The clock_detect_max_timer shall expire 6.6 ns to 8.0 ns after being started or restarted.

data_detect_max_timer
: Timer for the maximum time between a clock transition and the following data transition. This timer is used in conjunction with the data_detect_min_timer to detect whether the data bit between two clock transitions is a logical zero or a logical one. The data_detect_max_timer shall expire 3.4 ns to 4.8 ns from the last clock transition.

data_detect_min_timer
: Timer for the minimum time between a clock transition and the following data transition. This timer is used in conjunction with the data_detect_max_timer to detect whether the data bit between two clock transitions is a logical zero or a logical one. The data_detect_min_timer shall expire 1.6 ns 3.0 ns from the last clock transition.

interval_timer
: Timer for the separation of a transmitted clock pulse from a data bit. The interval_timer shall expire 3.2 ns ± 0.01% from each clock pulse and data bit.

link_fail_inhibit_timer
: Timer for qualifying a link_status=FAIL indication or a link_status=OK indication when a specific technology link is first being established. A link will only be considered “failed” if the link_fail_inhibit_timer has expired and the link has still not gone into the link_status=OK state. The link_fail_inhibit_timer shall expire 40 ms to 50 ms after entering the AN LINK GOOD CHECK state when the link is 1000BASE-KX or 10GBASE-KX4. Otherwise the link_fail_inhibit_timer shall expire 500 ms to 510 ms after entering the AN LINK GOOD CHECK state.

NOTE—The link_fail_inhibit_timer expiration value must be greater than the time required for the link partner to complete Auto-Negotiation after the local device has completed Auto-Negotiation plus the time required for the specific technology to enter the link_status=OK state.

page_test_max_timer
: Timer for the maximum time between detection of Manchester violation delimiters. This timer is used in conjunction with the page_test_min_timer to detect whether the link partner is transmitting

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DME pages. The page_test_max_timer shall expire 350 ns to 375 ns after being started or restarted.

page_test_min_timer
: Timer for the minimum time between detection of Manchester violation delimiters. This timer is used in conjunction with the page_test_max_timer to detect whether the link partner is transmitting DME pages. The page_test_min_timer shall expire 305 ns 330 ns after being started or restarted.

Table 73–7—Timer min/max value summary

Parameter	Min	Value and tolerance	Max	Units
autoneg_wait_timer	25		50	ms
break_link_timer	60		75	ms
clock_detect_min_timer	4.8		6.2	ns
clock_detect_max_timer	6.6		8.0	ns
data_detect_min_timer	1.6		3.0	ns
data_detect_max_timer	3.4		4.8	ns
interval_timer		3.2 ± 0.01%		ns
link_fail_inhibit_timer (when the link is neither 1000BASE-KX nor 10GBASE-KX4)	500		510	ms
link_fail_inhibit_timer (when the link is 1000BASE-KX or 10GBASE-KX4)	40		50	ms
page_test_min_timer	305		330	ns
page_test_max_timer	350		375	ns

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73.10.3 State diagram counters

remaining_ack_cnt

A counter that may take on integer values from 0 to 8. The number of additional link codewords with the Acknowledge Bit set to logical one to be sent to ensure that the link partner receives the acknowledgment.

Values: not_done; positive integers between 0 and 5 inclusive.
done; positive integers 6 to 8 inclusive (default).
init; counter is reset to zero.

rx_bit_cnt

A counter that may take on integer values from 0 to 49. This counter is used to keep a count of data bits received from a DME page and to ensure that when erroneous extra transitions are received, the first 48 bits are kept while the rest are ignored. When this variable reaches 49, enough data bits have been received. This counter does not increment beyond 49 and does not return to 0 until it is reinitialized.

Values: not_done; 0 to 48 inclusive.
done; 49
init; counter is reset to zero.

tx_bit_cnt

A counter that may take on integer values from 1 to 50. This counter is used to keep a count of data bits sent within a DME page. When this variable reaches 50, all data bits have been sent.

Values: not_done; 1 to 49 inclusive.
done; 50.
init; counter is initialized to 1.

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73.10.4 State diagrams

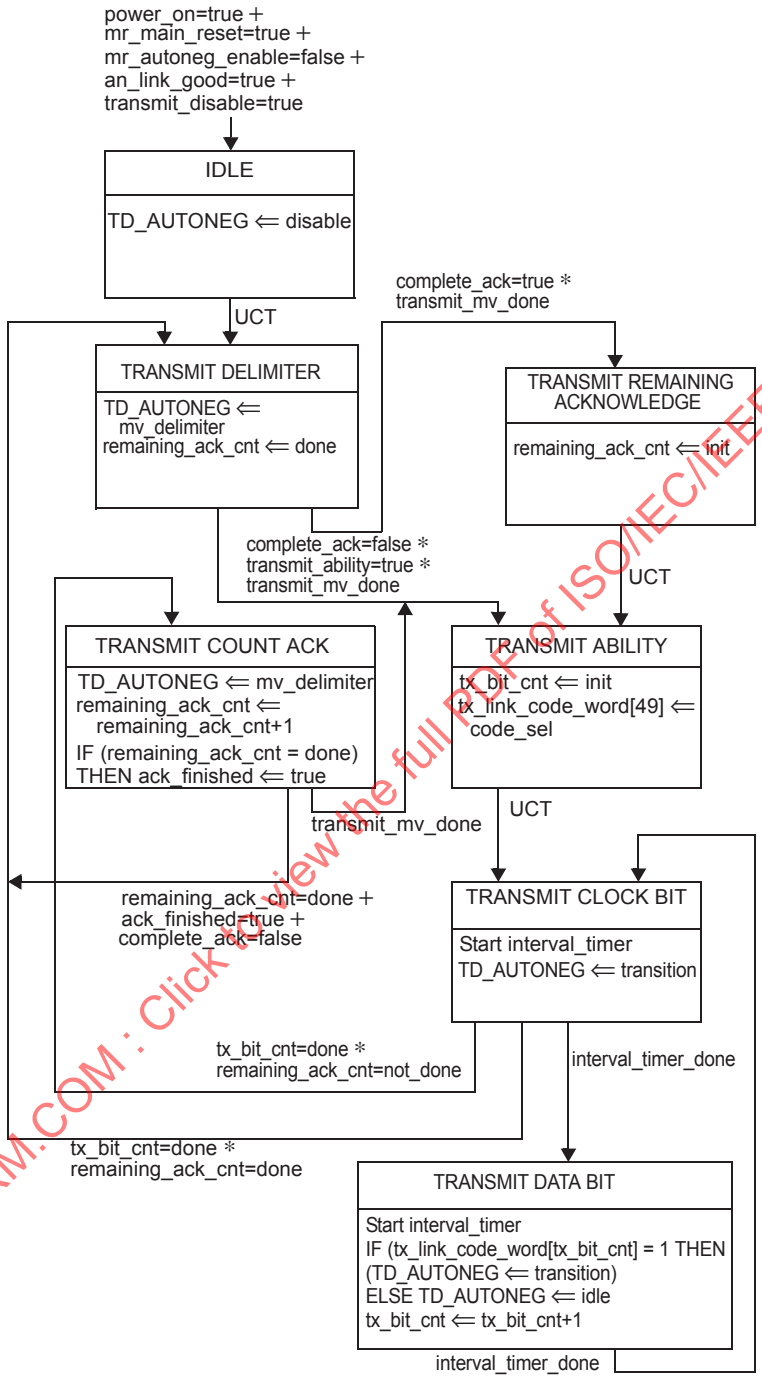

Figure 73–9—Transmit state diagram

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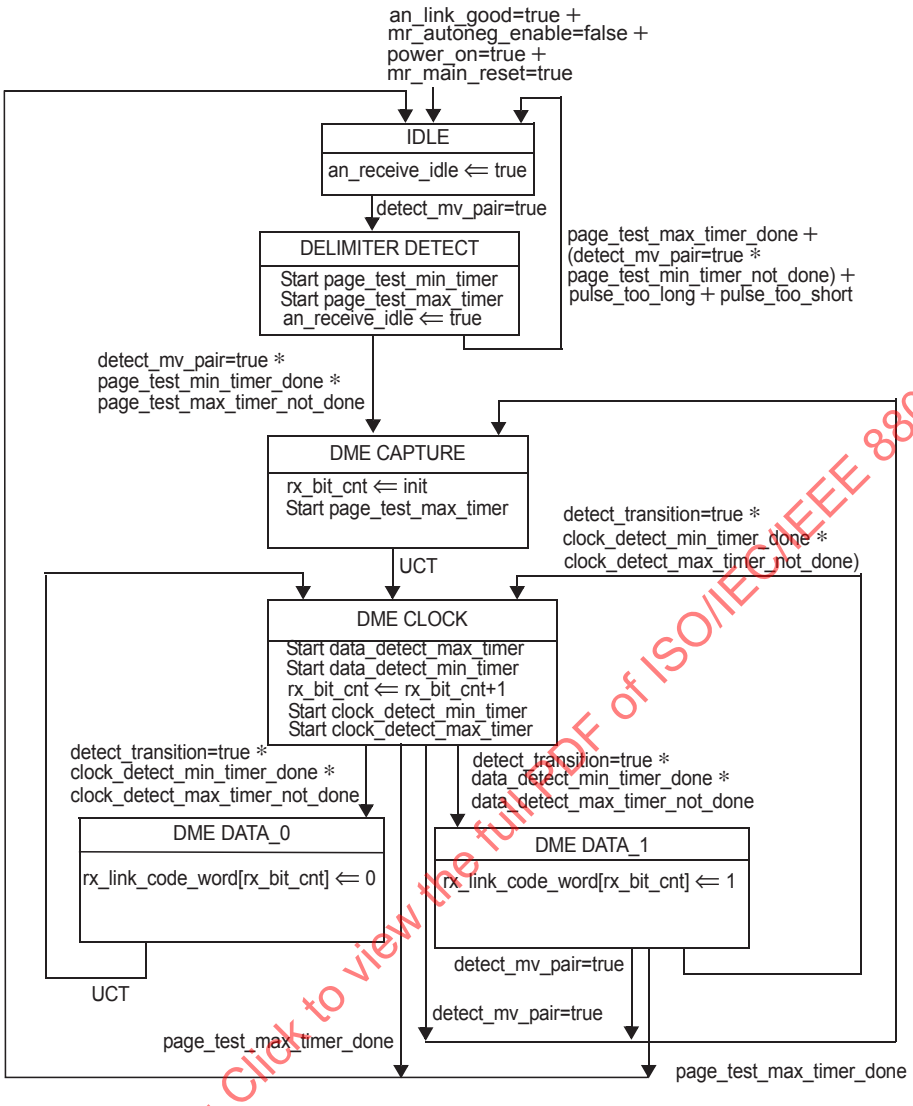

Figure 73–10—Receive state diagram

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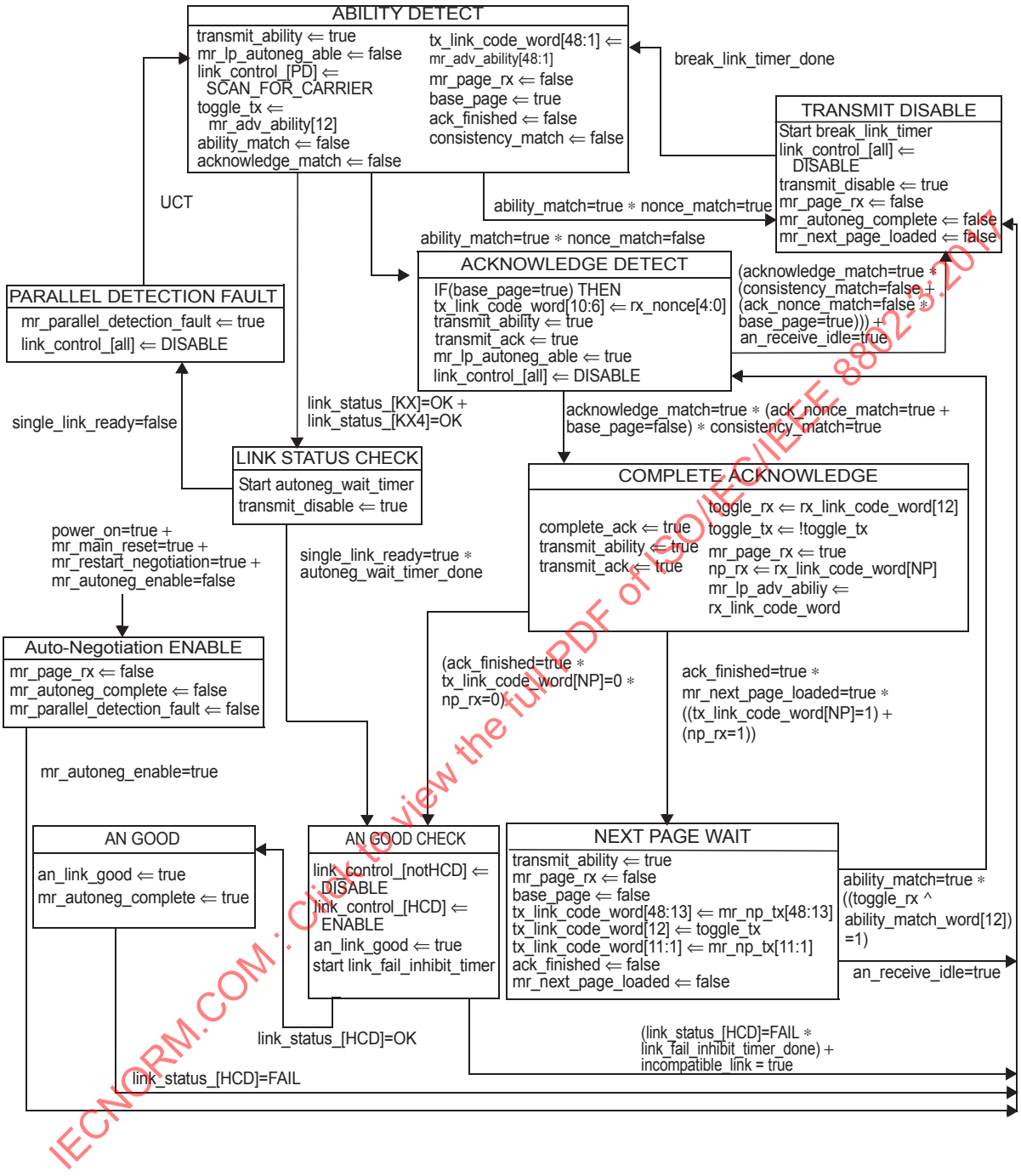

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Figure 73–11—Arbitration state diagram

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73.11 Protocol implementation conformance statement (PICS) proforma for Clause 73, Auto-Negotiation for backplane and copper cable assembly[30]

73.11.1 Introduction

The supplier of a protocol implementation that is claimed to conform to IEEE Std 802.3, Clause 73, Auto-Negotiation for backplane and copper cable assembly, shall complete the following protocol implementation conformance statement (PICS) proforma. A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

73.11.2 Identification

73.11.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

73.11.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 73, Auto-Negotiation for backplane and copper cable assembly
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	
Date of Statement	

[30]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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73.11.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
ANG	Auto-Negotiation	73.1		M	Yes [ ]
PLD	Parallel detection	73.1		M	Yes [ ]
NP	Next page support	73.6.9		M	Yes [ ]

73.11.4 PICS proforma tables for Auto-Negotiation for backplane and copper cable assembly

73.11.4.1 Functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FS1	Clause 37 Auto-Negotiation	73.1	Clause 37 Auto-Negotiation to be disabled	O	Yes [ ] No [ ]
FS2	Device intends to enable Clause 37 Auto-Negotiation after Clause 73 Auto-Negotiation	73.1	Ensure that link partner intends to enable Clause 37 Auto-Negotiation	FS1:M	Yes [ ]
FS3	Advertised abilities for Clause 37 Auto-Negotiation	73.1	Shall match those advertised in Clause 73 Auto-Negotiation	FS1:M	Yes [ ]
FS4	Auto-Negotiation functions	73.3	Auto-Negotiation function shall provide transmit, receive, and arbitration	M	Yes [ ]
FS5	Compliance with state diagrams	73.3	Figure 73–9 through Figure 73–11	M	Yes [ ]
FS6	Interaction with PHYs	73.3	Auto-Negotiation shall interact with technology-dependent PHYs through Technology -Dependent interface.	M	Yes [ ]

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73.11.4.2 DME transmission

Item	Feature	Subclause	Value/Comment	Status	Support
DT1	Transmission of DME pages	73.5	DME pages shall not be transmitted when Auto-Negotiation is complete and HCD PHY has been enabled	M	Yes [ ]
DT2	Multi-lane DME pages	73.5.1	Multi-lane DME pages shall be transmitted on Lane 0	M	Yes [ ]
DT3	DME electrical characteristics	73.5.1	Meet requirements of Table 73–1	M	Yes [ ]
DT4	Transitions in odd numbered positions	73.5.2	Remaining 49 odd-numbered positions shall contain a transition	M	Yes [ ]
DT5	Transitions in even numbered positions	73.5.2	Remaining 49 even-numbered positions shall represent data	M	Yes [ ]
DT6	First 48 even numbered positions	73.5.2	First 48 even numbered positions shall carry data of Auto-Negotiation page	M	Yes [ ]
DT7	Pseudo-random bit value	73.5.2	Value shall be derived from source as defined in 48.2.4.2	M	Yes [ ]
DT8	Pseudo-random counter	73.5.2	Counter shall increment once per DME page	M	Yes [ ]
DT9	DME page timing parameters	73.5.3	Meet requirements of Table 73–2	M	Yes [ ]

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73.11.4.3 Link codeword encoding

Item	Feature	Subclause	Value/Comment	Status	Support
LE1	Link codeword encoding	73.6	As shown in Figure 73–6	M	Yes [ ]
LE2	First bit transmitted	73.6	D0	M	Yes [ ]
LE3	RF, ACK, NP bits	73.6	As specified in 28.2.1.1	M	Yes [ ]
LE4	Reserved Selector Field	73.6.1	Shall not be transmitted	M	Yes [ ]
LE5	Echoed Nonce Field with Acknowledge set to zero	73.6.2	Contains logical zeros	M	Yes [ ]
LE6	Echoed Nonce Field with Acknowledge set to one	73.6.2	Values received in Transmitted Nonce Field from Link Partner	M	Yes [ ]
LE7	Transmitted Nonce Field	73.6.3	New value generated for each entry into Ability Detect	M	Yes [ ]
LE8	Support of multiple technologies	73.6.4	Shall support all technologies advertised	M	Yes [ ]
LE9	Technology ability reserved fields	73.6.4	Sent as zero and ignored by the receiver	M	Yes [ ]
LE10	FEC capability resolution	73.6.5	Resolve enabling of FEC capability based on F0 and F1 bits	M	Yes [ ]
LE11	Acknowledge with no Next Page	73.6.8	Set to 1 after three DME pages	M	Yes [ ]
LE12	Acknowledge with Next Page	73.6.8	Set to 1 after three DME pages	M	Yes [ ]
LE13	Device has no Next Pages to send	73.6.9	Next Page bit set to 0	M	Yes [ ]
LE14	Device has Next Pages to send	73.6.9	Next Page bit set to 1	M	Yes [ ]
LE15	Transmit switch function upon entry into the AN_GOOD_CHECK state	73.6.10	Connect the transmit path of HCD PHY to the MDI	M	Yes [ ]
LE16	Transmit switch function during Auto-Negotiation and prior to entry into the AN_GOOD_CHECK state	73.6.10	Connect only DME page generator to MDI	M	Yes [ ]
LE17	PHY connection to MDI	73.6.10	Signals at MDI conform to all PHY specifications within 20 ms	M	Yes [ ]
LE18	Incompatible abilities	73.6.4	PHYs for operation over electrical backplane are not simultaneously advertised with PHYs for operation over copper cable	M	Yes [ ]

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73.11.4.4 Receive function requirements

Item	Feature	Subclause	Value/Comment	Status	Support
RF1	Receive switch function upon entry into the AN_GOOD_CHECK state	73.7.2	Connect the receive path of HCD PHY to the MDI	M	Yes [ ]
RF2	Receive switch function during Auto-Negotiation and prior to entry into the AN_GOOD_CHECK state	73.7.2	Connect DME page receiver to MDI	M	Yes [ ]
RF3	Receive switch function during Auto-Negotiation and prior to entry into the AN_GOOD_CHECK state	73.7.2	Connect receive path of the 1000BASE-KX and 10GBASE-KX4 PHY when present	M	Yes [ ]
RF4	Receive function variables	73.7.3	As defined in Figure 73–11	M	Yes [ ]
RF5	Parallel detection for 1000BASE-KX and 10GBASE-KX4	73.7.4.1	Device provides parallel detection if it supports those PHYs	M	Yes [ ]
RF6	Parallel detection	73.7.4.1	Direct MDI receive activity to PHYs prior to DME detection	M	Yes [ ]
RF7	Enable one link after parallel detection	73.7.4.1	Enable link if signaling is present	M	Yes [ ]
RF8	Disable all other links after parallel detection	73.7.4.1	Disable all other PHYs	M	Yes [ ]
RF9	Parallel detection register settings	73.7.4.1	Set bit corresponding to technology detected	M	Yes [ ]
RF10	Detection of link_status=OK	73.7.4.1	autoneg_wait_timer starts	M	Yes [ ]
RF11	Renegotiation request	73.7.5	Disable PHYs and halt transmissions for break_link_timer	M	Yes [ ]
RF12	Resumption of Auto-Negotiation	73.7.5	Resume Auto-Negotiation after expiration of break_link_timer	M	Yes [ ]
RF13	Priority resolution	73.7.6	PHY with highest priority connected to MDI	M	Yes [ ]
RF14	Reception of reserved technology ability field bits	73.7.6	Ignore reserved technology ability field bits	M	Yes [ ]
RF15	Priority resolution through parallel detection	73.7.6	PHY chose through parallel detection is HCD	M	Yes [ ]
RF16	Priority resolution with no common technology	73.7.6	HCD takes on value of NULL and link_status=FAIL	M	Yes [ ]

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73.11.4.5 Next Page function

Item	Feature	Subclause	Value/Comment	Status	Support
NP1	Message codes	73.7.7	Each series of Next Pages has Message code	M	Yes [ ]
NP2	Next Page transmission while link partner not done	73.7.7	Device transmits Null Message code and sets NP bit to 0	M	Yes [ ]
NP3	Reception of Null message codes	73.7.7	Recognized as end of link partner's Next Pages	M	Yes [ ]
NP4	Next page encoding	73.7.7.1	As shown in Figure 73–7 and Figure 73–8	M	Yes [ ]
NP5	NP, Ack, MP, Ack2, T bits	73.7.7.1	As specified in 28.2.3.4	M	Yes [ ]
NP6	MP bit for message Next Pages	73.7.7.1	Set to logical one	M	Yes [ ]
NP7	Message Code Field in message Next Page	73.7.7.1	Encoded in D[10:0]	M	Yes [ ]
NP8	Unformatted Code Field in message Next Page	73.7.7.1	Encoded in D[47:16]	M	Yes [ ]
NP9	MP bit for Unformatted Next Pages	73.7.7.1	Set to logical zero	M	Yes [ ]
NP10	Unformatted Code Field in Unformatted Next Pages	73.7.7.1	Encoded in D[15:0] and D[47:16]	M	Yes [ ]
NP11	Continuation of Next Page exchange	73.7.7.2	Exchange continues until NP bit is zero on both devices	M	Yes [ ]
NP12	Transmission of Null Message Code field	73.7.7.2	Sent if device has no other information to transmit	M	Yes [ ]

73.11.4.6 Management register requirements

Item	Feature	Subclause	Value/Comment	Status	Support
MR1	MMD 7 of Clause 45 MDIO	73.8	Logical interface for access to device registers	M	Yes [ ]
MR2	Clause 45 electrical interface	73.8	Electrical interface for access to device registers	O	Yes [ ] No [ ]

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73.11.4.7 State diagrams and variable definitions

Item	Feature	Subclause	Value/Comment	Status	Support
SD1	Support of state diagrams	73.10	Transmit, Receive, Arbitration	M	Yes [ ]
SD2	Support of options	73.10	Options are allowed	M	Yes [ ]
SD3	Ambiguity between state diagrams and text	73.10	State diagrams take precedence	M	Yes [ ]
SD4	Pulse too short	73.10.1	Transitions separated by less than 1.6 ns	M	Yes [ ]
SD5	Pulse too short with valid transitions	73.10.1	Valid transitions not to cause this to be true	M	Yes [ ]
SD6	Pulse too long	73.10.1	Transitions separated by more than 20 ns	M	Yes [ ]
SD7	Pulse too long with valid violation delimiters	73.10.1	Valid Manchester violation delimiters not to set this	M	Yes [ ]
SD8	autoneg_wait_timer	73.10.2	25 ms to 50 ms	M	Yes [ ]
SD9	break_link_timer	73.10.2	60 ms to 75 ms	M	Yes [ ]
SD10	clock_detect_min_timer	73.10.2	4.8 ns to 6.2 ns	M	Yes [ ]
SD11	clock_detect_max_timer	73.10.2	6.6 ns to 8.0 ns	M	Yes [ ]
SD12	data_detect_max_timer	73.10.2	4.0 ns to 4.8 ns	M	Yes [ ]
SD13	data_detect_min_timer	73.10.2	1.6 ns to 2.4 ns	M	Yes [ ]
SD14	interval_timer	73.10.2	3.2 ns ± 0.01%	M	Yes [ ]
SD15	link_fail_inhibit_timer	73.10.2	500 to 510 ms when the link is not 1000BASE-KX or 10GBASE-KX4 and 40 ms to 50 ms otherwise	M	Yes [ ]
SD16	page_test_max_timer	73.10.2	350 ns to 375 ns	M	Yes [ ]
SD17	page_test_min_timer	73.10.2	305 ns to 330 ns	M	Yes [ ]

73.11.4.8 Service primitives

Item	Feature	Subclause	Value/Comment	Status	Support
SP1	link_status parameter	73.9.1.1	OK, FAIL	M	Yes [ ]
SP2	Generation of link_status primitive	73.9.1.2	Generated by technology dependent PCS	M	Yes [ ]
SP3	Receipt of link_status primitive	73.9.1.3	Governed by Figure 73–10	M	Yes [ ]

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73.11.4.9 Auto-Negotiation annexes

Item	Feature	Subclause	Value/Comment	Status	Support
AN1	Null Message code	73A.1	Transmitted during Next Page exchange when local device has no information to transmit and link partner has additional pages to transmit	M	Yes [ ]
AN2	OUI message code	73A.2	0000 0000 0101	M	Yes [ ]
AN3	OUI first user code	73A.2	OUI or CID (bits 23:13)	M	Yes [ ]
AN4	OUI second user code	73A.2	OUI or CID (bits 12:2)	M	Yes [ ]
AN5	OUI third user code	73A.2	OUI or CID (bits 1:0)	M	Yes [ ]
AN6	OUI fourth user code	73A.2	User-defined code value	M	Yes [ ]
AN7	AN device identifier Message code	73A.3	0000 0000 0110	M	Yes [ ]
AN8	AN device identifier first user code	73A.3	AN device identifier (7.2.15:5)	M	Yes [ ]
AN9	AN device identifier second user code	73A.3	AN device identifier (7.2.4:0 to 7.3.15:10)	M	Yes [ ]
AN10	AN device identifier third user code	73A.3	AN device identifier (7.3.9:0)	M	Yes [ ]
AN11	AN device identifier third user code bit 0	73A.3	User-defined code value	M	Yes [ ]
AN12	AN device identifier fourth user code	73A.3	User-defined code value	M	Yes [ ]
AN13	AN message code 10	73A.4	EEE technology message code	M	Yes [ ]

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74. Forward Error Correction (FEC) sublayer for BASE-R PHYs

74.1 Overview

This clause specifies an optional Forward Error Correction (FEC) sublayer for 10GBASE-R and other BASE-R PHYs. The FEC sublayer can be placed in between the PCS and PMA sublayers of the 10GBASE-R and other BASE-R Physical Layer implementations as shown in Figure 74–2, Figure 74–3, and Figure 74–4. For a PHY with a multi-lane BASE-R PCS, the FEC sublayer is instantiated for each PCS lane and operates autonomously on a per PCS lane basis. The FEC provides coding gain to increase the link budget and BER performance. The 10GBASE-KR and 40GBASE-KR4 PHYs described in Clause 72 and Clause 84 optionally use the FEC sublayer to increase the performance on a broader set of backplane channels than are defined in Clause 69. The FEC sublayer provides additional margin to account for variations in manufacturing and environmental conditions. The 40GBASE-CR4 and 100GBASE-CR10 PHYs described in Clause 85 optionally use the FEC sublayer to improve the BER performance beyond 10^{-12}.

74.2 Objectives

NOTE—The contents of this subclause have been deleted.

74.3 Relationship to other sublayers

Figure 74–1 depicts the relationships among the BASE-R FEC (shown shaded), the MAC and Reconciliation Sublayers, the BASE-R PCS, PMA and PMD, the ISO/IEC 8802-2 LLC, and the ISO/IEC Open System Interconnection (OSI) reference model.

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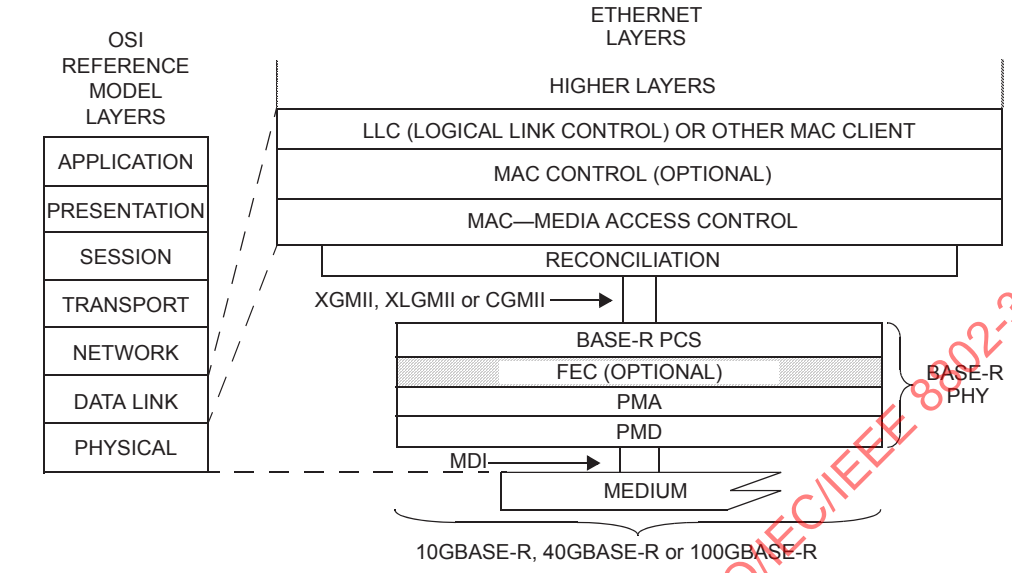

CGMII = 100 Gb/s MEDIA INDEPENDENT INTERFACE
FEC = FORWARD ERROR CORRECTION
MDI = MEDIUM DEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT
XGMII = 10 Gb/s MEDIA INDEPENDENT INTERFACE
XLGMII = 40 Gb/s MEDIA INDEPENDENT INTERFACE

Figure 74–1—BASE-R FEC relationship to ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 Ethernet model

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74.4 Inter-sublayer interfaces

An FEC service interface is provided to allow the FEC sublayer to transfer information to and from the PCS. An abstract service model is used to define the operation of this interface. For 10GBASE-R, the FEC service interface directly maps to the PMA service interface of the PCS defined in Clause 49 and the lower FEC sublayer interface maps to the service interface provided by the serial PMA sublayer defined in Clause 51. For 40GBASE-R and 100GBASE-R, the FEC service interface is an instance of the inter-sublayer service interface defined in 80.3 as is the PMA service interface defined in 83.2.

For 40GBASE-R and 100GBASE-R the FEC service interface can either connect to the PCS as illustrated in Figure 74–1 or the PMA as illustrated in Figure 83–2 where the FEC and PCS are in separate devices connected by XLAUI/CAUI-n.

This standard defines these interfaces in terms of bits, octets, data-group, data units, and signals; however, implementers may choose other data-path widths and other control mechanisms for implementation convenience, provided that the implementation adheres to the logical model of the service interface.

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74.4.1 Functional Block Diagram for 10GBASE-R PHYs

Figure 74–2 shows the functional block diagram of FEC for 10GBASE-R PHY and the relationship between the PCS and PMA sublayers.

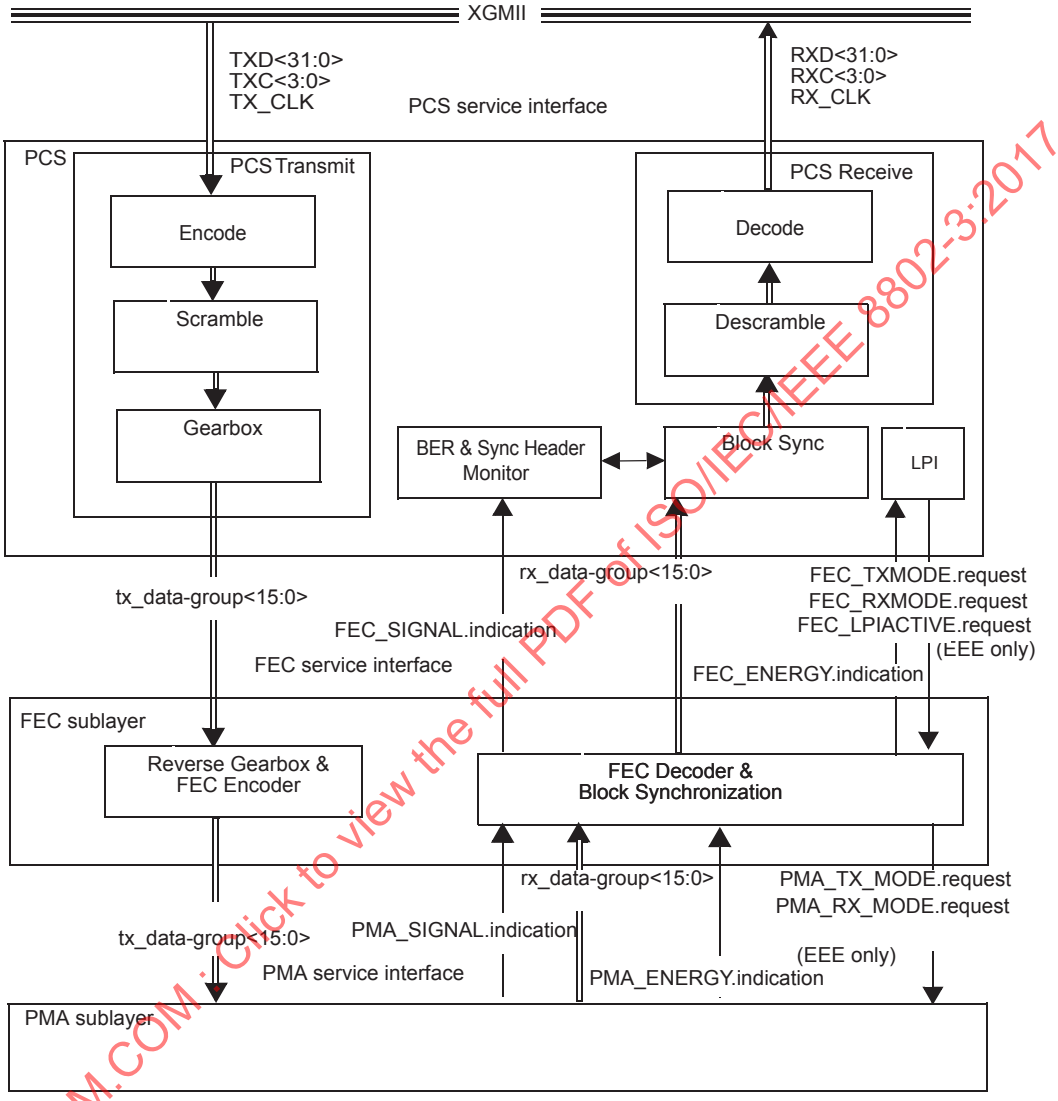

Figure 74–2—Functional block diagram for 10GBASE-R PHYs

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74.4.2 Functional block diagram for 40GBASE-R PHYs

Figure 74–3 shows the functional block diagram of FEC for 40GBASE-R PHYs and the relationship between the PCS and PMA sublayers.

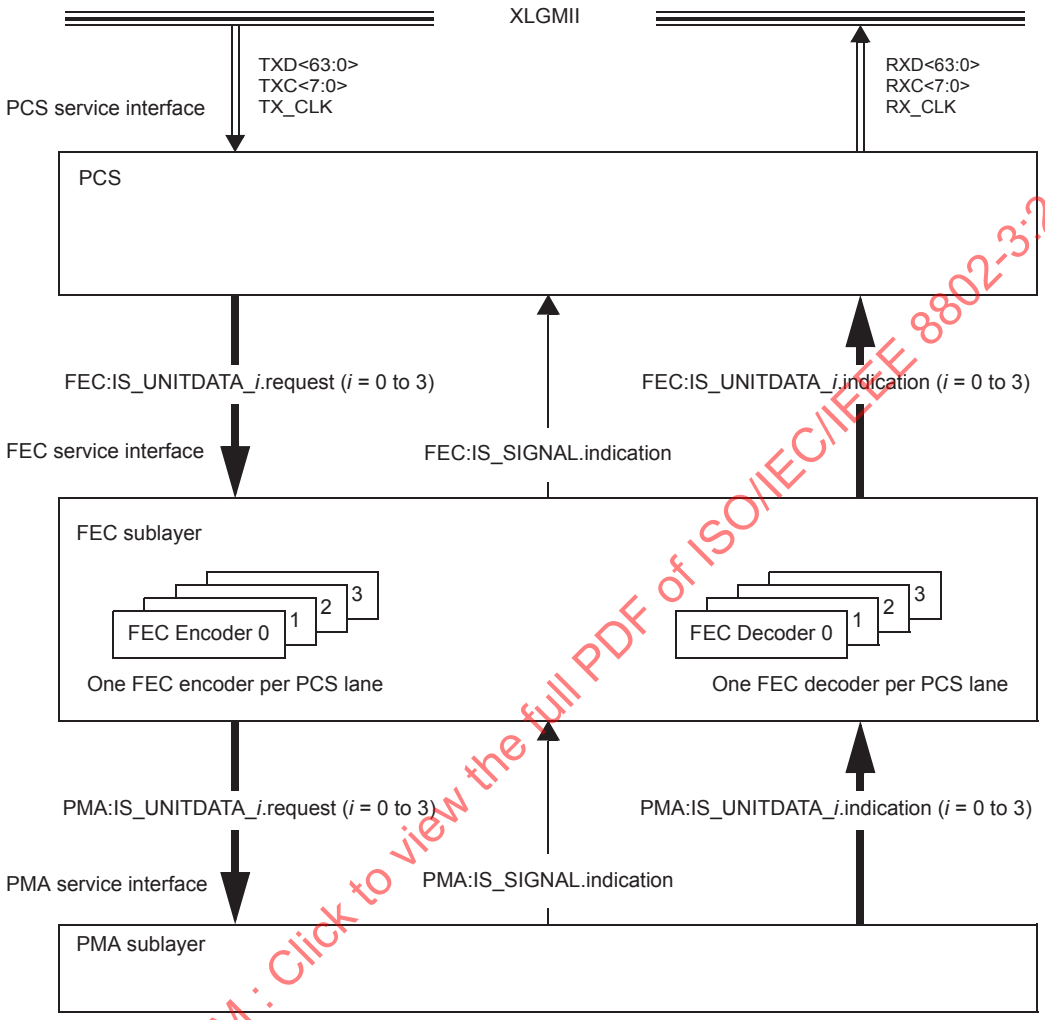

Figure 74–3—Functional block diagram for 40GBASE-R PHY

74.4.3 Functional block diagram for 100GBASE-R PHYs

Figure 74–4 shows the functional block diagram of FEC for 100GBASE-R PHYs and the relationship between the PCS and PMA sublayers.

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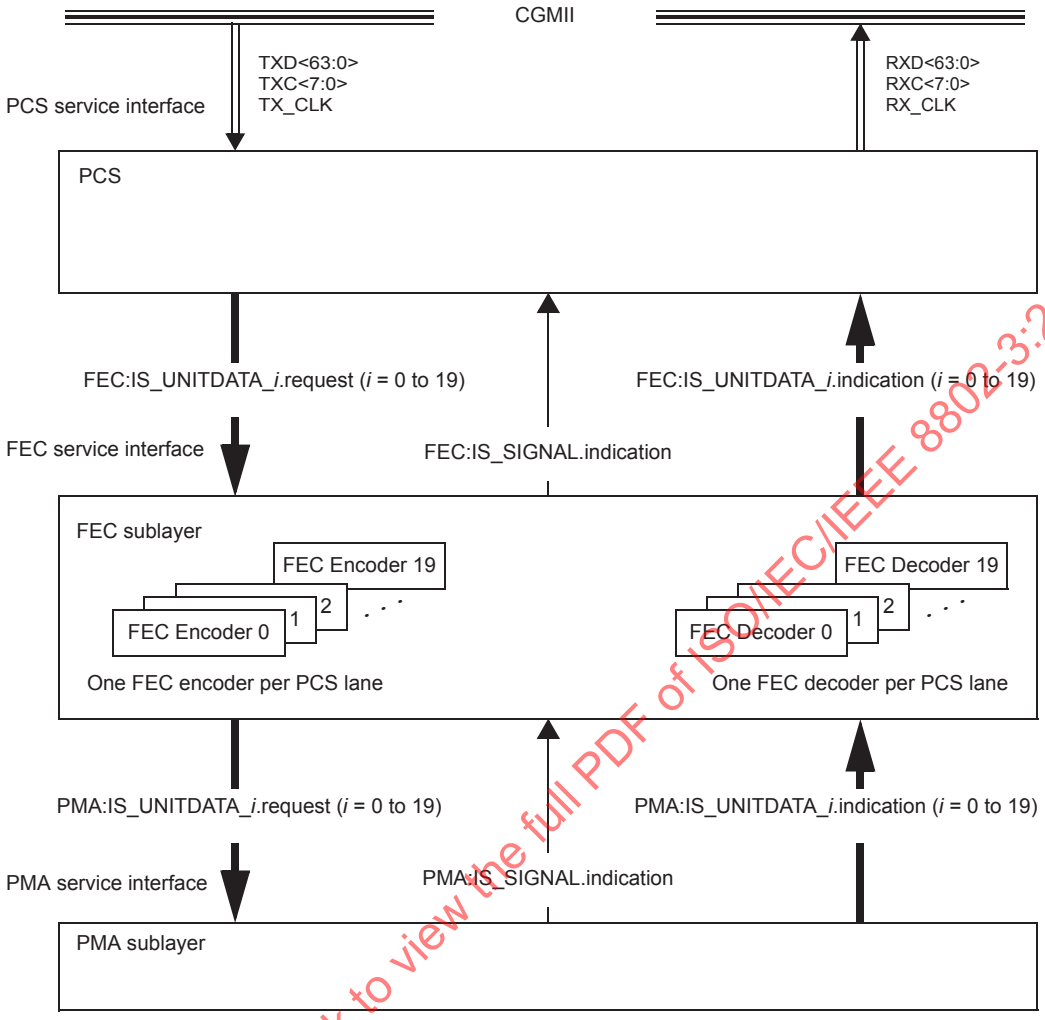

Figure 74–4—Functional block diagram for 100GBASE-R PHY

74.5 FEC service interface

The FEC service interface is provided to allow the PCS to transfer information to and from the FEC. The FEC service interface is equivalent to the PMA service interface for 10GBASE-R and an instance of the inter-sublayer service interface defined in 80.3 for 40GBASE-R and 100GBASE-R. These services are defined in an abstract manner and do not imply any particular implementation. The FEC service interface supports exchange of data units between PCS entities on either side of a link using request and indication primitives. Data units are mapped into FEC blocks by the FEC and passed to the PMA, and vice versa.

The service primitives are defined differently for 10GBASE-R and for 40GBASE-R and 100GBASE-R.

Optional physical instantiations of the PMA service interface have been defined (see Clause 51, Annex 83A, Annex 83B, Annex 83D, and Annex 83E). There is XSBI (10 Gigabit Sixteen-Bit Interface) for 10GBASE-R, XLAUI for 40GBASE-R and CAUI-n for 100GBASE-R. These physical instantiations, with a PMA if required, may also be used for the FEC service interface.

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74.5.1 10GBASE-R service primitives

The following primitives are defined within the FEC service interface:

a) FEC_UNITDATA.request(tx_data-group<15:0>)
b) FEC_UNITDATA.indication(rx_data-group<15:0>)
c) FEC_SIGNAL.indication(SIGNAL_OK)
d) FEC_TX_MODE.request(tx_mode)
e) FEC_RX_MODE.request(rx_mode)
f) FEC_ENERGY.indication(energy_detect)
g) FEC_LPI_ACTIVE.request(rx_lpi_active)

Items d), e), f), and g) are only required for the optional EEE capability.

The FEC service interface directly maps to the PMA service interface of the 10GBASE-R PCS defined in Clause 49. The FEC_UNITDATA.request maps to the PMA_UNITDATA.request primitive, the FEC_UNITDATA.indication maps to the PMA_UNITDATA.indication primitive, and the FEC_SIGNAL.indication maps to the PMA_SIGNAL.indication primitive of the 10GBASE-R PCS.

If the optional Energy-Efficient Ethernet (EEE) capability is supported (see Clause 78) then the interface with the PMA sublayer (or FEC sublayer) includes rx_mode and tx_mode to control power states in lower sublayers and energy_detect that indicates whether the PMD sublayer has detected a signal at the receiver.

74.5.1.1 FEC_UNITDATA.request

This primitive defines the transfer of data in the form of constant-width data units from the PCS to the FEC. The data supplied via FEC_UNITDATA.request is mapped by the FEC Transmit process into the payload capacity of the outgoing FEC block stream.

74.5.1.1.1 Semantics of the service primitive

FEC_UNITDATA.request(tx_data-group<15:0>)

The data conveyed by FEC_UNITDATA.request is a 16-bit vector representing a single data unit that has been prepared for transmission by the 10GBASE-R PCS Transmit process.

74.5.1.1.2 When generated

The 10GBASE-R PCS sends tx_data-group<15:0> to the FEC at a nominal rate of 644.53125 MHz, corresponding to the 10GBASE-R signaling rate of 10.3125 GBd.

74.5.1.1.3 Effect of receipt

Upon receipt of this primitive, the FEC Transmit process maps the data conveyed by the tx_data unit<15:0> parameter into the payload of the transmitted FEC block stream, adds FEC overhead as required, scrambles the data, and transfers the result to the PMA via the PMA_UNITDATA.request primitives.

74.5.1.2 FEC_UNITDATA.indication

This primitive defines the transfer of received data in the form of constant-width data units from the FEC to the PCS. FEC_UNITDATA.indication is generated by the FEC Receive process in response to FEC block data received from the PMA.

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74.5.1.2.1 Semantics of the service primitive

FEC_UNITDATA.indication(rx_data-group<15:0>)

The rx_data-group<15:0> parameter is a 16-bit vector that represents the data unit transferred by the FEC to the 10GBASE-R PCS.

74.5.1.2.2 When generated

The FEC sends one rx_data-group<15:0> to the 10GBASE-R PCS for each 16 bits received from the PMA sublayer. The nominal rate of generation of the FEC_UNITDATA.indication primitive is 644.53125 Mtransfers/s.

74.5.1.2.3 Effect of receipt

The effect of receipt of this primitive by the FEC client is unspecified by the FEC sublayer.

74.5.1.3 FEC_SIGNAL.indication

This primitive is sent by the FEC to the PCS to indicate the status of the Receive process. FEC_SIGNAL.indication is generated by the FEC Receive process in order to propagate the detection of severe error conditions (e.g., no valid signal being received from the PMA sublayer) to the PCS.

74.5.1.3.1 Semantics of the service primitive

FEC_SIGNAL.indication(SIGNAL_OK)

The SIGNAL_OK parameter can take one of two values: OK or FAIL. A value of OK denotes that the FEC Receive process is successfully delineating valid payload information from the incoming data stream received from the PMA sublayer indicated by the fec_signal_ok variable equal to true, and this payload information is being presented to the PCS via the FEC_UNITDATA.indication primitive. A value of FAIL denotes that errors have been detected by the Receive process indicated by the fec_signal_ok variable equal to false, that prevent valid data from being presented to the PCS, in this case the FEC_UNITDATA.indication primitive and its associated rx_data-group<15:0> parameter are meaningless.

74.5.1.3.2 When generated

The FEC generates the FEC_SIGNAL.indication primitive to the 10GBASE-R PCS whenever there is a change in the value of the SIGNAL_OK parameter and FEC block synchronization is achieved.

74.5.1.3.3 Effect of receipt

The effect of receipt of this primitive by the FEC client is unspecified by the FEC sublayer.

74.5.1.4 FEC_ENERGY.indication (optional)

FEC_ENERGY.indication(energy_detect)

A Boolean variable that reflects the value of the energy detection primitive PMA_ENERGY.indication.

74.5.1.4.1 Effect of receipt

The effect of receipt of this primitive by the FEC client is unspecified by the FEC sublayer.

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74.5.1.5 FEC_LPI_ACTIVE.request (optional)

FEC_LPI_ACTIVE.request(rx_lpi_active)

The rx_lpi_active parameter is a Boolean variable sent from the PCS that is set to TRUE when LPI mode is active at the receiver and set to FALSE otherwise.

74.5.1.5.1 When generated

The generation of this primitive by the FEC client is unspecified by the FEC sublayer.

74.5.1.5.2 Effect of receipt

When rx_lpi_active is TRUE, rapid block lock as specified in 74.7.4.8 will be used to quickly determine the start of the FEC block during EEE REFRESH or WAKE. When rx_lpi_active is FALSE, rapid block lock will not be used.

74.5.1.6 FEC_RX_MODE.request (optional)

FEC_RX_MODE.request(rx_mode)

The rx_mode parameter is a variable sent from the PCS. It is set to QUIET while the receiver is in the RX_QUIET state and is set to DATA otherwise.

74.5.1.6.1 When generated

The generation of this primitive by the FEC client is unspecified by the FEC sublayer.

74.5.1.6.2 Effect of receipt

When rx_mode is QUIET, the FEC decoder logic may deactivate functional blocks to conserve energy. When rx_mode is DATA, the FEC decoder logic operates normally. The value rx_mode is passed to the client layer through PMA_RX_MODE(rx_mode).request.

74.5.1.7 FEC_TX_MODE.request (optional)

FEC_TX_MODE.request(tx_mode)

The tx_mode parameter is a variable sent from the PCS. It is set to QUIET while the transmitter is in the TX_QUIET state, it is set to ALERT while the transmitter is in the TX_ALERT state and is set to DATA otherwise.

74.5.1.7.1 When generated

The generation of this primitive by the FEC client is unspecified by the FEC sublayer.

74.5.1.7.2 Effect of receipt

When tx_mode is QUIET or ALERT, the FEC encoder logic may deactivate functional blocks to conserve energy. When tx_mode is DATA, the FEC encoder logic operates normally. The value tx_mode is passed to the client layer through PMA_TX_MODE(tx_mode).request.

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74.5.2 40GBASE-R and 100GBASE-R service primitives

The FEC service interface for 40GBASE-R and 100GBASE-R is an instance of the inter-sublayer service interface defined in 80.3. The FEC service interface primitives are summarized as follows:

a) FEC:IS_UNITDATA_*i*.request
b) FEC:IS_UNITDATA_*i*.indication
c) FEC:IS_SIGNAL.indication
d) FEC_TX_MODE.request(tx_mode)
e) FEC_RX_MODE.request(rx_mode)
f) FEC_RX_TX_MODE.indication(rx_tx_mode)
g) FEC_LPI_ACTIVE.request(rx_lpi_active)
h) FEC_ENERGY.indication(energy_detect)

Items d), e), f), g), and h) are only required for the optional EEE capability.

The 40GBASE-R FEC has four parallel bit streams, hence $i = 0$ to 3 for 40GBASE-R and the 100GBASE-R FEC has twenty parallel bit streams, hence $i = 0$ to 19 for 100GBASE-R.

The PCS (or PMA) continuously sends four or twenty parallel bit streams to the FEC, one per PCS lane, each at a nominal signaling rate of 10.3125 GBd for 40GBASE-R and 5.15625 GBd for 100GBASE-R.

This FEC:IS_SIGNAL.indication primitive is sent by the FEC to the PCS (or PMA) to indicate the status of the Receive process. FEC:IS_SIGNAL.indication is generated by the FEC Receive process in order to propagate the detection of severe error conditions (e.g., no valid signal being received from the PMA sublayer) to the PCS (or PMA).

The SIGNAL_OK parameter in FEC:IS_SIGNAL.indication can take one of two values: OK or FAIL. A value of OK denotes that the FEC Receive process is successfully delineating valid payload information from all of the incoming data streams received from the PMA sublayer indicated by the fec_signal_ok variable equal to true, for all data streams, and this payload information is being presented to the PCS (or PMA) via the FEC:IS_UNITDATA_*i*.indication primitive. A value of FAIL denotes that errors have been detected by the Receive process indicated by the fec_signal_ok variable equal to false, in any of the data streams, that prevent valid data from being presented to the PCS (or PMA), in this case the FEC:IS_UNITDATA_*i*.indication primitive is a direct pass through of the PMA:IS_UNITDATA_*i*.indication from the PMA.

If the optional Energy-Efficient Ethernet (EEE) capability is supported (see Clause 78) then the interface with the PMA sublayer (or FEC sublayer) includes rx_mode and tx_mode to control power states in lower sublayers and energy_detect that indicates whether the PMD sublayer has detected a signal at the receiver. If the optional EEE deep sleep capability is supported, rx_tx_mode is passed through the FEC but is not used by it.

The tx_mode parameter in FEC_TX_MODE.request is sent from the PCS. It is set to QUIET while the transmitter is in the TX_QUIET state, it is set to ALERT while the transmitter is in the TX_ALERT state, and is set to DATA otherwise.

The rx_mode parameter in FEC_RX_MODE.request is sent from the PCS. It is set to QUIET while the receiver is in the RX_QUIET state and is set to DATA otherwise.

The FEC_RX_TX_MODE.indication primitive communicates the rx_tx_mode parameter. This parameter indicates the value of tx_mode that the PMA sublayer has inferred from the received signal. Without EEE deep sleep capability, the primitive is never generated and the sublayer behaves as if rx_tx_mode=DATA. The parameter rx_tx_mode is assigned one of the following values: DATA, QUIET, or ALERT.

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The rx_lpi_active parameter in FEC_LPI_ACTIVE.request is a Boolean variable sent from the PCS that is set to TRUE when LPI mode is active at the receiver and set to FALSE otherwise.

The energy_detect parameter in FEC_ENERGY.indication is a Boolean variable that indicates to the PCS that energy has been detected at the PMD.

74.6 Delay constraints

Predictable operation of the MAC Control PAUSE operation (Clause 31, Annex 31B) demands that there be an upper bound on the propagation delays through the network. This implies that MAC, MAC Control sublayer, and PHY implementers must conform to certain delay maxima, and that network planners and administrators conform to constraints regarding the cable topology and concatenation of devices.

The maximum delay contributed by the 10GBASE-R FEC (sum of transmit and receive delays at one end of the link) shall be no more than 6144 BT (or 12 pause_quanta or 614.4 ns).

The maximum delay contributed by the 40GBASE-R FEC (sum of transmit and receive delays at one end of the link) shall be no more than 24576 BT (or 48 pause_quanta or 614.4 ns).

The maximum delay contributed by the 100GBASE-R FEC (sum of transmit and receive delays at one end of the link) shall be no more than 122880 BT (or 240 pause_quanta or 1228.8 ns).

A description of overall system delay constraints and the definitions for bit-times and pause_quanta can be found in 80.4 and its references.

74.7 FEC principle of operation

On transmission, the FEC sublayer receives data from the PCS, transcodes 64B/66B words, performs the FEC coding/framing, scrambles and sends the data to the PMA. On reception, the FEC sublayer receives data from the PMA, performs descrambling, achieves FEC framing synchronization, decodes the FEC code, correcting data where necessary and possible, re-codes 64B/66B words, and sends the data to the PCS.

74.7.1 FEC code

The FEC code used is a shortened cyclic code (2112, 2080) for error checking and forward error correction. The FEC block length is 2112 bits. The code encodes 2080 bits of payload (or information symbols) and adds 32 bits of overhead (or parity symbols). The code is systematic—meaning that the information symbols are not disturbed in anyway in the encoder and the parity symbols are added separately to the end of each block.

The (2112,2080) code is constructed by shortening the cyclic code (42987, 42955). The shortened cyclic code (2112,2080) is guaranteed to correct an error burst of up to 11 bits per block. It is a systematic code that is well suited for correction of the burst errors typical in a backplane channel (see 69.3) resulting from error propagation in the receive equalizer.

See Blahut [B22] and Lin and Costello [B52] for additional information on cyclic codes and shortened cyclic codes for correcting burst errors.

74.7.2 FEC block format

The format of the FEC block is shown in Table 74–1. The length of the FEC block is 2112 bits. Each FEC block contains 32 rows of 65 bits each; 64 bits of payload and 1 bit transcoding overhead (T bits). At the end

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of each block there is 32-bit overhead or parity check bits. Transmission is from left to right within each row and from top to bottom between rows. The payload bits carry the information symbols from the PCS layer.

Table 74–1—FEC block format

T_0	64 bit payload Word 0	T_1	64 bit payload Word 1	T_2	64 bit payload Word 2	T_3	64 bit payload Word 3
T_4	64 bit payload Word 4	T_5	64 bit payload Word 5	T_6	64 bit payload Word 6	T_7	64 bit payload Word 7
T_8	64 bit payload Word 8	T_9	64 bit payload Word 9	T_{10}	64 bit payload Word 10	T_{11}	64 bit payload Word 11
T_{12}	64 bit payload Word 12	T_{13}	64 bit payload Word 13	T_{14}	64 bit payload Word 14	T_{15}	64 bit payload Word 15
T_{16}	64 bit payload Word 16	T_{17}	64 bit payload Word 17	T_{18}	64 bit payload Word 18	T_{19}	64 bit payload Word 19
T_{20}	64 bit payload Word 20	T_{21}	64 bit payload Word 21	T_{22}	64 bit payload Word 22	T_{23}	64 bit payload Word 23
T_{24}	64 bit payload Word 24	T_{25}	64 bit payload Word 25	T_{26}	64 bit payload Word 26	T_{27}	64 bit payload Word 27
T_{28}	64 bit payload Word 28	T_{29}	64 bit payload Word 29	T_{30}	64 bit payload Word 30	T_{31}	64 bit payload Word 31
32 parity bits							

Total FEC block length = $(32 \times 65) + 32 = 2112$ bits

74.7.3 Composition of the FEC block

The FEC sublayer does not decrease the symbol rate of the PCS, nor does it increase the signaling rate of the PMD sublayer. Instead, the FEC sublayer compresses the sync bits from the 64B/66B encoded data provided by the PCS to accommodate the addition of 32 parity check bits for every block of 2080 bits.

The BASE-R 64B/66B PCS maps 64 bits of scrambled payload and 2 bits of unscrambled sync header into 66-bit encoded blocks. The 2-bit sync header allows establishment of 64B/66B block boundaries by the PCS sync process. The sync header is 01 for data blocks and 10 for control blocks; the sync header is the only position in the PCS block that always contain a transition and this feature of the code is used to establish 64B/66B block boundaries.

The FEC sublayer compresses the 2 bits of the sync header to 1 transcode bit. The transcode bit carries the state of BASE-R sync bits for the associated payload. This is achieved by eliminating the first bit in 64B/66B block, which is also the first sync bit, and preserving the second bit. The value of the second bit defines the value of the removed first bit uniquely, since it is always an inversion of the first bit. The transcode bits are further scrambled (as explained in 74.7.4.2) to ensure DC balance.

The 32 sequential 64B/66B blocks are transcoded in this fashion, and then 32 bits of FEC parity are computed for them. The 32 transcoded words and the 32 FEC parity bits constitute an FEC block.

The error detection property of the FEC cyclic code is used to establish block synchronization at FEC block boundaries at the receiver. If decoding passes successfully, the FEC decoder produces 32 65-bit words, the

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first decoded bit of each word being the transcode bit. Then the first sync bit in 64B/66B code is constructed by the inversion of the transcode bit, and the value of the second sync bit is equal to the transcode bit.

74.7.4 Functions within FEC sublayer

The FEC sublayer comprises four functional blocks; FEC Encoder, Reverse Gearbox function, FEC decoder, and FEC block synchronization.

74.7.4.1 Reverse gearbox function

74.7.4.1.1 Reverse gearbox function for 10GBASE-R

The reverse gearbox function adapts between the 66-bit width of the 64B/66B blocks and the 16-bit width of the PCS interface. It receives the 16-bit stream from the PCS interface and converts them back to 66-bit encoded blocks for the FEC Encoder to process. The reverse gearbox function operates in the same manner as the block sync function defined in 49.2.9.

The reverse gearbox function receives data via 16-bit FEC_UNITDATA.request primitive. It will form a bit stream from the primitives by concatenating requests with the bits of each primitive in order to form tx_data-group<0> to tx_data-group<15> (see Figure 49–6). It obtains lock to the 66-bit blocks in the bit stream using the sync headers and outputs 66-bit blocks. Lock is obtained as specified in the block lock state diagram shown in Figure 49–14.

The reverse gearbox functionality is necessary only when the optional PMA compatibility interface named XSBI is implemented between the PCS and FEC functions, since that interface passes data via a 16-bit wide path. When the XSBI is not implemented, the internal data-path width between the PCS and FEC is an implementation choice. Depending on the path width, the reverse gearbox function may not be necessary.

74.7.4.1.2 Reverse gearbox function for 40GBASE-R and 100GBASE-R

The reverse gearbox function adapts between the 66-bit width of the 64B/66B blocks and the 1-bit wide lane of the 40GBASE-R or 100GBASE-R PCS to FEC interface (or PMA to FEC interface). It receives the 1-bit stream from the FEC service interface (or PMA service interface) and converts it back to 66-bit encoded blocks for the FEC Encoder to process. The reverse gearbox function, if implemented, shall operate in the same manner as the lane block sync function defined in 82.2.12.

The reverse gearbox function receives data via the 40GBASE-R and 100GBASE-R FEC:IS_UNITDATA_*i*.request primitive see 74.5.2 (or via the PMA:IS_UNITDATA_*i*.request primitive). It obtains lock to the 66-bit blocks in each bit stream using the sync headers and outputs 66-bit blocks to the FEC encoder function (see 74.7.4.4). PCS lane lock is obtained as specified in the PCS lane lock state diagram shown in Figure 82–12.

The internal data-path width from the PCS or PMA is an implementation choice. Depending on the path width, the reverse gearbox function may not be necessary.

74.7.4.2 FEC Encoder

The FEC encoder connects to the reverse gearbox function using the 66-bit wide data path. The FEC encoder takes 32 × 64B/66B blocks from the reverse gearbox and encodes it into a single FEC block of 2112 bits. The FEC Encoder compresses the two sync bits to one transcode bit as explained in 74.7.3. The transcode bit is then XOR'ed with data bit 8 of the corresponding 64B/66B block. The resulting 32 × 65b = 2080 bits with the block format as shown in Table 74–1 are fed to the (2112,2080) encoder, which produces 32 parity-check bits. The parity check bits are appended to the end of the FEC block. The FEC block is

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scrambled using the PN-2112 pseudo-noise sequence as described in 74.7.4.4.1. and sent to the PMA interface.

74.7.4.3 FEC transmission bit ordering

The format of the FEC block and the transmit bit ordering is shown in Figure 74–5.

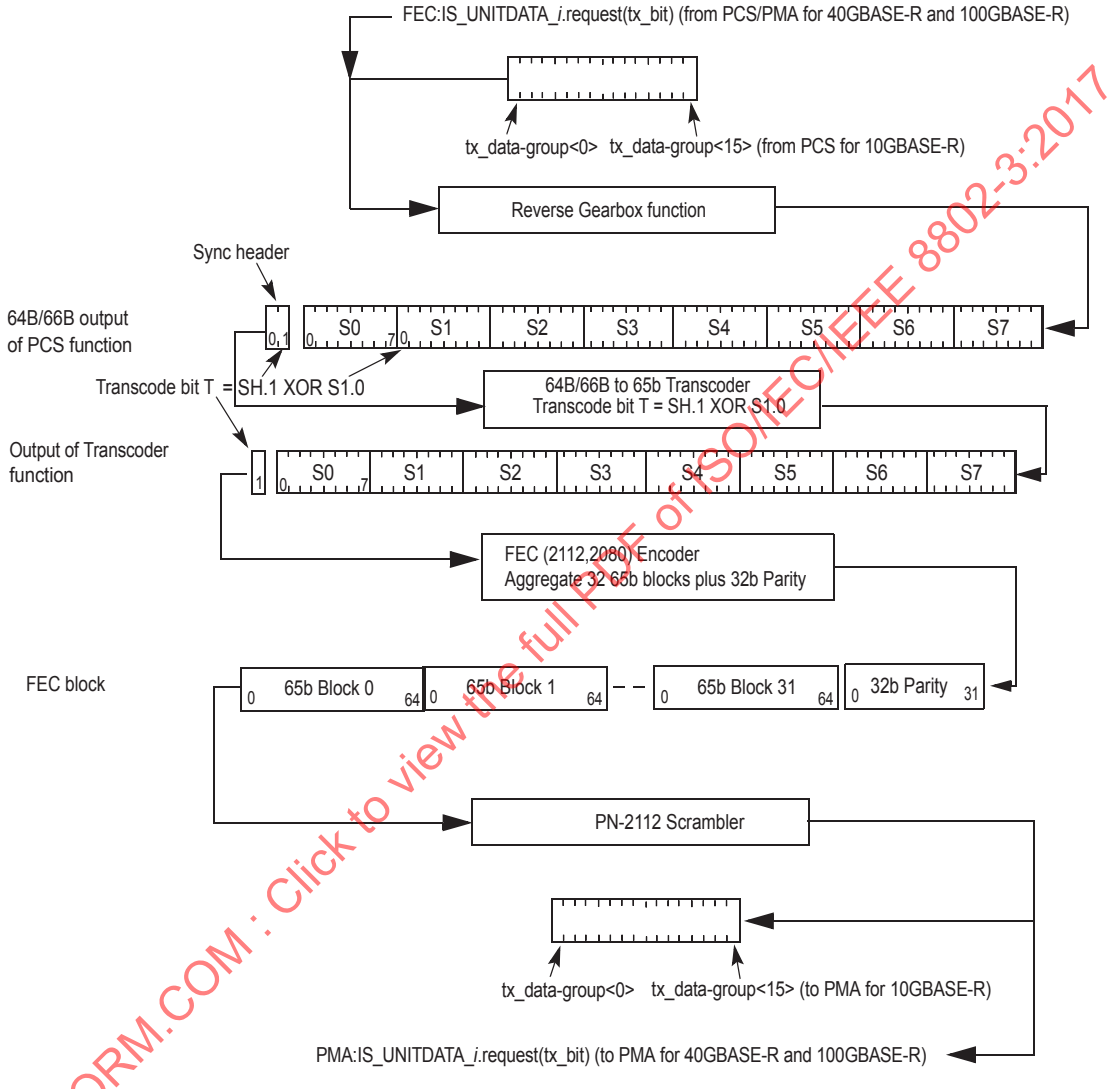

Figure 74–5—FEC Transmit bit ordering

74.7.4.4 FEC (2112,2080) encoder

The block diagram of the FEC Encoder is illustrated in Figure 74–6. The 32 × 65-bit payload blocks are encoded by the (2112, 2080) code. This code is a shortened cyclic code that can be encoded by generator polynomial *g(x)*. The FEC block is scrambled using the PN-2112 pseudo-noise sequence as described in 74.7.4.4.1.

The generator polynomial *g(x)* for the (2112, 2080) parity-check bits is defined as given in Equation (74–1).

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$$g(x) = x^{32} + x^{23} + x^{21} + x^{11} + x^{2} + 1 \quad (74–1)$$

If the polynomial representation of information bits is *m(x)*, the codeword *c(x)* can be calculated in systematic form as given in Equation (74–2) and Equation (74–3).

$$p(x) = x^{32} m(x) \bmod g(x) \quad (74–2)$$

$$c(x) = p(x) + x^{32} m(x) \quad (74–3)$$

(Multiplication by x^{32} is performed using shifts).

Systematic form of the codeword means that first 2080 bits of the codeword are information bits that can be extracted directly.

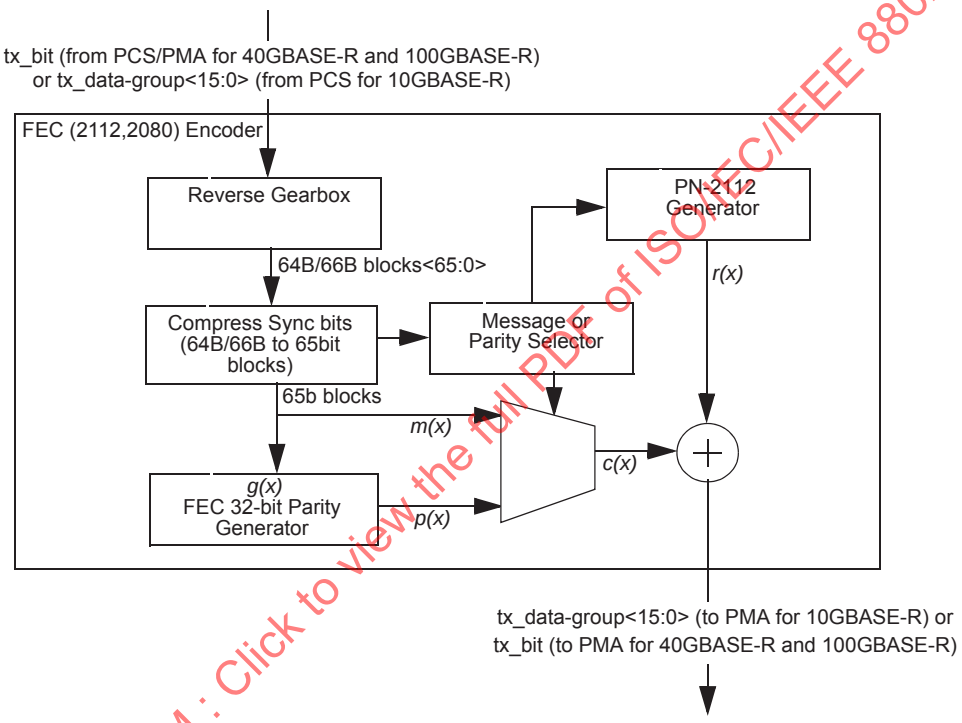

Figure 74–6—FEC (2112,2080) encoding

74.7.4.4.1 PN-2112 pseudo-noise sequence generator

PN-2112 is a pseudo-noise sequence of length 2112 generated by the polynomial *r(x)*, which is equal to the scrambler polynomial defined in 49.2.6 with initial state S57 = 1, Si–1 = Si XOR 1 or simply the binary sequence of 101010…. . Before each FEC block processing (encoding or decoding) the PN-2112 generator is initialized with this state. The PN-2112 generator shall produce the same result as the implementation shown in Figure 74–7. This implements the PN-2112 generator polynomial given in Equation (74–4).

$$r(x) = 1 + x^{39} + x^{58} \quad (74–4)$$

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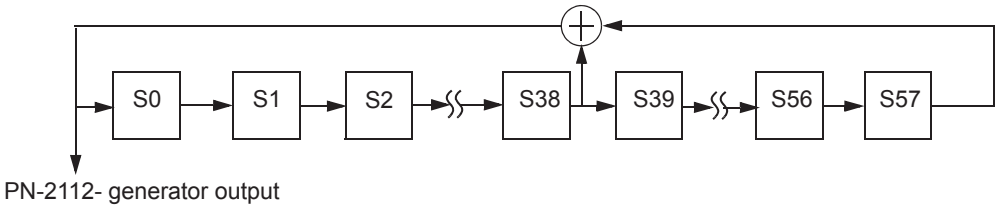

Figure 74–7—PN-2112 generator

Scrambling with the PN-2112 sequence at the FEC codeword boundary is necessary for establishing FEC block synchronization (to ensure that any shifted input bit sequence is not equal to another FEC codeword) and to ensure DC balance.

74.7.4.5 FEC decoder

The FEC decoder establishes FEC block synchronization based on repeated decoding of the received sequence. Decoding and error correction is performed after FEC synchronization is achieved. There is an option for the FEC decoder to indicate any decoding errors to the upper layer.

The FEC decoder recovers and extracts the information bits using the parity-check data. In case of successful decoding the decoder restores the sync bits in each of the 64B/66B blocks sent to the PCS function, by first performing an XOR operation of the received transcode bit with the associated data bit 8 and then generating the two sync bits.

When the decoder for 10GBASE-R is configured to indicate decoding error, the decoder indicates error to the PCS by means of setting both sync bits to the value 11 in the 1st, 9th, 17th, 25th, and 32nd of the 32 decoded 64B/66B blocks from the corresponding errored FEC block, thus forcing the PCS sublayer to consider this block as invalid.

When the decoder for 40GBASE-R or 100GBASE-R is configured to indicate decoding error, the decoder needs to mark errors in more of the 64B/66B blocks to ensure that detected errors are signaled to the MAC for every frame containing an error. The FEC sublayers for 40GBASE-R and 100GBASE-R set both sync bits to the value 11 in all thirty-two 64B/66B blocks to indicate error to the PCS.

The FEC Synchronization process continuously monitors PMA_SIGNAL.indication(SIGNAL_OK) or PMA:IS_SIGNAL.indication(SIGNAL_OK). When SIGNAL_OK indicates OK, the FEC Synchronization process accepts data units via the PMA_UNITDATA.indication primitive or the PMA:IS_UNITDATA_*i*.indication primitives. It attains block synchronization based on the decoding of FEC blocks and conveys received 64B/66B blocks to the PCS Receive process. The FEC Synchronization process sets the sync_status flag to the PCS function to indicate whether the FEC has obtained synchronization.

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74.7.4.5.1 FEC (2112,2080) decoding

The FEC decoding function block diagram is shown in Figure 74–8. The decoder processes the 16-bit rx_data-group stream received from the PMA sublayer and descrambles the data using the PN-2112 pseudo-noise sequence as described in 74.7.4.4.1.

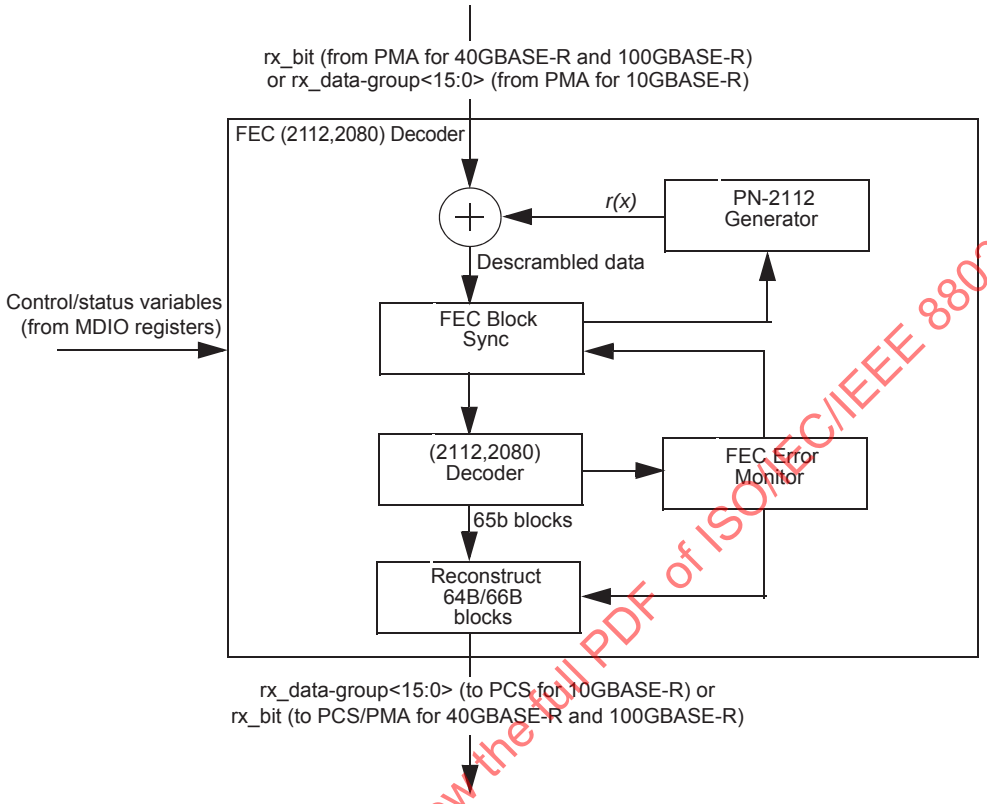

Figure 74–8—FEC (2112,2080) decoding

The synchronization of the 2112 bit FEC block is established using FEC decoding as described in 74.7.4.7. Each of the 32 65-bit data words is extracted from the recovered FEC block and the 2-bit sync is reconstructed for the 64B/66B codes from the transcode bit as shown in Figure 74–9. The FEC decoder provides an option to indicate decoding errors in the reconstructed sync bits. The sync bits {SH.0, SH.1} take the value as described in the following:

a) If decoding is successful (by either the parity match or the FEC block is correctable) and the descrambled received transcode bit (T) is 1 then the sync bits take a value of {SH.0,SH.1} = 01 or if the descrambled received transcode bit (T) is 0 then the sync bits take a value of {SH.0,SH.1} = 10.
b) If the variable FEC_Enable_Error_to_PCS is set to 1 to indicate error to PCS layer and the received FEC block has uncorrectable errors then the sync bits for the 1st, 9th, 17th, 25th, and 32nd of the 32 decoded 64B/66B blocks take a value of {SH.0,SH.1} = 11 for the 10GBASE-R PHY. For the 40GBASE-R and 100GBASE-R PHYs, sync bits in all thirty-two 64B/66B decoded 64B/66B blocks take a value of {SH.0,SH.1} = 11. The sync bits for all other 64B/66B blocks take a value as described in item a) above.
c) If the variable FEC_Enable_Error_to_PCS is set to 0 and the received FEC block has uncorrectable errors then the sync bits take a value as described in item a) above.

This information corresponds to one complete (2112,2080) FEC block that is equal to 32 64B/66B code blocks.

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The FEC code (2112, 2080) and its performance is specified in 74.7.1. The FEC (2112,2080) decoder implementations shall be able to correct up to a minimum of 11-bit burst errors per FEC block.

74.7.4.6 FEC receive bit ordering

The format of the FEC block and the receive bit ordering is shown in Figure 74–9.

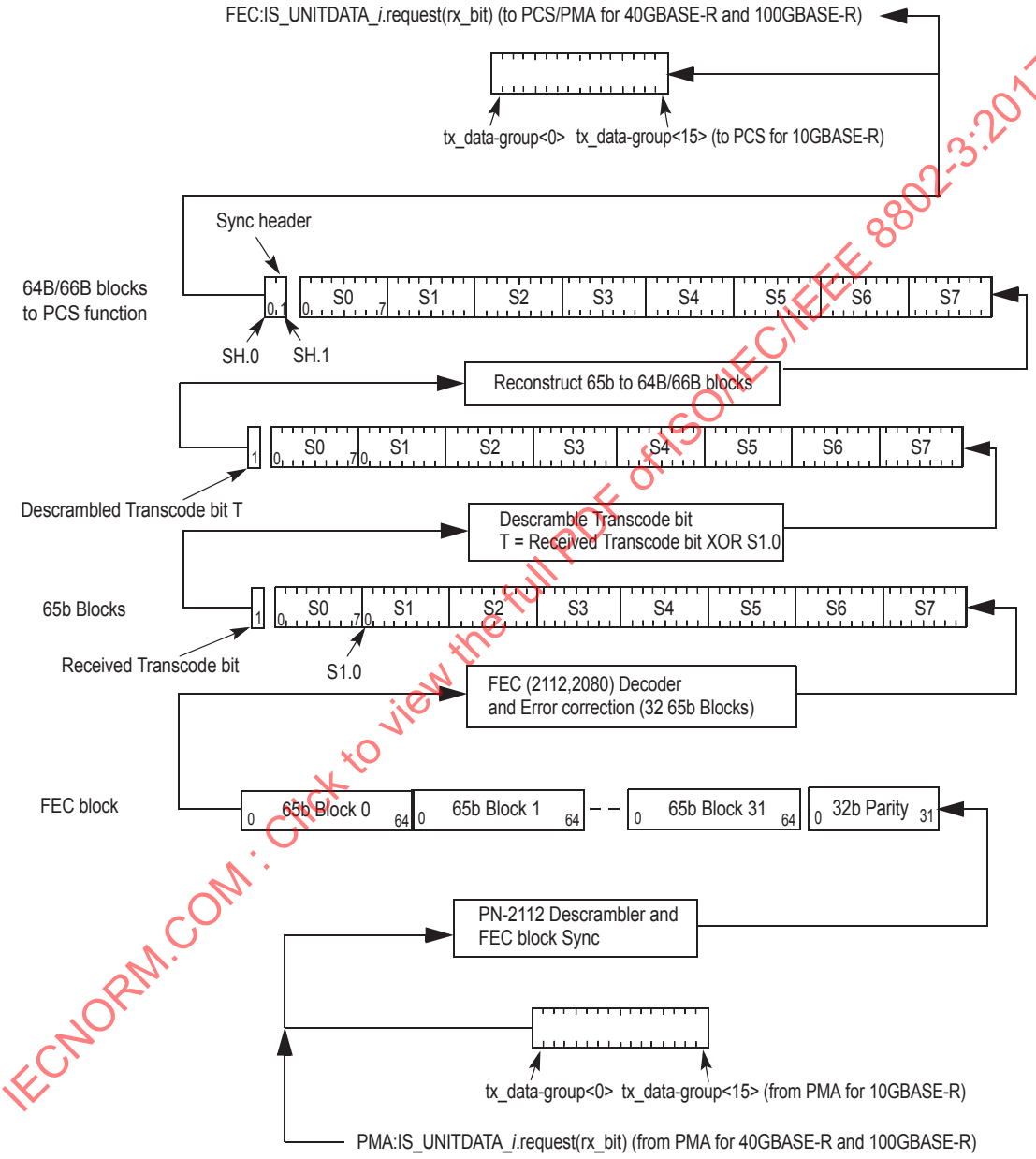

Figure 74–9—FEC Receive bit ordering

74.7.4.7 FEC block synchronization

The receive synchronization of FEC blocks is illustrated by FEC Lock state diagram in Figure 74–10.

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Receive FEC block synchronization is achieved using conventional n/m serial locking techniques as described as follows:

a) Test a potential candidate block start position
   1) Descramble block using PN-2112 Generator per 74.7.4.4.1
   2) Evaluate parity for the potential block
      i) If the parity does not match (i.e., the received parity does not match the computed parity), shift candidate start by one bit position and try again.
b) Validate potential block start position has good parity for "n" consecutive blocks
   1) If any of them fail shift candidate start one bit position and start again
   2) If "n" consecutive blocks are received with good parity, report Block Sync
c) Block Sync is established.
d) If "m" consecutive blocks are received with bad parity, drop Block Sync and restart again at item a).

The procedure is repeated at most 2111 times for all bits positions in the 2112 codeword. The values for m and n are as follows: m = 8 and n = 4.

74.7.4.8 FEC rapid block synchronization for EEE (optional)

If the optional EEE capability is supported then during the wake and refresh states the FEC decoder receives one of the two types of deterministic blocks to achieve rapid block synchronization. During these states the reverse gearbox of the remote FEC encoder is receiving unscrambled data from the PCS sublayer via 16-bit FEC_UNITDATA.request primitive. A Clause 49 PCS sublayer encodes /I/ during the wake state and /LI/ during the refresh state, which produces the two types of deterministic FEC blocks. If the optional EEE deep sleep capability is supported, then a Clause 82 PCS sublayer also encodes /I/ during the wake state and /LI/ during the refresh state, but in addition inserts Rapid Alignment Markers into each of the PCS Lanes (see 82.2.9). This causes the two types of deterministic FEC blocks to have a number of 65-bit words within the deterministic FEC block replaced with Rapid Alignment Markers, thus not matching the two deterministic patterns as shown in Table 74A–5 and Table 74A–6. The locations of the Rapid Alignment Markers within the Rapid FEC block are consistent for a given entry into the wake or refresh states, but the locations can vary for subsequent entries. This modification to the two deterministic patterns needs to be taken into account by the Rapid FEC Lock implementation.

When rx_lpi_active is TRUE and rx_mode (or rx_tx_mode if appropriate) transitions to DATA, start a hold-off timer whose duration is greater than or equal to 13.7 µs and enable the FEC Rapid block lock mechanism, which attempts to determine the FEC start of block location based on the deterministic pattern. When the rapid block lock is locked, the determined start of block location is used as the FEC lock state diagram candidate start of block location until the rapid block lock loses lock. Assuming the rapid block lock determined the correct start of block location, the FEC lock state diagram achieves lock without requiring subsequent slips. The rapid block lock mechanism is implementation dependent and outside the scope of this standard. The FEC sublayer shall hold off asserting SIGNAL_OK until one of the following two events occurs:

1) Two 65b payload blocks after the transition from deterministic FEC block to normal scrambled FEC block
2) Expiration of the hold-off timer

74.8 FEC MDIO function mapping

The optional MDIO capability described in Clause 45 defines several variables that provide control, status, abilities/capabilities, error indication information for and about the PHY. If MDIO is implemented, it shall map MDIO variables to FEC variables as shown in Table 74–1.

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Table 74–1—MDIO/FEC variable mapping

MDIO variable	PMA/PMD register name	Register/ bit number	FEC variable
BASE-R FEC ability	BASE-R FEC ability register	1.170.0	FEC_ability
BASE-R FEC Error Indication ability	BASE-R FEC ability register	1.170.1	FEC_Error_Indication_ability
FEC Enable	BASE-R FEC control register	1.171.0	FEC_Enable
FEC Enable Error Indication	BASE-R FEC control register	1.171.1	FEC_Enable_Error_to_PCS
FEC corrected blocks	10GBASE-R FEC corrected blocks counter register	1.172, 1.173	FEC_corrected_blocks_counter
FEC uncorrected blocks	10GBASE-R FEC uncorrected blocks counter register	1.174, 1.175	FEC_uncorrected_blocks_counter
FEC corrected blocks, lanes 0 through 19	BASE-R FEC corrected blocks counter register, lanes 0 through 19	1.300 through 1.339	FEC_corrected_blocks_counter_*i*
FEC uncorrected blocks, lanes 0 through 19	BASE-R FEC uncorrected blocks counter register, lanes 0 through 19	1.700 through 1.739	FEC_uncorrected_blocks_counter_*i*

74.8.1 FEC capability

Since the FEC is an optional sublayer, the FEC ability is indicated by the variable FEC_ability for each of the BASE-R PHY types. An MDIO interface or an equivalent management interface shall be provided to access the variable FEC_ability for the BASE-R PHY type. The FEC_ability variable bit is set to a one to indicate that the PHY supports FEC sublayer, it defaults to zero otherwise.

The FEC_ability variable for the BASE-R PHY is mapped to register bit 1.170.0 (refer to 45.2.1.92.1).

The FEC capability between the link partners can be negotiated using the Clause 73 Auto-Negotiation as defined in 73.6.5. The FEC function is enabled on the link only if both the link partners advertise they have FEC ability and either one of them requests to enable FEC through the Auto-Negotiation function.

74.8.2 FEC Enable

The FEC sublayer shall have capability to enable or disable the FEC function. An MDIO interface or an equivalent management interface shall be provided to access the variable FEC_Enable for the BASE-R PHY (refer to 45.2.1.93 register bit 1.171.0). When FEC_Enable variable bit is set to a one, this enables the FEC for the BASE-R PHY. When the variable is set to zero, the FEC is disabled in the BASE-R PHY. This variable shall be set to zero upon execution of PHY reset. When the FEC function is disabled, the PHY shall have a mechanism to bypass the FEC Encode and Decode functions so as not to cause additional latency associated with encoding or decoding functions.

74.8.3 FEC Enable Error Indication

The FEC sublayer may have the option to enable the BASE-R FEC decoder to indicate decoding errors to the upper layers (PCS) through the sync bits for the BASE-R PHY as defined in 74.7.4.5, if this ability is

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supported. An MDIO interface or an equivalent management interface shall be provided to access the variable FEC_Enable_Error_to_PCS. When the variable is set to one, this enables indication of decoding errors through the sync bits to the PCS layer. When set to zero, the error indication function is disabled.

74.8.3.1 FEC Error Indication ability

The FEC error indication ability shall be indicated by the variable FEC_Error_Indication_ability. The variable is set to one to indicate that the BASE-R FEC has the ability to indicate decoding errors to the PCS layer. The variable is set to zero if this ability is not supported by the BASE-R FEC. An MDIO interface or an equivalent management interface shall be provided to access the variable FEC_Error_Indication_ability.

74.8.4 FEC Error monitoring capability

The following counters apply to FEC sublayer management and error monitoring. If an MDIO interface is provided (see Clause 45), it is accessed via that interface. If not, it is recommended that an equivalent access be provided. These counters are reset to zero upon read or upon reset of the FEC sublayer. When a counter reaches all ones, it stops counting. The counters' purpose is to help monitor the quality of the link.

These counters shall be disabled if FEC_LPI_ACTIVE.request(rx_lpi_active) is TRUE.

74.8.4.1 FEC_corrected_blocks_counter

A corrected block is an FEC block that has invalid parity, and has been corrected by the FEC decoder.

FEC_corrected_blocks_counter (for single-lane PHYs) or FEC_corrected_blocks_counter_*i* (for multi-PCS-lane PHYs, where $i = 0$ to 3 for 40 Gb/s and $i = 0$ to 19 for 100 Gb/s,) count once for each corrected FEC block processed when FEC_SIGNAL.indication or FEC:IS_SIGNAL.indication is OK. These are 32-bit counters. These variables are accessed through a management interface that may be mapped to the registers defined in 45.2.1.94 (1.172, 1.173) for single-lane PHYs and 45.2.1.116 (1.300 to 1.339) for multi-lane PHYs.

74.8.4.2 FEC_uncorrected_blocks_counter

An uncorrected block is an FEC block that has invalid parity, and has not been corrected by the FEC decoder.

FEC_uncorrected_blocks_counter (for single-lane PHYs) or FEC_uncorrected_blocks_counter_*i* (for multi-PCS-lane PHYs, where $i = 0$ to 3 for 40 Gb/s and $i = 0$ to 19 for 100 Gb/s,) count once for each uncorrected FEC block processed when FEC_SIGNAL.indication or FEC:IS_SIGNAL.indication is OK. These are 32-bit counters. These variables are accessed through a management interface that may be mapped to the registers defined in 45.2.1.95 (1.174, 1.175) for single-lane PHYs and 45.2.1.117 (1.700 to 1.739) for multi-lane PHYs.

74.9 BASE-R PHY test-pattern mode

The 10GBASE-R PCS provides test-pattern functionality and the PCS transmit channel and receive channel can each operate in normal mode or test-pattern mode (see 49.2.2). When the 10GBASE-R PHY is configured for test-pattern mode, the FEC function may be disabled by setting the FEC Enable variable to zero, so the test-pattern from the 10GBASE-R PCS can be sent to the PMA service interface, bypassing the FEC Encode and Decode functions.

The Clause 82 PCS can also operate in test pattern mode (see 82.2.11); however, the scrambled idle test pattern does not require bypassing FEC encode and decode.

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74.10 Detailed functions and state diagrams

74.10.1 State diagram conventions

The body of this subclause is comprised of state diagrams, including the associated definitions of variables, constants, and functions. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

The notation used in the state diagrams follows the conventions of 21.5. State diagram timers follow the conventions of 14.2.3.2. The notation ++ after a counter or integer variable indicates that its value is to be incremented.

74.10.2 State variables

74.10.2.1 Constants

m
: Positive integer constant set to value 8.

n
: Positive integer constant set to value 4.

74.10.2.2 Variables

fec_block_lock
: Boolean variable that is set to true when receiver acquires FEC block delineation.

fec_block<2111:0>
: Vector containing 2112 bits of a new FEC block accumulated from the candidate start position received from the PMA and descrambled using PN-2112 as specified in 74.7.4.4.1. For each FEC block processing, the PN-2112 is returned to the initial state as described in 74.7.4.4.1.

fec_signal_ok
: Boolean variable that is set based on the most recently received value of PMA_UNITDATA.indication(SIGNAL_OK) or PMA:IS_SIGNAL.indication(SIGNAL_OK) and fec_block_lock. It is set to true if the fec_block_lock value is true and PMA_UNITDATA.indication(SIGNAL_OK) or PMA:IS_SIGNAL.indication(SIGNAL_OK) value was OK and set to false otherwise. The value is sent to the PCS layer through the primitive FEC_SIGNAL.indication or FEC:IS_SIGNAL.indication as specified in 74.5.1.3 or 74.5.2.

parity_good
: Boolean indication that is set to true if the FEC_PARITY_CHECK function returns “match” and false if the FEC_PARITY_CHECK function returns “no_match”.

parity_invalid
: Boolean indication that is set to true if the FEC_PARITY_CHECK function returns “no_match” and false if the FEC_PARITY_CHECK function returns “match”.

reset
: Boolean variable that controls the resetting of the FEC sublayer. It is true whenever a reset is necessary, including when reset is initiated from the MDIO during power on.

signal_ok
: Boolean variable that is set based on the most recently received value of PMA_UNITDATA.indication(SIGNAL_OK). It is true if the value was OK and false if the value was FAIL.

slip_done
: Boolean variable that is asserted true when the SLIP requested by the FEC Block Lock state diagram has been completed indicating that the next candidate block sync position can be tested.

test_fec_block
: Boolean variable that is set to true when a new FEC block is available for testing and false when

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TEST_FEC_BLOCK state is entered. A new FEC block is available for testing when the FEC Block Sync process has accumulated one FEC block from the candidate start position (fec_block<2111:0>) from the PMA to evaluate the parity of the next block.

74.10.2.3 Functions

FEC_PARITY_CHECK(fec_block<2111:0>)

Computes parity based on the FEC generator polynomial *g(x)* on fec_block<2079:0> and compares it against the received 32-bit parity bits fec_block<2111:2080>. The FEC_PARIY_CHECK function returns "match" if the parity check matches, and returns "no_match" if the computed parity does not match the received parity.

SLIP

Causes the next candidate FEC block sync position to be tested. The precise method for determining the next candidate block sync position is not specified and is implementation dependent. However, an implementation shall ensure that all possible bit positions are evaluated.

74.10.2.4 Counters

parity_good_cnt

Count of the number of times the computed parity of received message bits matched the received parity.

parity_invalid_cnt

Count of the number of times the computed parity of received message bits did not match the received parity.

74.10.3 State diagrams

The FEC sublayer shall implement the FEC Lock state diagram shown in Figure 74–10, including compliance with the associated state variables as specified in 74.10.2. The FEC Lock state diagram determines when the receiver has obtained FEC block lock on the received data stream.

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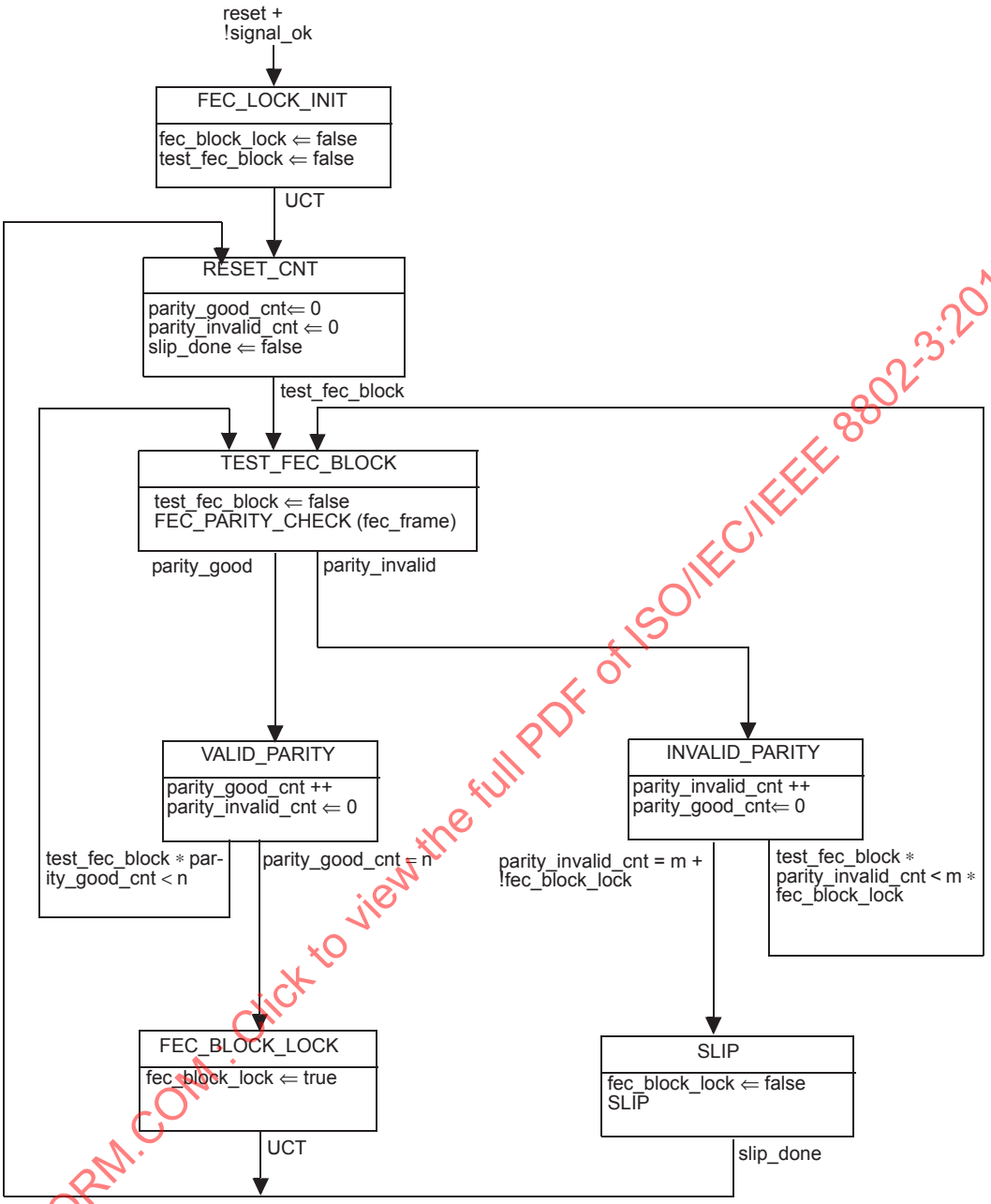

Figure 74–10—FEC Lock state diagram

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74.11 Protocol implementation conformance statement (PICS) proforma for Clause 74, Forward Error Correction (FEC) sublayer for BASE-R PHYs[31]

74.11.1 Introduction

The supplier of a protocol implementation that is claimed to conform to IEEE Std 802.3, Clause 74 Forward Error Correction (FEC) sublayer for BASE-R PHYs, shall complete the following protocol implementation conformance statement (PICS) proforma. A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

74.11.2 Identification

74.11.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Names(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

74.11.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 74, Forward Error Correction (FEC) sublayer for BASE-R PHYs
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015)	
Date of Statement	

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[31] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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74.11.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
DC	FEC Delay Constraints	74.6	Sum of transmit and receive. No more than 12 pause_quanta for 10GBASE-R, 48 pause_quanta for 40GBASE-R, and 240 pause_quanta for 100GBASE-R	M	Yes [ ]
*MD	MDIO Interface	45, 74.8.2, 74.8.4	Device implements MDIO registers and interface	O	Yes [ ] No [ ]
EF	FEC_Enable	74.8.2	The device has the capability to enable/disable the FEC function	M	Yes [ ]
*EIA	FEC Error Indication ability	74.8.3, 74.8.3.1	The device has ability to indicate FEC decoding errors to the PCS layer as specified in 74.8.3	O	Yes [ ] No [ ]
BF	Bypass FEC function	74.8.2	The device has mechanism to bypass FEC encode/decode functions to reduce latency	M	Yes [ ]
EEE	Rapid Block Lock	74.7.4.8	Device implements Rapid block lock mechanism to support EEE	O	Yes[]/No []
*XSBI	PMA compatibility interface XSBI	51, 74.7.4.1	Optional PMA compatibility interface named XSBI is implemented between the PCS and FEC functions	O	Yes [ ] No [ ]

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74.11.4 Management

Item	Feature	Subclause	Value/Comment	Status	Support
M1	Alternate access to FEC Management objects is provided	74.8.2, 74.8.4		M	Yes [ ]
M2	Default value for FEC_Enable	74.8.2	FEC_Enable variable is set to zero upon execution of PHY reset	M	Yes [ ]
M3	MDIO Register Mapping	74.8	If MDIO is implemented, the FEC variables and capabilities are mapped to the appropriate registers found in Table 74–1	MD:M	N/A [ ] Yes [ ]
M4	FEC_Error_Indication_ability variable access	74.8.3.1	An MDIO or equivalent managment interface is provided to access this variable	M	Yes [ ]
M5	FEC_Enable_Error_to_PCS variable access	74.8.3	An MDIO or equivalent managment interface is provided to access this variable	EIA:M	N/A [ ] Yes [ ]
M6	FEC_Enable variable access	74.8.2	An MDIO or equivalent managment interface is provided to access this variable	M	Yes [ ]
M7	FEC_ability variable access	74.8.1	An MDIO or equivalent managment interface is provided to access this variable	M	Yes [ ]

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74.11.5 FEC Requirements

Item	Feature	Subclause	Value/Comment	Status	Support
FE1	FEC coding	74.7.1	The FEC code used is a shortened cyclic code (2112, 2080) for error checking and forward error correction	M	Yes [ ]
FE2	FEC block format	74.7.2	Meets the requirements of 74.7.2	M	Yes [ ]
FE3	Reverse gearbox function for 10GBASE-R	74.7.4.1.1	Reverse gearbox function implemented	XSBI:M	N/A[ ] Yes [ ]
FE4	Reverse gearbox function for 40GBASE-R and 100GBASE-R	74.7.4.1.2	Reverse gearbox function meets the requirements of 82.2.12	O	Yes [ ] No [ ]
FE5	FEC transmission bit ordering	74.7.4.3	Implements FEC transmission bit ordering as specified in 74.7.4.3	M	Yes [ ]
FE6	FEC encoder	74.7.4.4	Meets FEC encoder requirements of 74.7.4.4	M	Yes [ ]
FE7	PN-2112 generator	74.7.4.4.1	PN-2112 generator produces the same result as the implementation shown in Figure 74–7	M	Yes [ ]
FE8	PN-2112 Scrambler	74.7.4.4.1	Meets PN-2112 scrambler requirements of 74.7.4.4.1	M	Yes [ ]
FE9	PN-2112 descrambler	74.7.4.5.1	Meets PN-2112 descrambler requirements of 74.7.4.5.1	M	Yes [ ]
FE10	FEC decoding	74.7.4.5	Meets FEC decoder requirements of 74.7.4.5	M	Yes [ ]
FE11	FEC decoder error correction capability	74.7.4.5	The FEC decoder implementation is able to correct up to a minimum of 11 bit burst errors per FEC block as specified in 74.7.4.5.1	M	Yes [ ]
FE12	Indication of decoding errors	74.7.4.5, 74.7.4.5.1, 74.8.3	Device implements indication of decoding errors to PCS layer.	EIA:M	N/A[ ] Yes [ ]
FE13	FEC block sync	74.7.4.7	Meets FEC block sync requirements as specified in 74.7.4.7	M	Yes [ ]
FE14	FEC Enable Error Indication	74.8.3	Enable FEC decoder to indicate decoding errors to PCS layer	EIA:M	N/A[ ] Yes [ ]
FE15	SLIP function	74.10.2.3	All possible bit positions can be evaluated	M	Yes [ ]
FE16	FEC Lock function	74.10.3	The FEC lock function meets the requirements of the state diagram in 74.10.3	M	Yes [ ]

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74.11.6 FEC Error Monitoring

Item	Feature	Subclause	Value/Comment	Status	Support
FEM1	FEC Error Monitoring	74.8.4	Meets FEC error monitoring capability requirements of 74.8.4	M	Yes [ ]
FEM2	FEC_corrected_blocks_counter	74.8.4.1	Meets 32-bit FEC corrected blocks counter requirements of 74.8.4.1	M	Yes [ ]
FEM3	FEC_uncorrected_blocks_counter	74.8.4.2	Meets 32-bit FEC uncorrected blocks counter requirements of 74.8.4.2	M	Yes [ ]
FEM4	FEC Error Monitoring during EEE	74.8.4	Disables FEC Error Monitoring during EEE as specified in 74.8.4	EEE:M	Yes[]

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75. Physical Medium Dependent (PMD) sublayer and medium for passive optical networks, type 10GBASE–PR and 10/1GBASE–PRX

75.1 Overview

Clause 75 describes Physical Medium dependent (PMD) sublayer for Ethernet Passive Optical Networks operating at the line rate of 10.3125 GBd in either downstream or in both downstream and upstream directions.

75.1.1 Terminology and conventions

The following list contains references to terminology and conventions used in Clause 75:

Basic terminology and conventions, see 1.1 and 1.2.

Normative references, see 1.3.

Definitions, see 1.4

Abbreviations, see 1.5.

Informative references, see Annex A.

Introduction to 1000 Mb/s baseband networks, see Clause 34.

Introduction to 10 Gb/s baseband network, see Clause 44.

Introduction to Ethernet for subscriber access networks, see Clause 56.

EPONs operate over a point-to-multipoint (P2MP) topology, also called a tree or trunk-and-branch topology. The device connected at the root of the tree is called an Optical Line Terminal (OLT) and the devices connected as the leaves are referred to as Optical network Units (ONUs). The direction of transmission from the OLT to the ONUs is referred to as the *downstream* direction, while the direction of transmission from the ONUs to the OLT is referred to as the *upstream* direction.

75.1.2 Goals and objectives

The following are the PMD objectives fulfilled by Clause 75:

a) Support subscriber access networks using point-to-multipoint topologies on optical fiber.
b) Provide Physical Layer specifications:
   1) PHY for PON, 10 Gb/s downstream / 1 Gb/s upstream, on a single SMF
   2) PHY for PON, 10 Gb/s downstream / 10 Gb/s upstream, on a single SMF
c) PHY(s) to have a BER better than or equal to 10^{-12} at the PHY service interface.
d) Define up to four optical power budgets that support split ratios of at least 1:16, 1:32, and 1:64, and distances of at least 10 km and 20 km.

75.1.3 Power budget classes

To support the above-stated objectives, Clause 75 defines the following four power budget classes:

— *Low power budget class* supports P2MP media channel insertion loss of ≤ 20 dB e.g., a PON with the split ratio of at least 1:16 and the distance of at least 10 km.

— *Medium power budget class* supports P2MP media channel insertion loss of ≤ 24 dB e.g., a PON with the split ratio of at least 1:16 and the distance of at least 20 km or a PON with the split ratio of at least 1:32 and the distance of at least 10 km.

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— *High power budget class* supports P2MP media channel insertion loss of ≤ 29 dB e.g., a PON with the split ratio of at least 1:32 and the distance of at least 20 km.

— *Extended power budget class* supports P2MP media channel insertion loss of ≤ 33 dB e.g., a PON with the split ratio of at least 1:64 and the distance of at least 20 km.

75.1.4 Power budgets

Each power budget class is represented by PRX-type power budget and PR-type power budget as follows:

— PRX–type power budget describes asymmetric-rate PHY for PON operating at 10 Gb/s downstream and 1 Gb/s upstream over a single SMF [see objective b 1) in 75.1.2].
— PR–type power budget describes symmetric-rate PHY for PON operating at 10 Gb/s downstream and 10 Gb/s upstream over a single SMF [see objective b 2) in 75.1.2].

Each power budget is further identified with a numeric representation of its class, where a value of 10 represents low power budget, a value of 20 represents medium power budget, and a value of 30 represents high power budget. Thus, the following power budgets are defined in Clause 75:

— PRX10: asymmetric-rate, low power budget, compatible with PX10 power budget defined in Clause 60.
— PRX20: asymmetric-rate, medium power budget, compatible with PX20 power budget defined in Clause 60.
— PRX30: asymmetric-rate, high power budget, compatible with PX30 power budget defined in Clause 60.
— PRX40: asymmetric-rate, extended power budget, compatible with PX40 power budget defined in Clause 60.
— PR10: symmetric-rate, high power budget, compatible with PX10 power budget defined in Clause 60
— PR20: symmetric-rate, high power budget, compatible with PX20 power budget defined in Clause 60
— PR30: symmetric-rate, high power budget, compatible with PX30 power budget defined in Clause 60.
— PR40: symmetric-rate, extended power budget, compatible with PX40 power budget defined in Clause 60.

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Table 75–1 shows the primary attributes of all power budget types defined in Clause 75.

Table 75–1—Power budgets

Description	Low Power Budget		Medium Power Budget		High Power Budget		Extended Power Budget		Units
	PRX10	PR10	PRX20	PR20	PRX30	PR30	PRX40	PR40	
Number of fibers	1								–
Nominal downstream line rate	10.3125								GBd
Nominal upstream line rate	1.25	10.3125	1.25	10.3125	1.25	10.3125	1.25	10.3125	GBd
Nominal downstream wavelength	1577								nm
Downstream wavelength tolerance	–2, +3								nm
Nominal upstream wavelength	1310	1270	1310	1270	1310	1270	1310	1270	nm
Upstream wavelength tolerance	±50	±10	±50	±10	±50	±10	±20	±10	nm
Maximum reach[a]	≥10		≥20						km
Maximum channel insertion loss	20		24		29		33		dB
Minimum channel insertion loss	5		10		15		18		dB

[a]A compliant system may exceed the maximum reach designed for given power budget as long as optical power budget and other mandatory optical layer specifications are met.

75.1.5 Positioning of PMD sublayer within the IEEE 802.3 architecture

Figure 75–1 and Figure 75–2 depict the relationships of the symmetric-rate (10/10G–EPON) and asymmetric-rate (10/1G–EPON) PMD sublayer (shown hatched) with other sublayers and the ISO/IEC Open System Interconnection (OSI) reference model.

75.2 PMD types

Similarly to power budget classes, asymmetric-rate and symmetric-rate PMDs are identified by PRX and PR designations, respectively.

The characteristics of the P2MP topology result in significantly different ONU and OLT PMDs. For example, the OLT PMD operates in a continuous mode in the transmit direction (downstream), but uses a burst mode in the receive direction (upstream). On the other hand, the ONU PMD receives data in a continuous mode, but transmits in a burst mode. To differentiate OLT PMDs from ONU PMDs, the OLT

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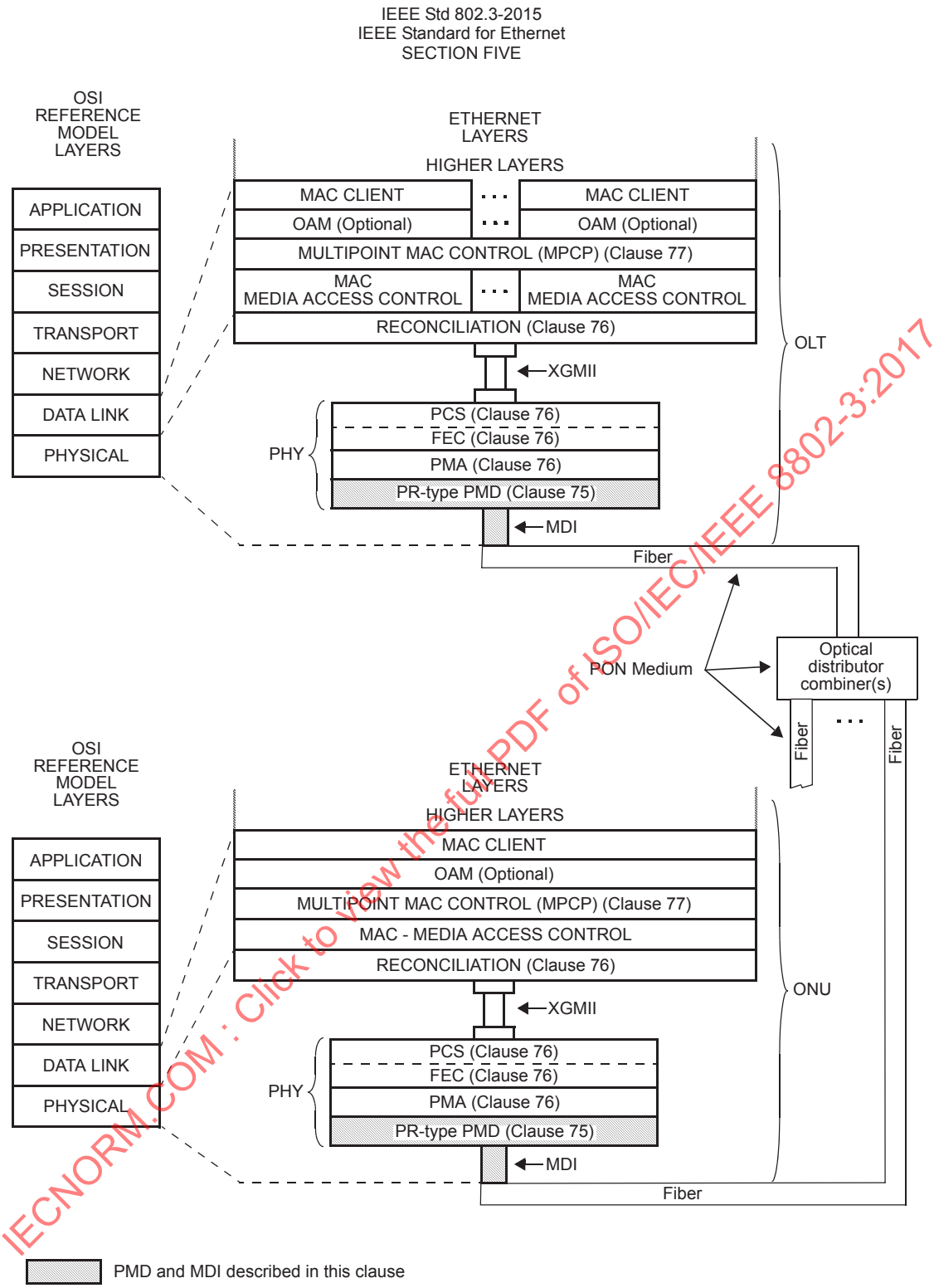

XGMII= 10 GIGABIT MEDIA INDEPENDENT INTERFACE
MDI = MEDIUM DEPENDENT INTERFACE
OAM = OPERATIONS, ADMINISTRATION & MAINTENANCE
OLT = OPTICAL LINE TERMINAL
ONU = OPTICAL NETWORK UNIT
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

Figure 75–1—Relationship of 10/10G–EPON P2MP PMD to the ISO/IEC OSI reference model and the IEEE 802.3 Ethernet model

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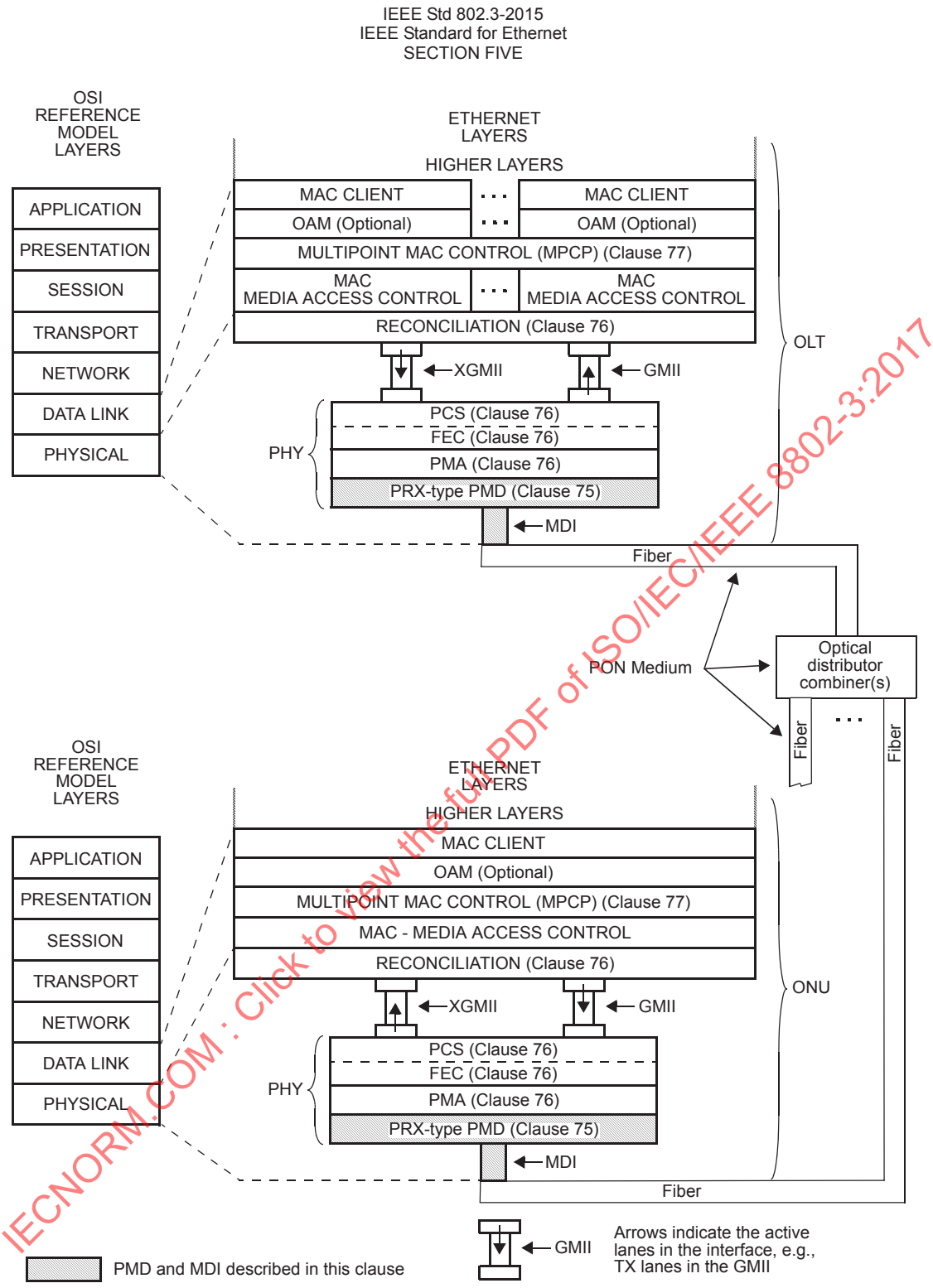

XGMII= 10 GIGABIT MEDIA INDEPENDENT INTERFACE
GMII = GIGABIT MEDIA INDEPENDENT INTERFACE
MDI = MEDIUM DEPENDENT INTERFACE
OAM = OPERATIONS, ADMINISTRATION & MAINTENANCE
OLT = OPTICAL LINE TERMINAL
ONU = OPTICAL NETWORK UNIT
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

Figure 75–2—Relationship of 10/1G–EPON P2MP PMD to the ISO/IEC OSI reference model and the IEEE 802.3 Ethernet model

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PMD name has a suffix “D” appended to it, where D stands for downstream–facing PMD, e.g., 10GBASE–PR–D1. ONU PMDs have suffix “U” for upstream–facing PMD, e.g., 10GBASE–PR–U1.

In the downstream direction, the signal transmitted by the D-type PMD is received by all U-type PMDs. In the upstream direction, the D-type PMD receives data bursts from each of the U-type PMDs.

Clause 75 defines several D-type and several U-type PMDs, that differ in their receive and/or transmit characteristics. Such PMDs are further distinguished by appending a digit after the suffix D or U, e.g., 10GBASE–PR–D1 or 10GBASE–PR–D2.

The following OLT PMDs (D-type) are defined in this subclause:

a) Asymmetric-rate D-type PMDs (collectively referred to as 10/1GBASE–PRX–D), transmitting at 10.3125 GBd continuous mode and receiving at 1.25 GBd burst mode:
   1) 10/1GBASE–PRX–D1
   2) 10/1GBASE–PRX–D2
   3) 10/1GBASE–PRX–D3
   4) 10/1GBASE–PRX–D4
b) Symmetric-rate D-type PMDs (collectively referred to as 10GBASE–PR–D), transmitting at 10.3125 GBd continuous mode and receiving at 10.3125 GBd burst mode:
   1) 10GBASE–PR–D1
   2) 10GBASE–PR–D2
   3) 10GBASE–PR–D3
   4) 10GBASE–PR–D4

The following ONU PMDs (U-type) are defined in this subclause:

c) Asymmetric-rate U-type PMDs (collectively referred to as 10/1GBASE–PRX–U), transmitting at 1.25 GBd burst mode and receiving at 10.3125 GBd continuous mode:
   1) 10/1GBASE–PRX–U1
   2) 10/1GBASE–PRX–U2
   3) 10/1GBASE–PRX–U3
   4) 10/1GBASE–PRX–U4
d) Symmetric-rate U-type PMDs (collectively referred to as 10GBASE–PR–U), transmitting at 10.3125 GBd burst mode and receiving at 10.3125 GBd continuous mode:
   1) 10GBASE–PR–U1
   2) 10GBASE–PR–U3
   3) 10GBASE–PR–U4

A specific power budget is achieved by combining an OLT PMD (D-type) with an ONU PMD (U-type) as shown in 75.2.1. Detailed PMD receive and transmit characteristics for D-type PMDs are given in 75.4 and characteristics for U-type PMDs are presented in 75.5. Every PMD has non-overlapping transmit and receive wavelength bands and operates over a single SMF (see 75B.2).

75.2.1 Mapping of PMDs to power budgets

The power budget is determined by the PMDs located at the ends of the physical media. This subclause describes how PMDs may be combined to achieve the power budgets listed in Table 75–1.

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75.2.1.1 Asymmetric-rate, 10 Gb/s downstream and 1 Gb/s upstream power budgets (PRX type)

Table 75–2 illustrates recommended pairings of asymmetric-rate ONU PMDs with asymmetric-rate OLT PMDs to achieve the power budgets shown in Table 75–1.

Table 75–2—PMD – power budget mapping for asymmetric-rate PRX–type power budgets

		OLT PMDs			
		10/1GBASE–PRX–D1	**10/1GBASE–PRX–D2**	**10/1GBASE–PRX–D3**	**10/1GBASE–PRX–D4**
ONU PMDs	**10/1GBASE–PRX–U1**	PRX10	N/A	N/A	N/A
	10/1GBASE–PRX–U2	N/A	PRX20	N/A	N/A
	10/1GBASE–PRX–U3	N/A	N/A	PRX30	N/A
	10/1GBASE–PRX–U4	N/A	N/A	N/A	PRX40

75.2.1.2 Symmetric-rate, 10 Gb/s power budgets (PR type)

Table 75–3 illustrates recommended pairings of symmetric-rate ONU PMDs with symmetric-rate OLT PMDs to achieve the power budgets as shown in Table 75–1.

Table 75–3—PMD – power budget mapping for symmetric-rate PR–type power budgets

		OLT PMDs			
		10GBASE–PR–D1	**10GBASE–PR–D2**	**10GBASE–PR–D3**	**10GBASE–PR–D4**
ONU PMDs	**10GBASE–PR–U1**	PR10	PR20	N/A	N/A
	10GBASE–PR–U3	N/A	N/A	PR30	N/A
	10GBASE–PR–U4	N/A	N/A	N/A	PR40

75.3 PMD functional specifications

The 10GBASE–PR and 10/1GBASE–PRX type PMDs perform the transmit and receive functions that convey data between the PMD service interface and the MDI.

75.3.1 PMD service interface

The following specifies the services provided by Clause 75 PMDs. These PMD sublayer service interfaces are described in an abstract manner and do not imply any particular implementation.

The PMD Service Interface supports the exchange of a continuous stream of bits, representing either 64B/66B blocks (the transmit and receive paths in 10GBASE–PR PMDs, transmit path in 10/1GBASE–PRX–D PMDs) or 8B/10B blocks (transmit path in 10/1GBASE–PRX–U PMDs, receive path in 10/1GBASE–PRX–D PMDs), between the PMA and PMD entities. The PMD translates the serialized data

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received from the compatible PMA to and from signals suitable for the specified medium. The following primitives are defined:

— PMD_UNITDATA.request
— PMD_UNITDATA.indication
— PMD_SIGNAL.request
— PMD_SIGNAL.indication

75.3.1.1 Delay constraints

The PMD shall introduce a transmit delay of not more than 4 time_quanta with the variability of no more than 0.5 time_quanta, and a receive delay of not more than 4 time_quanta with the variability of no more than 0.5 time_quanta. A description of the overall system delay constraints can be found in 76.1.2 and the definition for the time_quantum can be found in 77.2.2.1.

75.3.1.2 PMD_UNITDATA.request

This primitive defines the transfer of a serial data stream from the Clause 65 or Clause 76 PMA to the PMD.

The semantics of the service primitive are PMD_UNITDATA.request(tx_bit). The data conveyed by PMD_UNITDATA.request is a continuous stream of bits. The tx_bit parameter can take one of two values: ONE or ZERO. The Clause 76 PMA continuously sends the appropriate stream of bits to the PMD for transmission on the medium, at a nominal signaling speed of 10.3125 GBd in the case of 10/10G–EPON OLT, 10/10G–EPON ONU, and 10/1G–EPON OLT PMDs. The Clause 65 PMA continuously sends the appropriate stream of bits to the PMD for transmission on the medium, at a nominal signaling speed of 1.25 GBd in the case of 10/1G–EPON ONU PMDs. Upon the receipt of this primitive, the PMD converts the specified stream of bits into the appropriate signals at the MDI.

75.3.1.3 PMD_UNITDATA.indication

This primitive defines the transfer of data from the PMD to the Clause 65 or Clause 76 PMA.

The semantics of the service primitive are PMD_UNITDATA.indication(rx_bit). The data conveyed by PMD_UNITDATA.indication is a continuous stream of bits. The rx_bit parameter can take one of two values: ONE or ZERO. The PMD continuously sends a stream of bits to the Clause 76 PMA corresponding to the signals received from the MDI, at the nominal signaling speed of 10.3125 GBd in the case of 10/10G–EPON OLT, 10/10G–EPON ONU, and 10/1G–EPON ONU PMDs or to the Clause 65 PMA at the nominal signaling speed of 1.25 GBd in the case of 10/1G–EPON OLT PMDs.

75.3.1.4 PMD_SIGNAL.request

In the upstream direction, this primitive is generated by the Clause 76 PMA to turn on and off the transmitter according to the granted time. A signal for laser control is generated as described in 76.4.1.1 for the Clause 76 PCS.

The semantics of the service primitive are PMD_SIGNAL.request(tx_enable). The tx_enable parameter can take on one of two values: ENABLE or DISABLE, determining whether the PMD transmitter is on (enabled) or off (disabled). The Clause 76 PMA generates this primitive to indicate a change in the value of tx_enable. Upon the receipt of this primitive, the PMD turns the transmitter on or off as appropriate.

75.3.1.5 PMD_SIGNAL.indication

This primitive is generated by the PMD to indicate the status of the signal being received from the MDI.

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The semantics of the service primitive are PMD_SIGNAL.indication(SIGNAL_DETECT). The SIGNAL_DETECT parameter can take on one of two values: OK or FAIL, indicating whether the PMD is detecting light at the receiver (OK) or not (FAIL). When SIGNAL_DETECT = FAIL, PMD_UNITDATA.indication(rx_bit) is undefined. The PMD generates this primitive to indicate a change in the value of SIGNAL_DETECT. If the MDIO interface is implemented, then PMD_global_signal_detect shall be continuously set to the value of SIGNAL_DETECT.

NOTE—SIGNAL_DETECT = OK does not guarantee that PMD_UNITDATA.indication(rx_bit) is known good. It is possible for a poor quality link to provide sufficient light for a SIGNAL_DETECT = OK indication and still not meet the specified bit error ratio. PMD_SIGNAL.indication(SIGNAL_DETECT) has different characteristics for upstream and downstream links, see 75.3.5.

75.3.2 PMD block diagram

The PMD sublayer is defined at the eight reference points shown in Figure 75–3 for 10GBASE–PR and 10/1GBASE–PRX PMDs.

For 10GBASE–PR and 10/1GBASE–PRX PMDs, test points TP1 through TP4 refer to the downstream channel, while test points TP5 through TP8 refer to the upstream channel. In the downstream channel, TP2 and TP3 are compliance points, while in the upstream channel TP6 and TP7 are compliance points. TP1, TP4, TP5, and TP8 are reference points for use by implementers. The optical transmit signal is defined at the output end of a patch cord (TP2 for the downstream channel and TP6 for the upstream channel), between 2 m and 5 m in length, of a fiber type consistent with the link type connected to the transmitter. Unless specified otherwise, all transmitter measurements and tests defined in 75.7 are made at TP2 or TP6, while tests defined in 60.9 are made at TP6. The optical receive signal is defined at the output of the fiber optic cabling (TP3 for the downstream channel and TP7 for the upstream channel) connected to the receiver. Unless specified otherwise, all receiver measurements and tests defined in 75.7 are made at TP3 or TP7.

The electrical specifications of the PMD service interface (TP1 and TP4 for the downstream channel and TP5 and TP8 for the upstream channel) are not system compliance points (these are not readily testable in a system implementation).

75.3.3 PMD transmit function

The PMD Transmit function shall convey the bits requested by the PMD service interface message PMD_UNITDATA.request(tx_bit) to the MDI according to the optical specifications in Clause 75.

In the upstream direction, the flow of bits is interrupted according to PMD_SIGNAL.request(tx_enable). This implies three optical levels, 1, 0, and dark, the latter corresponding to the transmitter being in the OFF state. The higher optical power level shall correspond to tx_bit = ONE.

75.3.4 PMD receive function

The PMD Receive function shall convey the bits received from the MDI according to the optical specifications in Clause 75 to the PMD service interface using the message PMD_UNITDATA.indication(rx_bit). The higher optical power level shall correspond to rx_bit = ONE.

75.3.5 PMD signal detect function

75.3.5.1 ONU PMD signal detect

The PMD Signal Detect function for the continuous mode downstream signal shall report to the PMD service interface, using the message PMD_SIGNAL.indication(SIGNAL_DETECT), which is signaled continuously. PMD_SIGNAL.indication is intended to be an indicator of the presence of the optical signal.

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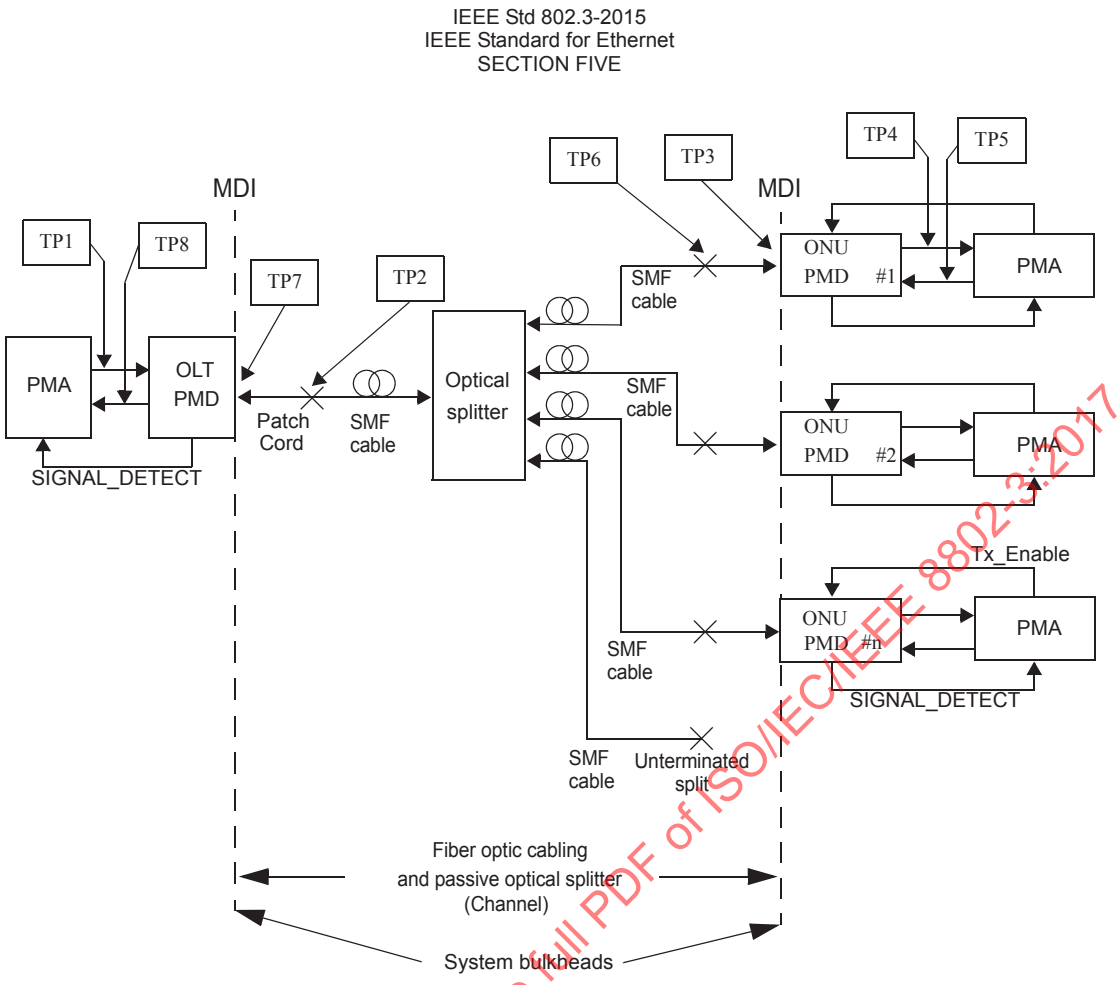

Figure 75–3—10GBASE–PR and 10/1GBASE–PRX block diagram

The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 75–4 for 10GBASE–PR and 10/1GBASE–PRX type PMDs. The ONU PMD receiver is not required to verify whether a compliant 10GBASE–PR signal is being received.

75.3.5.2 OLT PMD signal detect

The response time for the PMD Signal Detect function for the burst mode upstream signal may be longer or shorter than a burst length; thus, it may not fulfill the traditional requirements placed on Signal Detect. PMD_SIGNAL.indication is intended to be an indicator of optical signal presence. The signal detect function in the OLT may be realized in the PMD or the Clause 76 PMA sublayer.

The value of the SIGNAL_DETECT parameter shall be generated according to the conditions defined in Table 75–4 for PMDs defined in Clause 75. The 10GBASE–PR–D PMD receiver is not required to verify whether a compliant 10GBASE–PR signal is being received. Similarly, the 10/1GBASE–PRX–D PMD receiver is not required to verify whether a compliant 1000BASE–PX signal is being received.

75.3.5.3 10GBASE–PR and 10/1GBASE–PRX Signal detect functions

The Signal Detect value definitions for Clause 75 PMDs are shown in Table 75–4.

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Table 75–4—SIGNAL_DETECT value definitions for Clause 75 PMDs

PMD type	Receive conditions	SIGNAL_DETECT value
10GBASE–PR–D1, 10GBASE–PR–D2, 10GBASE–PR–D3, 10GBASE–PR–D4	Average input optical power ≤ Signal Detect Threshold (min) in Table 75–6 at the specified receiver wavelength	FAIL
	Average input optical power ≥ Receive sensitivity (max) in Table 75–6 with a compliant 10GBASE–PR signal input at the specified receiver wavelength	OK
	All other conditions	Unspecified
10GBASE–PR–U1, 10GBASE–PR–U3, 10GBASE–PR–U4 10/1GBASE–PRX–U1, 10/1GBASE–PRX–U2, 10/1GBASE–PRX–U3, 10/1GBASE–PRX–U4	Average input optical power ≤ Signal Detect Threshold (min) in Table 75–10 at the specified receiver wavelength	FAIL
	Average input optical power ≥ Receive sensitivity (max) in Table 75–10 with a compliant 10GBASE–PR signal input at the specified receiver wavelength	OK
	All other conditions	Unspecified
10/1GBASE–PRX–D1, 10/1GBASE–PRX–D2, 10/1GBASE–PRX–D3, 10/1GBASE–PRX–D4	Average input optical power ≤ Signal Detect Threshold (min) in Table 75–7 at the specified receiver wavelength	FAIL
	Average input optical power ≥ Receive sensitivity (max) in Table 75–7 with a compliant 1000BASE–PX signal input at the specified receiver wavelength	OK
	All other conditions	Unspecified

75.3.6 PMD transmit enable function for ONU

PMD_SIGNAL.request(tx_enable) is defined for all ONU PMDs specified in Clause 75. PMD_SIGNAL.request(tx_enable) is asserted prior to data transmission by the ONU PMDs.

75.4 PMD to MDI optical specifications for 10/10G–EPON and 10/1G–EPON OLT PMDs

This subclause details the PMD to MDI optical specifications for 10/10G–EPON and 10/1G–EPON OLT PMDs, as specified in 75.2. Specifically, 75.4.1 defines the OLT transmit parameters, while 75.4.2 defines the OLT receive parameters.

The operating ranges for PR and PRX power budget classes are defined in Table 75–1. A PR or PRX compliant transceiver operates over the media types listed in Table 75–14 according to the specifications described in 75.9. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant.

NOTE—The specifications for OMA have been derived from extinction ratio and average launch power (minimum) or receiver sensitivity (maximum). The calculation is defined in 58.7.6.

75.4.1 Transmitter optical specifications

The signaling speed, operating wavelength, side mode suppression ratio, average launch power, extinction ratio, return loss tolerance, OMA, eye, and Transmitter and Dispersion Penalty (TDP) for transmitters making part of the 10/10G–EPON and 10/1G–EPON OLT PMDs (as specified in 75.2) shall meet the specifications defined in Table 75–5 per measurement techniques described in 75.7. Their $RIN_{15}OMA$ should meet the value listed in Table 75–5 per measurement techniques described in 75.7.8. Note that there are only two groups of transmit parameters. The first group is shared by 10GBASE–PR–D1, 10/1GBASE–PRX–D1, 10GBASE–PR–D3, and 10/1GBASE–PRX–D3. The second group is shared by 10GBASE–PR–D2, 10GBASE–PR–D4, 10/1GBASE–PRX–D2, and 10/1GBASE-PRX-D4.

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Table 75–5—PR and PRX type OLT PMD transmit characteristics

Description	10GBASE–PR–D1, 10GBASE–PR–D3, 10/1GBASE–PRX–D1, 10/1GBASE–PRX–D3	10GBASE–PR–D2, 10GBASE–PR–D4, 10/1GBASE–PRX–D2, 10/1GBASE-PRX-D4	Unit
Signaling speed (range)	10.3125 ± 100 ppm		GBd
Wavelength (range)	1575 to 1580		nm
Side Mode Suppression Ratio (min)[a]	30		dB
Average launch power (max)	5	9	dBm
Average launch power (min)[b]	2	5	dBm
Average launch power of OFF transmitter (max)	–39		dBm
Extinction ratio (min)	6		dB
$RIN_{15}OMA$ (max)	–128		dB/Hz
Launch OMA (min)[b]	3.91 (2.46)	6.91 (4.91)	dBm (mW)
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3}[c]	{0.25, 0.4, 0.45, 0.25, 0.28, 0.4}		UI
Optical return loss tolerance (max)	15		dB
Transmitter reflectance (max)	–10		dB
Transmitter and dispersion penalty (max)	1.5		dB
Decision timing offset for transmitter and dispersion penalty	±0.05		UI

[a]Transmitter is a single longitudinal mode device. Chirp is allowed such that the total optical path penalty does not exceed that found in Table 75B–1 and Table 75B–2.
[b]Minimum average launch power and minimum launch OMA are valid for ER = 9 dB (see Figure 75–4 for details)
[c]As defined in Figure 75–6.

The relationship between OMA, extinction ratio, and average power is described in 58.7.6 and illustrated in Figure 75–4 for a compliant transmitter. Note that the OMA_{min} and AVP_{min} are calculated for ER = 9 dB, where AVP_{min} represents the Average launch power (min) as presented in Table 75–5. The transmitter specifications are further relaxed by allowing lower ER = 6 dB while maintaining the OMA_{min} and AVP_{min} constant. The shaded area indicates a compliant part.

75.4.2 Receiver optical specifications

The signaling speed, operating wavelength, overload, stressed sensitivity, reflectance, and signal detect for receivers forming part of the 10/10G–EPON and 10/1G–EPON OLT PMDs (as specified in 75.2) shall meet the specifications defined in Table 75–6 for 10/10G–EPON OLT PMDs and in Table 75–7 for 10/1G–EPON OLT PMDs, per measurement techniques defined in 75.7. Their unstressed receive characteristics should meet the values listed in Table 75–6 and Table 75–7 per measurement techniques described in 75.7.11. Either the damage threshold included in Table 75–6 or Table 75–7 shall be met, or the receiver shall be labeled to indicate the maximum optical input power level to which it can be continuously exposed without damage.

The damage threshold included in Table 75–6 and Table 75–7 does not guarantee direct ONU–OLT connection, which may result in damage of the receiver. If direct ONU–OLT connection is necessary, optical attenuators and/or equivalent loss components should be inserted to decrease receive power below the damage threshold.

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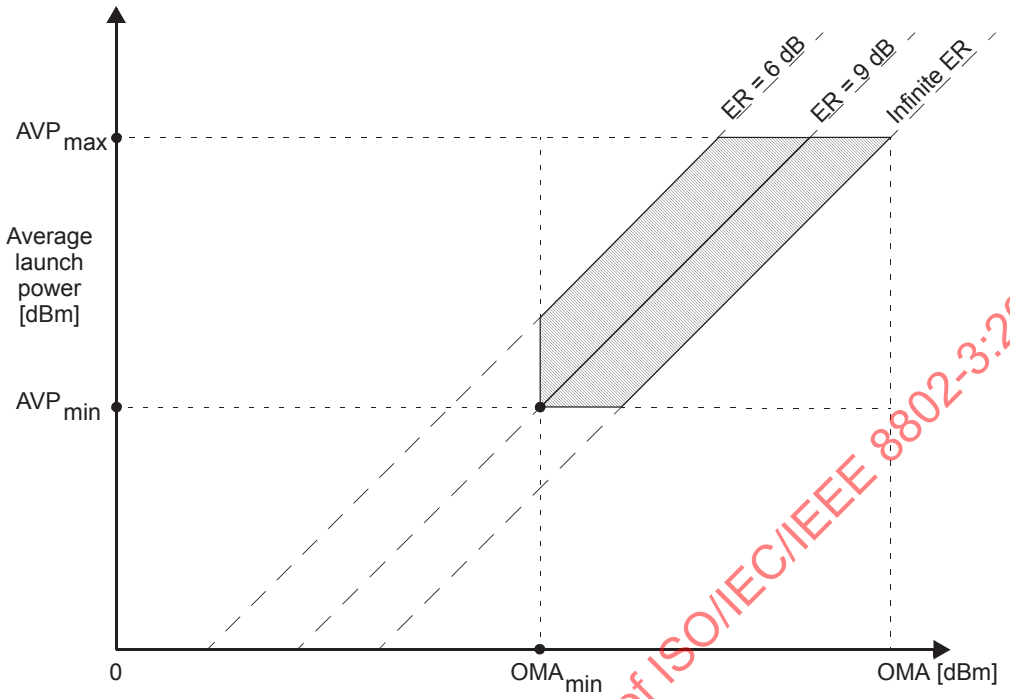

Figure 75–4—Graphical representation of region of PR–D type transmitter compliance

Table 75–6—PR type OLT PMD receive characteristics

Description	10GBASE–PR–D1	10GBASE–PR–D2, 10GBASE–PR–D3	10GBASE–PR–D4	Unit
Signaling speed (range)	10.3125 ± 100 ppm			GBd
Wavelength (range)	1260 to 1280			nm
Bit error ratio (max)[a]	10^{-3}			–
Average receive power (max)	–1	–6	–9	dBm
Damage threshold (max)[b]	0	–5	–8	dBm
Receiver sensitivity (max)	–24	–28	–29	dBm
Receiver sensitivity OMA (max)	–23.22 (4.77)	–27.22 (1.9)	–28.22 (1.51)	dBm (μW)
Signal detect threshold (min)	–45			dBm
Receiver reflectance (max)	–12			dB
Stressed receive sensitivity (max)[c]	–21	–25	–27	dBm

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Table 75–6—PR type OLT PMD receive characteristics *(continued)*

Description	10GBASE–PR–D1	10GBASE–PR–D2, 10GBASE–PR–D3	10GBASE–PR–D4	Unit
Stressed receive sensitivity OMA (max)	–20.22 (9.51)	–24.22 (3.79)	–26.22 (2.39)	dBm (μW)
Vertical eye–closure penalty[d]	2.99			dB
$T_{receiver_settling}$ (max)[e]	800			ns
Stressed eye jitter	0.3			UI pk-pk
Jitter corner frequency for a sinusoidal jitter	4			MHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	(0.05, 0.15)			UI

[a]The BER of 10^{-12} is achieved by the utilization of FEC as described in 76.3.
[b]Direct ONU–OLT connection may result in damage of the receiver.
[c]The stressed receiver sensitivity is mandatory.
[d]Vertical eye closure penalty and the jitter specifications are test conditions for measuring stressed receiver sensitivity. They are not required characteristics of the receiver.
[e]$T_{receiver_settling}$ represents an upper bound. Optics with better performance may be used in compliant implementations, since the OLT notifies the ONUs of its requirements in terms of the $T_{receiver_settling}$ time via the syncTime parameter (see 77.3.3.2).

Table 75–7—PRX type OLT PMD receive characteristics

PMD type	Receive parameters	Reference
10/1GBASE–PRX–D1	same as 1000BASE–PX10–D receive parameters	see Table 60–5
10/1GBASE–PRX–D2	same as 1000BASE–PX20–D receive parameters	see Table 60–8
10/1GBASE–PRX–D3	same as 1000BASE–PX30–D receive parameters[a]	see Table 60–11
10/1GBASE–PRX–D4	same as 1000BASE–PX40–D receive parameters[a]	see Table 60–13

[a]Stressed receive sensitivity (max) is mandatory for 10/1GBASE–PRX–D3 and 10/1GBASE–PRX–D4 PMDs.

75.5 PMD to MDI optical specifications for 10/10G–EPON and 10/1G–EPON ONU PMDs

This subclause details the PMD to MDI optical specifications for 10/10G–EPON and 10/1G–EPON ONU PMDs, as specified in 75.2. Specifically, 75.5.1 defines the ONU transmit parameters, while 75.5.2 defines the ONU receive parameters.

The operating ranges for PR and PRX power budget classes are defined in Table 75–1. A PR or PRX compliant transceiver operates over the media types listed in Table 75–14 according to the specifications described in 75.9. A transceiver which exceeds the operational range requirement while meeting all other optical specifications is considered compliant.

NOTE—The specifications for OMA have been derived from extinction ratio and average launch power (minimum) or receiver sensitivity (maximum). The calculation is defined in 58.7.6.

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75.5.1 Transmitter optical specifications

The signaling speed, operating wavelength, spectral width (for 10/1G–EPON ONU PMDs) or side mode suppression ratio (for 10/10G–EPON ONU PMDs), average launch power, extinction ratio, return loss tolerance, OMA, eye and TDP for transmitters forming part of the 10/10G–EPON and 10/1G–EPON ONU PMDs (as specified in 75.2) shall meet the specifications defined in Table 75–8 for 10/10G–EPON ONU PMDs and in Table 75–9 for 10/1G–EPON ONU PMDs, per measurement techniques described in 75.7. Their $RIN_{15}OMA$ should meet the value listed in Table 75–8 or Table 75–9, as appropriate, per measurement techniques described in 75.7.8.

Table 75–8—PR type ONU PMD transmit characteristics

Description	10GBASE –PR–U1	10GBASE –PR–U3	10GBASE –PR–U4	Unit
Signaling speed (range)	10.3125 ± 100 ppm			GBd
Wavelength (range)	1260 to 1280			nm
Side Mode Suppression Ratio (min)[a]	30			dB
Average launch power (max)	4	9	9	dBm
Average launch power (min)[b]	–1	4	6	dBm
Average launch power of OFF transmitter (max)	–45			dBm
Extinction ratio (min)	6			dB
$RIN_{15}OMA$ (max)	–128			dB/Hz
Launch OMA (min)[b]	–0.22 (0.95)	4.78 (3.01)	6.78 (4.77)	dBm (mW)
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3}[c]	{0.25, 0.4, 0.45, 0.25, 0.28, 0.4}			UI
T_{on} (max)	512			ns
T_{off} (max)	512			ns
Optical return loss tolerance (max)	15			dB
Transmitter reflectance (max)	–10			dB
Transmitter and dispersion penalty (max)[d]	3	3	2	dB
Decision timing offset for transmitter and dispersion penalty	±0.0625			UI

[a]Transmitter is a single longitudinal mode device. Chirp is allowed such that the total optical path penalty does not exceed that found in Table 75B–2.
[b]Minimum average launch power and minimum launch OMA are valid for ER = 6 dB (see Figure 75–5 for details).
[c]As defined in Figure 75–6.
[d]If a transmitter has a lower TDP, the minimum transmitter launch OMA (OMA_{min}) and average minimum launch power (AVP_{min}) may be relaxed by the amount 3 dB – TDP for 10GBASE-PR-U1 and 10GBASE-PR-U3 and 2 dB – TDP for 10G-BASE-PR-U4.

The relationship between OMA, extinction ratio and average power is described in 58.7.6 and illustrated in Figure 75–5 for a compliant transmitter. Note that the OMA_{min} and AVP_{min} are calculated for ER = 6 dB. The transmitter average launch power specifications are further relaxed by allowing ER higher than 6 dB while maintaining the OMA_{min} constant. The shaded area indicates a compliant part.

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Table 75–9—PRX type ONU PMD transmit characteristics

PMD type	Transmit parameters[a]	Reference
10/1GBASE–PRX–U1	same as 1000BASE–PX10–U transmit parameters	see Table 60–3
10/1GBASE–PRX–U2	same as 1000BASE–PX20–U transmit parameters	see Table 60–6
10/1GBASE–PRX–U3	same as 1000BASE–PX30–U transmit parameters	see Table 60–9
10/1GBASE–PRX–U4	same as 1000BASE–PX40–U transmit parameters	see Table 60–12

[a]Optical return loss of ODN (min) is informative for 10/1GBASE–PRX–U1, 10/1GBASE–PRX–U2, 10/1GBASE–PRX–U3, and 10/1GBASE–PRX–U4 PMDs.

The maximum RMS spectral width vs. wavelength for 10/1GBASE–PRX–U1, 10/1GBASE–PRX–U2 and 10/1GBASE–PRX–U3 PMDs are shown, respectively, in Table 60–4, Table 60–7, and Table 75–10. The equation used to generate these values is included in 60.9.2.

75.5.2 Receiver optical specifications

The signaling speed, operating wavelength, overload, stressed sensitivity, reflectance, and signal detect for receivers forming part of the 10/10G–EPON ONU and 10/1G–EPON ONU PMDs (as specified in 75.2) shall meet the specifications defined in Table 75–10 for Clause 75 ONU PMDs, per measurement techniques defined in 75.7. Their unstressed receive characteristics should meet the values listed in Table 75–10 per measurement techniques described in 75.7.11. Either the damage threshold included in Table 75–10 shall be met, or the receiver shall be labeled to indicate the maximum optical input power level to which it can be continuously exposed without damage.

The damage threshold included in Table 75–10 does not guarantee direct ONU–OLT connection, which may result in damage of the receiver. If direct ONU–OLT connection is necessary, optical attenuators and/or equivalent loss components should be inserted to decrease receive power below damage threshold.

Table 75–10—PR and PRX type ONU PMD receive characteristics

Description	10GBASE–PR–U1, 10/1GBASE–PRX–U1, 10/1GBASE–PRX–U2	10GBASE–PR–U3, 10/1GBASE–PRX–U3	10GBASE–PR–U4, 10/1GBASE–PRX–U4	Unit
Signaling speed (range)	10.3125 ± 100 ppm			GBd
Wavelength (range)	1575 to 1580			nm
Bit error ratio (max)[a]	10^{-3}			—
Average receive power (max)	0	–10	–9	dBm
Damage threshold (max)[b]	1	–9	–8	dBm
Receiver sensitivity (max)	–20.5	–28.5	–29.5	dBm
Receiver sensitivity OMA (max)	–18.59 (13.84)	–26.59 (2.19)	–27.59 (1.74)	dBm (μW)

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Table 75–10—PR and PRX type ONU PMD receive characteristics *(continued)*

Description	10GBASE–PR–U1, 10/1GBASE–PRX–U1, 10/1GBASE–PRX–U2	10GBASE–PR–U3, 10/1GBASE–PRX–U3	10GBASE–PR–U4, 10/1GBASE–PRX–U4	Unit
Signal detect threshold (min)	–44			dBm
Receiver reflectance (max)	–12			dB
Stressed receive sensitivity (max)[c]	–19	–27	–28	dBm
Stressed receive sensitivity OMA (max)	–17.09 (19.55)	–25.09 (3.1)	–26.09 (2.46)	dBm (µW)
Vertical eye–closure penalty[d]	1.5			dB
Stressed eye jitter (min)	0.3			UI pk-pk
Jitter corner frequency for a sinusoidal jitter	4			MHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	(0.05, 0.15)			UI

[a]The BER of 10^{-12} is achieved by the utilization of FEC as described in 76.3.
[b]Direct ONU–OLT connection may result in damage of the receiver.
[c]The stressed receiver sensitivity is mandatory over the entire PR–D transmitter compliance region, as illustrated in Figure 75–4.
[d]Vertical eye closure penalty and the jitter specifications are test conditions for measuring stressed receiver sensitivity. They are not required characteristics of the receiver.

75.6 Dual-rate (coexistence) mode

To support coexistence of 10G–EPON and 1G–EPON ONUs on the same outside plant, the OLT may be configured to use a dual-rate mode. Dual-rate mode supports transmission and/or reception of both 10 Gb/s and 1 Gb/s data rates, and can be introduced as options for 10G–EPON OLTs, functionally combining PMDs supporting 10 Gb/s and 1 Gb/s data rates.

Table 75–11 depicts PMD coexistence mapping for dual-rate mode options.

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Table 75–11—PMD coexistence mapping for dual-rate mode option[a]

Direction of dual-rate operation	OLT PMD combination	ONU PMDs coexisting on the same ODN
Downstream	1000BASE–PX–D 10/1GBASE–PRX–D	(1) 1000BASE–PX–U (2) 10/1GBASE–PRX–U
Upstream	10GBASE–PR–D 10/1GBASE–PRX–D	(1) 10GBASE–PR–U (2) 10/1GBASE–PRX–U
Downstream and upstream	1000BASE–PX–D 10GBASE–PR–D	(1) 1000BASE–PX–U (2) 10/1GBASE–PRX–U (3) 10GBASE–PR–U

[a]Only PMDs with compatible power budgets can be connected to the same ODN.

75.6.1 Downstream dual-rate operation

When the downstream dual-rate operation is enabled, the OLT transmits both 10 Gb/s and 1 Gb/s downstream signals in a WDM manner. The OLT should meet both 10 Gb/s and 1 Gb/s specifications defined in Table 75–5 (10GBASE–PR–D transmit characteristics) and in Table 60–3, Table 60–6, Table 60–9, or Table 60–12 (1000BASE–PX–D transmit characteristics).

75.6.2 Upstream dual-rate operation

When the upstream dual-rate operation is enabled, the OLT receives both 10 Gb/s and 1 Gb/s upstream signals in a TDMA manner. Further implementation details are described in Annex 75A. The OLT should meet both 10 Gb/s and 1 Gb/s specifications defined in Table 75–6 (10GBASE–PR–D receive characteristics), and in Table 60–5, Table 60–8, Table 60–11, and Table 60–13 (1000BASE–PX–D receive characteristics).

NOTE—The damage threshold values in Table 60–5, Table 60–8, Table 60–11, and Table 60–13 are considerably higher than those in Table 75–6; the dual-rate PMD should be labeled appropriately.

75.7 Definitions of optical parameters and measurement methods

When measuring jitter at TP1 and TP5, it is recommended that jitter contributions at frequencies below receiver corner frequencies (i.e., 4 MHz for 10.3125 GBd receiver and 637 kHz for 1.25 GBd receiver) are filtered at the measurement unit. The following subclauses describe definitive patterns and test procedures for certain PMDs of this standard. Implementers using alternative verification methods should ensure adequate correlation and allow adequate margin such that specifications are met by reference to the definitive methods. All optical measurements, except TDP and $RIN_{15}OMA$ shall be made through a short patch cable between 2 m and 5 m in length.

75.7.1 Insertion loss

Insertion loss for SMF fiber optic cabling (channel) is defined at 1270 nm, 1310 nm, or 1577 nm, depending on the particular PMD. A suitable test method is described in ITU–T G.650.1.

75.7.2 Allocation for penalties in 10G–EPON PMDs

All the receiver types specified in Clause 75 are required to tolerate a path penalty not exceeding 1 dB to account for total degradations due to reflections, intersymbol interference, mode partition noise, laser chirp and detuning of the central wavelength, including chromatic dispersion penalty. All the transmitter types specified in Clause 75 introduce less than 1 dB of optical path penalty over the channel. The path penalty is

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a component of transmitter and dispersion penalty (TDP), which is specified in Table 75–5, Table 75–8, and Table 75–9 and described in 58.7.9.

75.7.3 Test patterns

Two types of test patterns are used for testing of 10 Gb/s optical PMDs: square wave (52.9.1.2) and patterns 1, 2, or 3 (52.9.1.1). These 10 Gb/s test patterns for 10GBASE–PR and 10/1GBASE–PRX are in Table 75–12. Two types of test frames [random and jitter (59.7.1)] are used for 1 Gb/s tests relevant to the 10/1GBASE–PRX PHY. All test patterns are listed in Table 75–12.

Table 75–12—Test patterns

Test	10 Gb/s pattern[a]	1 Gb/s pattern	Related subclause
Average optical power	1 or 3	Valid 8B/10B	75.7.5
OMA (modulated optical power)	Square	Idles	75.7.7
Extinction ratio	1 or 3	Idles	75.7.6
Transmit eye	1 or 3	Valid 8B/10B	75.7.7
$RIN_{15}OMA$	Square	Idles	75.7.8
Wavelength, spectral width	1 or 3	Valid 8B/10B	75.7.4
Side mode suppression ratio	1 or 3	Valid 8B/10B	—
VECP calibration	2 or 3	Jitter frame	75.7.12
Receiver sensitivity	1 or 3	Random frame	75.7.11
Receiver overload	1 or 3	Valid 8B/10B	—
Stressed receive sensitivity	2 or 3	Random frame	75.7.12
Transmitter and dispersion penalty	2 or 3	Random frame	75.7.10
Jitter	2 or 3	Jitter frame	75.7.13
Laser On/Off	1 or 3	Valid 8B/10B	75.7.14
Receiver settling	1 or 3	Valid 8B/10B	75.7.15

[a]Individual 10 Gb/s test patterns are described in 52.9.1.2 for a square wave and 52.9.1.1 for test patterns represented by numbers.

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75.7.4 Wavelength and spectral width measurement

The center wavelength and spectral width (RMS) shall meet the specifications when measured according to TIA-455-127-A under modulated conditions using an appropriate PRBS or a valid 10GBASE–PR signal, 1000BASE–X signal, or another representative test pattern.

NOTE—The allowable range of central wavelengths is narrower than the operating wavelength range by the actual RMS spectral width at each extreme.

75.7.5 Optical power measurements

Optical power shall meet specifications according to the methods specified in ANSI/EIA-455-95. A measurement may be made with the port transmitting any valid encoded 8B/10B or 64B/66B data stream.

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75.7.6 Extinction ratio measurements

The extinction ratio shall meet the specifications when measured according to IEC 61820-2-2 with the port transmitting a repeating idle pattern /I2/ ordered set (see 36.2.4.12) or valid 10GBASE–PR signal, and with minimal back reflections into the transmitter, lower than –20 dB. The test receiver has the frequency response as specified for the transmitter optical waveform measurement.

75.7.7 Optical modulation amplitude (OMA) test procedure

A description of OMA measurements for 1 Gb/s PHYs is found in 58.7.5. The OMA measurements for 10 Gb/s PHYs shall be compliant with the description found in 52.9.5.

75.7.8 Relative intensity noise optical modulation amplitude (RIN_xOMA) measuring procedure

This procedure describes a component test that may not be appropriate for a system level test depending on the implementation. If used, the procedure shall be performed as described in 52.9.6 for 10 Gb/s PHYs and in 58.7.7 for 1 Gb/s PHYs.

75.7.9 Transmit optical waveform (transmit eye)

The required transmitter pulse shape characteristics are specified in the form of a mask of the transmitter eye diagram as shown in Figure 75–5 for upstream direction of 10/1GBASE–PRX PMD and Figure 75–6 for downstream direction of 10/1GBASE–PRX PMD and both directions of 10GBASE–PR PMD.

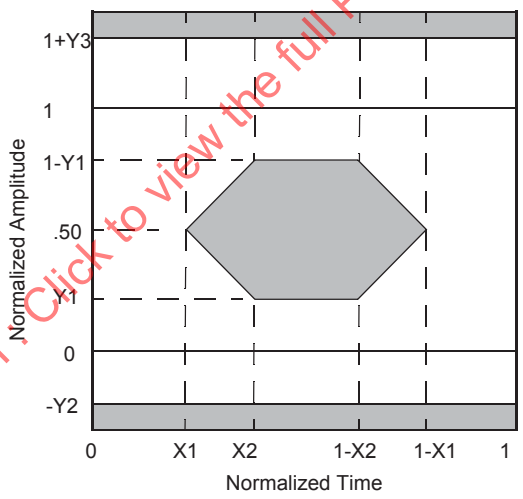

Figure 75–5—Transmitter eye mask definition for upstream direction of 10/1GBASE–PRX PMD

The measurement procedure is described in 58.7.8 for 1 Gb/s PHYs and 52.9.7 for 10 Gb/s PHYs and references therein. The eye shall comply to the mask of the eye using a fourth-order Bessel-Thomson receiver response as defined in 60.9.8 for 1 Gb/s PMD transmitters and 52.9.7 for 10 Gb/s PMD transmitters.

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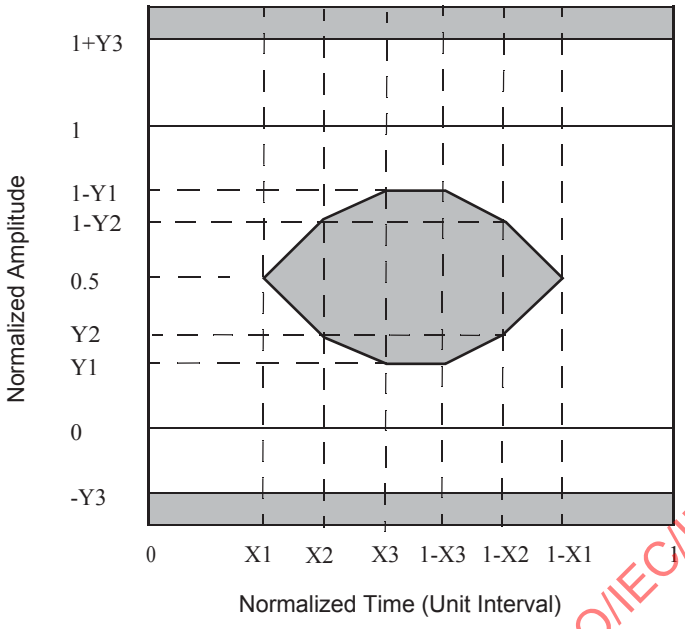

Figure 75–6—Transmitter eye mask definition for downstream direction of 10/1GBASE–PRX PMD and both directions of 10GBASE–PR PMD

75.7.10 Transmitter and dispersion penalty (TDP)

TDP measurement tests transmitter impairments, including chromatic dispersion effects, due to signal propagation in SMF used in PON. Possible causes of impairment include intersymbol interference, jitter, and RIN. Meeting the separate requirements (e.g., eye mask, spectral characteristics) does not in itself guarantee the TDP. The TDP limit shall be met. See 58.7.9 for details of the measurement for 1 Gb/s PHYs. For 10 Gb/s PHYs, TDP is measured as defined in 52.9.10 with an optical channel that meets the requirements listed in Table 75–13.

A 10 Gb/s transmitter is to be compliant with a total dispersion at least as negative as the “minimum dispersion” and at least as positive as the “maximum dispersion” columns specified in Table 75–13 for the wavelength of the device under test. This may be achieved with channels consisting of fibers with lengths chosen to meet the dispersion requirements.

75.7.11 Receive sensitivity

Receiver sensitivity is defined for the random pattern test frame, or test pattern 1, or test pattern 3, and an ideal input signal quality with the specified extinction ratio. The measurement procedure is described in 58.7.10 for 1 Gb/s PHYs and 52.9.8 for 10 Gb/s PHYs. The sensitivity shall be met for the bit error ratio defined in Table 75–6, Table 75–7, or Table 75–10 as appropriate.

75.7.12 Stressed receiver conformance test

Compliance with stressed receiver sensitivity is mandatory for the following PMDs: 10GBASE–PR–D1, 10GBASE–PR–D2, 10GBASE–PR–D3, 10GBASE–PR–D4, 10GBASE–PR–U1, 10GBASE–PR–U3, 10GBASE–PR–U4, 10/1GBASE–PRX–D3, 10/1GBASE–PRX–D4, 10/1GBASE–PRX–U1, 10/1GBASE–PRX–U2, 10/1GBASE–PRX–U3, and 10/1GBASE–PRX–U4. The stressed receiver conformance test is intended to screen against receivers with poor frequency response or timing characteristics that could cause errors when combined with a distorted but compliant signal. To be compliant with stressed receiver

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Table 75–13—10 Gb/s transmitter compliance channel specifications

PMD type	Max reach L (km)	Dispersion[a] (ps/nm)		Insertion loss	Optical return loss (dB)
		Minimum	Maximum		
10GBASE–PR–D1 10/1GBASE–PRX–D1	10	0	$0.2325 L \lambda [1–(1300/\lambda)^4]$	Minimum[b]	15
10GBASE–PR–D2 10GBASE–PR–D3 10GBASE–PR–D4 10/1GBASE–PRX–D2 10/1GBASE–PRX–D3 10/1GBASE–PRX–D4	20				
10GBASE–PR–U1	10	$0.2325 L \lambda [1–(1324/\lambda)^4]$	0		
10GBASE–PR–U3 10GBASE–PR–U4	20				

[a]The dispersion is measured for the wavelength of the device under test (λ in nm).
[b]There is no intent to stress the sensitivity of the BERT's optical receiver.

sensitivity, the receiver shall meet the specified bit error ratio at the power level and signal quality defined in Table 75–6, Table 75–7, or Table 75–10 as appropriate, according to the measurement procedures of 58.7.11 for 1 Gb/s PHYs and 52.9.9 for 10 Gb/s PHYs.

75.7.13 Jitter measurements

Jitter measurements for 1 Gb/s are described in 58.7.12. Jitter measurements for 10 Gb/s are described in 52.8.1.

75.7.14 Laser on/off timing measurement

The laser on/off timing measurement procedure is described in 60.9.13.1 with the following changes:

a) T_{on} is defined in 60.9.13.1.1, and its value is less than 512 ns (defined in Table 75–8 and Table 75–9).
b) $T_{receiver_settling}$ is defined in 60.9.13.2.1, and its value is defined in Table 75–6 and Table 75–7.
c) T_{CDR} is defined in 76.4.2.1, and its value is less than 400 ns.
d) $T_{code_group_align}$ is defined in 36.3.2.4, and its value is less than 4 ten bit code–groups for 1 Gb/s PHYs, and is defined as 0 for 10 Gb/s PHYs.
e) T_{off} is defined in 60.9.13.1.1, and its value is less than 512 ns (defined in Table 75–8 and Table 75–9).

75.7.15 Receiver settling timing measurement

75.7.15.1 Definitions

$T_{receiver_settling}$ is denoted as the time beginning from the time that the optical power in the receiver at TP7 reaches the conditions specified in 75.7.12 and ending at the time that the electrical signal after the PMD at TP8 reaches within 15 % of its steady state parameter (average power, jitter) (see Table 75–6 for 10GBASE–PR–D1, 10GBASE–PR–D2, 10GBASE–PR–D3, and 10GBASE–PR–D4, and Table 75–7 for 10/1GBASE–PRX–D1, 10/1GBASE–PRX–D2, 10/1GBASE–PRX–D3, and 10/1GBASE–PRX–D4).

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$T_{receiver_settling}$ is presented in Figure 75–7. The data transmitted may be any valid 64B/66B symbols (or a specific power synchronization sequence). The optical signal at TP7, at the beginning of the locking, may have any valid 64B/66B pattern, optical power level, jitter, or frequency shift matching the standard specifications.

75.7.15.2 Test specification

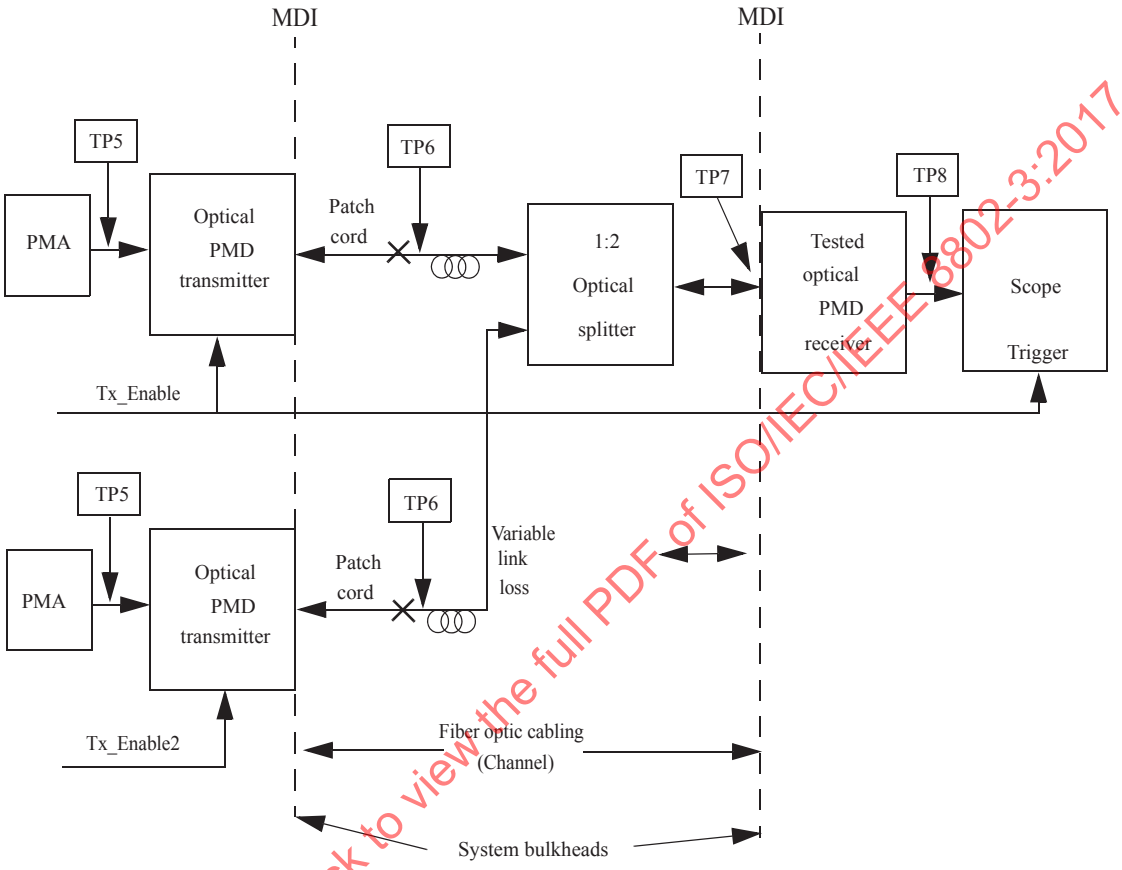

Figure 75–7—Receiver settling time measurement setup

Figure 75–7 illustrates the test setup for the OLT PMD receiver (upstream) $T_{receiver_settling}$ time. The optical PMD transmitter has well–known parameters, with a fixed known T_{on} time. After T_{on} time the parameters of the reference transmitter, at TP6 and therefore at TP7, reach within 15% of its steady state values as specified in Table 75–8 for 10GBASE–PR–U1, 10GBASE–PR–U3, and 10GBASE–PR–U4 and Table 75–9 for 10/1GBASE–PRX–U1, 10/1GBASE–PRX–U2, 10/1GBASE–PRX–U3, and 10/1GBASE–PRX–U4.

Define $T_{receiver_settling}$ time as the time from the Tx_Enable assertion, minus the known T_{on} time, to the time the electrical signal at TP8 reaches within 15% of its steady state conditions.

Conformance should be assured for an optical signal at TP7 with any level of its specified parameters before the Tx_Enable assertion. Especially the $T_{receiver_settling}$ time must be met in the following scenarios:

— Switching from a ‘weak’ (minimal received power at TP7) ONU to a ‘strong’ (maximal received power at TP7) ONU, with minimal guard band between.
— Switching from a ‘strong’ ONU to a ‘weak’ ONU, with minimal guard band between.
— Switching from noise level, with maximal duration interval, to ‘strong’ ONU power level.

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A non-rigorous way to describe this test setup would be (using a transmitter with a known T_{on}).

For a tested PMD receiver with a declared $T_{receiver_settling}$ time, measure all PMD receiver electrical parameters at TP8 after $T_{receiver_settling}$ from the TX_ENABLE trigger minus the reference transmitter T_{on}, reassuring conformance to within 15% of its specified steady state values.

75.8 Environmental, safety, and labeling

75.8.1 General safety

All equipment subject to this clause shall conform to IEC 60950–1.

75.8.2 Laser safety

10GBASE–PR and 10/1GBASE–PRX optical transceivers shall conform to Hazard Level 1 laser requirements as defined in IEC 60825–1 and IEC 60825–2, under any condition of operation. This includes single fault conditions whether coupled into a fiber or out of an open bore.

Conformance to additional laser safety standards may be required for operation within specific geographic regions.

Laser safety standards and regulations require that the manufacturer of a laser product provide information about the product's laser, safety features, labeling, use, maintenance, and service. This documentation explicitly defines requirements and usage restrictions on the host system necessary to meet these safety certifications.

75.8.3 Installation

It is recommended that proper installation practices, as defined by applicable local codes and regulation, be followed in every instance in which such practices are applicable.

75.8.4 Environment

The 10GBASE–PR and 10/1GBASE–PRX operating environment specifications are as defined in 52.11, as defined in 52.11.1 for electromagnetic emission, and as defined in 52.11.2 for temperature, humidity, and handling.

See Annex 67A for additional environmental information. Two optional temperature ranges are defined in Table 60–18. Implementations shall be declared as compliant over one or both complete ranges, or not so declared (compliant over parts of these ranges or another temperature range).

75.8.5 PMD labeling

The 10GBASE–PR and 10/1GBASE–PRX labeling recommendations and requirements are as defined in 52.12.

Defined PMDs are as follows:

— 10/1GBASE–PRX–D1
— 10/1GBASE–PRX–D2
— 10/1GBASE–PRX–D3
— 10/1GBASE–PRX–D4
— 10GBASE–PR–D1
— 10GBASE–PR–D2

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— 10GBASE–PR–D3
— 10GBASE–PR–D4
— 10/1GBASE–PRX–U1
— 10/1GBASE–PRX–U2
— 10/1GBASE–PRX–U3
— 10/1GBASE–PRX–U4
— 10GBASE–PR–U1
— 10GBASE–PR–U3
— 10GBASE–PR–U4

Each field-pluggable component shall be clearly labeled with its operating temperature range over which compliance is ensured.

75.9 Characteristics of the fiber optic cabling

The 10GBASE–PR and 10/1GBASE–PRX fiber optic cabling shall meet the dispersion specifications defined in IEC 60793–2 and ITU–T G.652, or the requirements of Table 75–14 where they differ. The fiber optic cabling consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together. It also includes a connector plug at each end to connect to the MDI. The fiber optic cabling spans from one MDI to another MDI, as shown in Figure 75–3.

75.9.1 Fiber optic cabling model

The fiber optic cabling model is shown in Figure 75–3.

NOTE—The optical splitter presented in Figure 75–3 may be replaced by a number of smaller 1:n splitters such that a different topology may be implemented while preserving the link characteristics and power budget as defined in Table 75B–1 and Table 75B–2.

The maximum channel insertion losses shall meet the requirements specified in Table 75–1. Insertion loss measurements of installed fiber cables are made in accordance with IEC 61280–4–2:2000. The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment. The term *channel* is used here for consistency with generic cabling standards.

75.9.2 Optical fiber and cable

The fiber optic cable requirements are satisfied by the fibers specified in IEC 60793–2 Type B1.1 (dispersion un–shifted SMF) and Type B1.3 (low water peak SMF), ITU–T G.652 and ITU–T G.657 (bend–insensitive SMF), or by the requirements of Table 75–14 where they differ.

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75.9.3 Optical fiber connection

Table 75–14—Optical fiber and cable characteristics

Description[a]	IEC 60793–2 B1.1, B1.3 SMF, ITU–T G.652, G.657 SMF[b]				Unit
Nominal wavelength[c]	1270	1310	1550	1577	nm
Cable attenuation (max)[d]	0.44	0.4	0.35	0.35	dB/km
Zero dispersion wavelength[e]	$1300 \leq \lambda_0 \leq 1324$				nm
Dispersion slope (max)	0.093				$ps/nm^2 \cdot km$

[a]The fiber dispersion values are normative, all other values in the table are informative.
[b]Other fiber types are acceptable if the resulting ODN meets channel insertion loss and dispersion requirements.
[c]Wavelength specified is the nominal wavelength and typical measurement wavelength. Power penalties at other wavelengths are accounted for.
[d]Attenuation for single-mode optical fiber cables for 1310 nm and 1550 nm is defined in ITU–T G.652. The attenuation values in the 1270 nm and 1577 nm windows were calculated using spectral attenuation modelling method (5.4.4) included in G.650.1 and the matrix coefficients included in Appendix III therein. 1310 nm (0.4 dB/km), 1380 nm (0.5 dB/km) and 1550 nm (0.35 dB/km) attenuation values were used as the input for the predictor model.
[e]See IEC 60793 or ITU–T G.652.

An optical fiber connection as shown in Figure 75–3 consists of a mated pair of optical connectors. The 10GBASE–PR or 10/1GBASE–PRX PMD is coupled to the fiber optic cabling through an optical connection and any optical splitters into the MDI optical receiver, as shown in Figure 75–3. The channel insertion loss includes the loss for connectors, splices, and other passive components such as splitters, see Table 75B–1 and Table 75B–2.

The channel insertion loss was calculated under the assumption of 14.5 dB loss for a 1:16 splitter/18.1 dB loss for a 1:32 splitter (ITU–T G.671 am 1). Unitary fiber attenuation for particular transmission wavelength is provided in Table 75–14. The number of splices/connectors is not predefined; the number of individual fiber sections between the OLT MDI and the ONU MDI is not defined. The only requirements are that the resulting channel insertion loss is within the limits specified in Table 75–1 and the maximum reach in Table 75–1 is not exceeded. Other fiber arrangements (e.g., increasing the split ratio while decreasing the fiber length) are supported as long as the limits for the channel insertion loss specified in Table 75–1 are observed.

The maximum discrete reflectance for single-mode connections shall be less than –26 dB.

75.9.4 Medium Dependent Interface (MDI)

The 10GBASE–PR or 10/1GBASE–PRX PMD is coupled to the fiber cabling at the MDI. The MDI is the interface between the PMD and the "fiber optic cabling" as shown in Figure 75–3. Examples of an MDI include the following:

a) Connectorized fiber pigtail
b) PMD receptacle

When the MDI is a remateable connection, it shall meet the interface performance specifications of IEC 61753–1. The MDI carries the signal in both directions for 10GBASE–PR or 10/1GBASE–PRX PMD and couples to a single fiber.

NOTE—Compliance testing is performed at TP2 and TP3 as defined in 75.3.2, not at the MDI.

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75.10 Protocol implementation conformance statement (PICS) proforma for Clause 75, Physical Medium Dependent (PMD) sublayer and medium for passive optical networks, type 10GBASE–PR and 10/1GBASE–PRX[32]

75.10.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 75, Physical Medium Dependent (PMD) sublayer and medium for passive optical networks, type 10GBASE–PR and 10/1GBASE–PRX, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

75.10.2 Identification

75.10.2.1 Implementation identification

Supplier[1]	
Contact point for inquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1,3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

75.10.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 75, Physical Medium Dependent (PMD) sublayer and medium for passive optical networks, type 10GBASE–PR and 10/1GBASE–PRX
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required?	No [ ] Yes [ ]
(See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	

Date of Statement	

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75.10.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
DTX	Transmit delay	75.3.1.1	Delay of 4 TQ (max) with variability 0.5 TQ (max)	M	Yes [ ]
DRX	Receive delay	75.3.1.1	Delay of 4 TQ (max) with variability 0.5 TQ (max)	M	Yes [ ]
HT	High temperature operation	75.8.4	–5 ºC to 85 ºC	O	Yes [ ] No [ ]
LT	Low temperature operation	75.8.4	–40 ºC to 60 ºC	O	Yes [ ] No [ ]
*PR10U	10GBASE–PR–U1 PHY or 10GBASE–PR–U1 PMD	75.5	Maximum channel insertion loss of 20 dB	O/1	Yes [ ] No [ ]
*PR10D	10GBASE–PR–D1 PHY or 10GBASE–PR–D1 PMD	75.4	Maximum channel insertion loss of 20 dB	O/1	Yes [ ] No [ ]
*PR20D	10GBASE–PR–D2 PHY or 10GBASE–PR–D2 PMD	75.4	Maximum channel insertion loss of 24 dB	O/1	Yes [ ] No [ ]
*PR30U	10GBASE–PR–U3 PHY or 10GBASE–PR–U3 PMD	75.5	Maximum channel insertion loss of 29 dB	O/1	Yes [ ] No [ ]
*PR30D	10GBASE–PR–D3 PHY or 10GBASE–PR–D3 PMD	75.4	Maximum channel insertion loss of 29 dB	O/1	Yes [ ] No [ ]
*PR40U	10GBASE–PR–U4 PHY or 10GBASE–PR–U4 PMD	75.5	Maximum channel insertion loss of 33 dB	O/1	Yes [ ] No [ ]
*PR40D	10GBASE–PR–D4 PHY or 10GBASE–PR–D4 PMD	75.4	Maximum channel insertion loss of 33 dB	O/1	Yes [ ] No [ ]
*PRX10U	10/1GBASE–PRX–U1 PHY or 10/1GBASE–PRX–U1 PMD	75.5	Maximum channel insertion loss of 20 dB	O/1	Yes [ ] No [ ]
*PRX10D	10/1GBASE–PRX–D1 PHY or 10/1GBASE–PRX–D1 PMD	75.4	Maximum channel insertion loss of 20 dB	O/1	Yes [ ] No [ ]
*PRX20U	10/1GBASE–PRX–U2 PHY or 10/1GBASE–PRX–U2 PMD	75.5	Maximum channel insertion loss of 24 dB	O/1	Yes [ ] No [ ]
*PRX20D	10/1GBASE–PRX–D2 PHY or 10/1GBASE–PRX–D2 PMD	75.4	Maximum channel insertion loss of 24 dB	O/1	Yes [ ] No [ ]
*PRX30U	10/1GBASE–PRX–U3 PHY or 10/1GBASE–PRX–U3 PMD	75.5	Maximum channel insertion loss of 29 dB	O/1	Yes [ ] No [ ]
*PRX30D	10/1GBASE–PRX–D3 PHY or 10/1GBASE–PRX–D3 PMD	75.4	Maximum channel insertion loss of 29 dB	O/1	Yes [ ] No [ ]
*PRX40U	10/1GBASE–PRX–U4 PHY or 10/1GBASE–PRX–U4 PMD	75.5	Maximum channel insertion loss of 33 dB	O/1	Yes [ ] No [ ]
*PRX40D	10/1GBASE–PRX–D4 PHY or 10/1GBASE–PRX–D4 PMD	75.4	Maximum channel insertion loss of 33 dB	O/1	Yes [ ] No [ ]
*INS	Installation/Cable	75.4.1	Items marked with INS include installation practices and cable specifications not applicable to a PHY manufacturer	O	Yes [ ] No [ ]

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75.10.4 PICS proforma tables for Physical Medium Dependent (PMD) sublayer and medium for passive optical networks, type 10GBASE–PR and 10/1GBASE–PRX

75.10.4.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FN1	Transmit function	75.3.3	Conveys bits from PMD service interface to MDI	M	Yes [ ]
FN2	Transmitter optical signal	75.3.3	Higher optical power transmitted is a logic 1	M	Yes [ ]
FN3	Receive function	75.3.4	Conveys bits from MDI to PMD service interface	M	Yes [ ]
FN4	Receiver optical signal	75.3.4	Higher optical power received is a logic 1	M	Yes [ ]
FN5	ONU signal detect function	75.3.5.1	Mapping to PMD service interface	M	Yes [ ]
FN6	ONU signal detect parameter	75.3.5.1	Generated according to Table 75–4	M	Yes [ ]
FN7	OLT signal detect function	75.3.5.2	Mapping to PMD service interface	O/2	Yes [ ]
FN8	OLT signal detect function	75.3.5.2	Provided by higher layer	O/2	Yes [ ]
FN9	OLT signal detect parameter	75.3.5.1	Generated according to Table 75–4	O	Yes [ ]

75.10.4.2 PMD to MDI optical specifications for 10GBASE–PR–D1

Item	Feature	Subclause	Value/Comment	Status	Support
PRD1F1	10GBASE–PR–D1 transmitter	75.4.1	Meets specifications in Table 75–5	PR10D:M	Yes [ ] N/A [ ]
PRD1F2	10GBASE–PR–D1 receiver	75.4.2	Meets specifications in Table 75–6	PR10D:M	Yes [ ] N/A [ ]
PRD1F3	10GBASE–PR–D1 receiver damage threshold	75.4.2	If the receiver does not meet the damage requirements in Table 75–6 then label accordingly	PR10D:M	Yes [ ] N/A [ ]

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75.10.4.3 PMD to MDI optical specifications for 10GBASE–PR–D2

Item	Feature	Subclause	Value/Comment	Status	Support
PRD2F1	10GBASE–PR–D2 transmitter	75.4.1	Meets specifications in Table 75–5	PR20D:M	Yes [ ] N/A [ ]
PRD2F2	10GBASE–PR–D2 receiver	75.4.2	Meets specifications in Table 75–6	PR20D:M	Yes [ ] N/A [ ]
PRD2F3	10GBASE–PR–D2 receiver damage threshold	75.4.2	If the receiver does not meet the damage requirements in Table 75–6 then label accordingly	PR20D:M	Yes [ ] N/A [ ]

75.10.4.4 PMD to MDI optical specifications for 10GBASE–PR–D3

Item	Feature	Subclause	Value/Comment	Status	Support
PRD3F1	10GBASE–PR–D3 transmitter	75.4.1	Meets specifications in Table 75–5	PR30D:M	Yes [ ] N/A [ ]
PRD3F2	10GBASE–PR–D3 receiver	75.4.2	Meets specifications in Table 75–6	PR30D:M	Yes [ ] N/A [ ]
PRD3F3	10GBASE–PR–D3 receiver damage threshold	75.4.2	If the receiver does not meet the damage requirements in Table 75–6 then label accordingly	PR30D:M	Yes [ ] N/A [ ]

75.10.4.5 PMD to MDI optical specifications for 10GBASE–PR–D4

Item	Feature	Subclause	Value/Comment	Status	Support
PRD4F1	10GBASE–PR–D4 transmitter	75.4.1	Meets specifications in Table 75–5	PR40D:M	Yes [ ] N/A [ ]
PRD4F2	10GBASE–PR–D4 receiver	75.4.2	Meets specifications in Table 75–6	PR40D:M	Yes [ ] N/A [ ]
PRD4F3	10GBASE–PR–D4 receiver damage threshold	75.4.2	If the receiver does not meet the damage requirements in Table 75–6 then label accordingly	PR40D:M	Yes [ ] N/A [ ]

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75.10.4.6 PMD to MDI optical specifications for 10/1GBASE–PRX–D1

Item	Feature	Subclause	Value/Comment	Status	Support
PRXD1F1	10/1GBASE–PRX–D1 transmitter	75.4.1	Meets specifications in Table 75–5	PRX10D:M	Yes [ ] N/A [ ]
PRXD1F2	10/1GBASE–PRX–D1 receiver	75.4.2	Meets specifications in Table 75–7	PRX10D:M	Yes [ ] N/A [ ]
PRXD1F3	10/1GBASE–PRX–D1 receiver damage threshold	75.4.2	If the receiver does not meet the damage requirements in Table 75–7 then label accordingly	PRX10D:M	Yes [ ] N/A [ ]

75.10.4.7 PMD to MDI optical specifications for 10/1GBASE–PRX–D2

Item	Feature	Subclause	Value/Comment	Status	Support
PRXD2F1	10/1GBASE–PRX–D2 transmitter	75.4.1	Meets specifications in Table 75–5	PRX20D:M	Yes [ ] N/A [ ]
PRXD2F2	10/1GBASE–PRX–D2 receiver	75.4.2	Meets specifications in Table 75–7	PRX20D:M	Yes [ ] N/A [ ]
PRXD2F3	10/1GBASE–PRX–D2 receiver damage threshold	75.4.2	If the receiver does not meet the damage requirements in Table 75–7 then label accordingly	PRX20D:M	Yes [ ] N/A [ ]

75.10.4.8 PMD to MDI optical specifications for 10/1GBASE–PRX–D3

Item	Feature	Subclause	Value/Comment	Status	Support
PRXD3F1	10/1GBASE–PRX–D3 transmitter	75.4.1	Meets specifications in Table 75–5	PRX30D:M	Yes [ ] N/A [ ]
PRXD3F2	10/1GBASE–PRX–D3 receiver	75.4.2	Meets specifications in Table 75–7	PRX30D:M	Yes [ ] N/A [ ]
PRXD3F3	10/1GBASE–PRX–D3 receiver damage threshold	75.4.2	If the receiver does not meet the damage requirements in Table 75–7 then label accordingly	PRXD3F4:M	Yes [ ] N/A [ ]

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75.10.4.9 PMD to MDI optical specifications for 10/1GBASE–PRX–D4

Item	Feature	Subclause	Value/Comment	Status	Support
PRXD4F1	10/1GBASE–PRX–D4 transmitter	75.4.1	Meets specifications in Table 75–5	PRX40D:M	Yes [ ] N/A [ ]
PRXD4F2	10/1GBASE–PRX–D4 receiver	75.4.2	Meets specifications in Table 75–7	PRX40D:M	Yes [ ] N/A [ ]
PRXD4F3	10/1GBASE–PRX–D4 receiver damage threshold	75.4.2	If the receiver does not meet the damage requirements in Table 75–7 then label accordingly	PRX40D:M	Yes [ ] N/A [ ]

75.10.4.10 PMD to MDI optical specifications for 10GBASE–PR–U1

Item	Feature	Subclause	Value/Comment	Status	Support
PRU1F1	10GBASE–PR–U1 transmitter	75.5.1	Meets specifications in Table 75–8	PR10U:M	Yes [ ] N/A [ ]
PRU1F2	10GBASE–PR–U1 receiver	75.5.2	Meets specifications in Table 75–10	PR10U:M	Yes [ ] N/A [ ]
PRU1F3	10GBASE–PR–U1 receiver damage threshold	75.5.2	If the receiver does not meet the damage requirements in Table 75–10 then label accordingly	PR10U:M	Yes [ ] N/A [ ]

75.10.4.11 PMD to MDI optical specifications for 10GBASE–PR–U3

Item	Feature	Subclause	Value/Comment	Status	Support
PRU3F1	10GBASE–PR–U3 transmitter	75.5.1	Meets specifications in Table 75–8	PR30U:M	Yes [ ] N/A [ ]
PRU3F2	10GBASE–PR–U3 receiver	75.5.2	Meets specifications in Table 75–10	PR30U:M	Yes [ ] N/A [ ]
PRU3F3	10GBASE–PR–U3 receiver damage threshold	75.5.2	If the receiver does not meet the damage requirements in Table 75–10 then label accordingly	PR30U:M	Yes [ ] N/A [ ]

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75.10.4.12 PMD to MDI optical specifications for 10GBASE–PR–U4

Item	Feature	Subclause	Value/Comment	Status	Support
PRU4F1	10GBASE–PR–U4 transmitter	75.5.1	Meets specifications in Table 75–8	PR40U:M	Yes [ ] N/A [ ]
PRU4F2	10GBASE–PR–U4 receiver	75.5.2	Meets specifications in Table 75–10	PR40U:M	Yes [ ] N/A [ ]
PRU4F3	10GBASE–PR–U4 receiver damage threshold	75.5.2	If the receiver does not meet the damage requirements in Table 75–10 then label accordingly	PR40U:M	Yes [ ] N/A [ ]

75.10.4.13 PMD to MDI optical specifications for 10/1GBASE–PRX–U1

Item	Feature	Subclause	Value/Comment	Status	Support
PRXU1F1	10/1GBASE–PRX–U1 transmitter	75.5.1	Meets specifications in Table 75–9	PRX10U:M	Yes [ ] N/A [ ]
PRXU1F2	10/1GBASE–PRX–U1 receiver	75.5.2	Meets specifications in Table 75–10	PRX10U:M	Yes [ ] N/A [ ]
PRXU1F3	10/1GBASE–PRX–U1 receiver damage threshold	75.5.2	If the receiver does not meet the damage requirements in Table 75–10 then label accordingly	PRX10U:M	Yes [ ] N/A [ ]

75.10.4.14 PMD to MDI optical specifications for 10/1GBASE–PRX–U2

Item	Feature	Subclause	Value/Comment	Status	Support
PRXU2F1	10/1GBASE–PRX–U2 transmitter	75.5.1	Meets specifications in Table 75–9	PRX20U:M	Yes [ ] N/A [ ]
PRXU2F2	10/1GBASE–PRX–U2 receiver	75.5.2	Meets specifications in Table 75–10	PRX20U:M	Yes [ ] N/A [ ]
PRXU2F3	10/1GBASE–PRX–U2 receiver damage threshold	75.5.2	If the receiver does not meet the damage requirements in Table 75–10 then label accordingly	PRX20U:M	Yes [ ] N/A [ ]

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75.10.4.15 PMD to MDI optical specifications for 10/1GBASE–PRX–U3

Item	Feature	Subclause	Value/Comment	Status	Support
PRXU3F1	10/1GBASE–PRX–U3 transmitter	75.5.1	Meets specifications in Table 75–9	PRX30U:M	Yes [ ] N/A [ ]
PRXU3F2	10/1GBASE–PRX–U3 receiver	75.5.2	Meets specifications in Table 75–10	PRX30U:M	Yes [ ] N/A [ ]
PRXU3F3	10/1GBASE–PRX–U3 receiver damage threshold	75.5.2	If the receiver does not meet the damage requirements in Table 75–10 then label accordingly	PRX30U:M	Yes [ ] N/A [ ]

75.10.4.16 PMD to MDI optical specifications for 10/1GBASE–PRX–U4

Item	Feature	Subclause	Value/Comment	Status	Support
PRXU4F1	10/1GBASE–PRX–U4 transmitter	75.5.1	Meets specifications in Table 75–9	PRX40U:M	Yes [ ] N/A [ ]
PRXU4F2	10/1GBASE–PRX–U4 receiver	75.5.2	Meets specifications in Table 75–10	PRX40U:M	Yes [ ] N/A [ ]
PRXU4F3	10/1GBASE–PRX–U4 receiver damage threshold	75.5.2	If the receiver does not meet the damage requirements in Table 75–10 then label accordingly	PRX40U:M	Yes [ ] N/A [ ]

75.10.4.17 Definitions of optical parameters and measurement methods

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	Measurement cable	75.7.1	2 m to 5 m in length	M	Yes [ ]
OM2	Wavelength and spectral width	75.7.4	Per TIA–455–127–A under modulated conditions.	M	Yes [ ]
OM3	Average optical power	75.7.5	Per TIA/EIA–455–95.	M	Yes [ ]
OM4	Extinction ratio	75.7.6	Per ANSI/TIA/EIA–526–4A with minimal back reflections and fourth-order Bessel–Thomson receiver.	M	Yes [ ]
OM5	Optical modulation amplitude (OMA) test procedure	75.7.7	As described in 58.7.5 for 1 Gb/s PHY and in 52.9.5 for 10 Gb/s PHY.	M	Yes [ ]
OM6	RIN_xOMA	75.7.8	As described in 58.7.7for 1 Gb/s PHY and in 52.9.6 for 10 Gb/s PHY	M	Yes [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
OM7	Transmit optical waveform (transmit eye)	75.7.9	Per ANSI/TIA/EIA–526–4A with test pattern and fourth-order Bessel–Thomson receiver.	M	Yes [ ]
OM8	Transmitter and dispersion penalty	75.7.10	As described in 58.7.7 for 1 Gb/s PHY and in 52.9.6 for 10 Gb/s PHY.	M	Yes [ ]
OM9	Receive sensitivity	75.7.11	As described in 58.7.10 for 1 Gb/s PHY and in 52.9.8 for 10 Gb/s PHY. Values defined in Table 75–6, Table 75–7, or Table 75–10 as appropriate.	M	Yes [ ]
*OM10	Stressed receiver conformance test	75.7.12	As described in 58.7.11 for 1 Gb/s PHY and in 52.9.9 for 10 Gb/s PHY. Values defined in Table 75–6, Table 75–7, or Table 75–10 as appropriate.	O	Yes[ ] N/A[ ]
OM11	Jitter measurements	75.7.13	As described in 58.7.12 for 1 Gb/s PHY and in 52.8.1 for 10 Gb/s PHY.	M	Yes [ ]
OM12	Laser On/Off timing measurement	75.7.14	As described in 60.9.13.1 for 1 Gb/s PHY and in 60.9.13.1 with modifications defined in 75.7.14 for 10 Gb/s PHY.	M	Yes [ ]
OM13	Receiver settling timing measurement	75.7.15	As described in 60.9.13.2 for 1 Gb/s and 10 Gb/s PHY.	O	Yes [ ] No [ ]

75.10.4.18 Characteristics of the fiber optic cabling and MDI

Item	Feature	Subclause	Value/Comment	Status	Support
FO1	Fiber optic cabling	75.9	Specified in Table 75–14	INS:M	Yes [ ] N/A[ ]
F02	End –to–end channel loss	75.9	Meeting the requirements of Table 75B–1 and Table 75B–2	INS:M	Yes [ ] N/A[ ]
FO3	Maximum discrete reflectance – single-mode fiber	75.9.3	Less than –26 dB	INS:M	Yes [ ] N/A [ ]
FO4	MDI requirements	75.9.4	Meet the interface performance specifications of IEC 61753–1, if remateable	INS:O	Yes [ ] No [ ] N/A [ ]

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75.10.4.19 Environmental specifications

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	General safety	75.8.1	Conforms to IEC–60950–1	M	Yes [ ]
ES2	Laser safety —IEC Hazard Level 1	75.8.1	Conform to Hazard Level 1 laser requirements defined in IEC 60825–1 and IEC 60825–2	M	Yes [ ]
ES3	Documentation	75.8.1	Explicitly defines requirements and usage restrictions to meet safety certifications	M	Yes [ ]
ES4	Operating temperature range labeling	75.8.5	If required	M	Yes [ ] N/A[ ]

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76. Reconciliation Sublayer, Physical Coding Sublayer, and Physical Media Attachment for 10G-EPON

76.1 Overview

This clause describes the Reconciliation Sublayer (RS), Physical Coding Sublayer (PCS) with FEC, and Physical Medium Attachment (PMA) used with 10GBASE-PR and 10/1GBASE-PRX point-to-multipoint (P2MP) networks. These are passive optical multipoint networks (PONs) that connect multiple DTEs using a single shared fiber. The architecture is asymmetric, based on a tree and branch topology utilizing passive optical splitters. This type of network requires that the Multipoint MAC Control sublayer exists above the MACs, as described in Clause 77.

76.1.1 Conventions

The notation used in the state diagrams in this clause follows the conventions in 21.5. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails. The notation ++ after a counter indicates it is to be incremented by 1. The notation −− after a counter indicates it is to be decremented by 1. The notation −= after a counter indicates that the counter value is to be decremented by the following value. The notation += after a counter indicates that the counter value is to be incremented by the following value. Code examples given in this clause adhere to the style of the "C" programming language.

76.1.2 Delay constraints

The MPCP relies on strict timing based on the distribution of timestamps. The actual delay is implementation dependent but an implementation shall maintain a combined delay variation through RS, PCS, and PMA sublayers of no more than 1 time_quantum (see 77.2.2.1) so as not to interfere with the MPCP timing.

76.2 Reconciliation Sublayer (RS) for 10G-EPON

76.2.1 Overview

This subclause extends Clause 46 to enable multiple MACs to interface with a single Physical Layer, and to enable data links with one data rate (e.g., 10 Gb/s) in one direction but another (e.g., 1 Gb/s) in the opposite direction. The number of MACs supported is limited only by the implementation. It is acceptable for only one MAC to be connected to this Reconciliation Sublayer. Figure 76–1 and Figure 76–2 show the relationship between this RS and the ISO/IEC OSI reference model. The mapping of GMII/XGMII signals to PLS service primitives is described in 35.2.1 for GMII and 46.1.7 for XGMII with exceptions noted herein.

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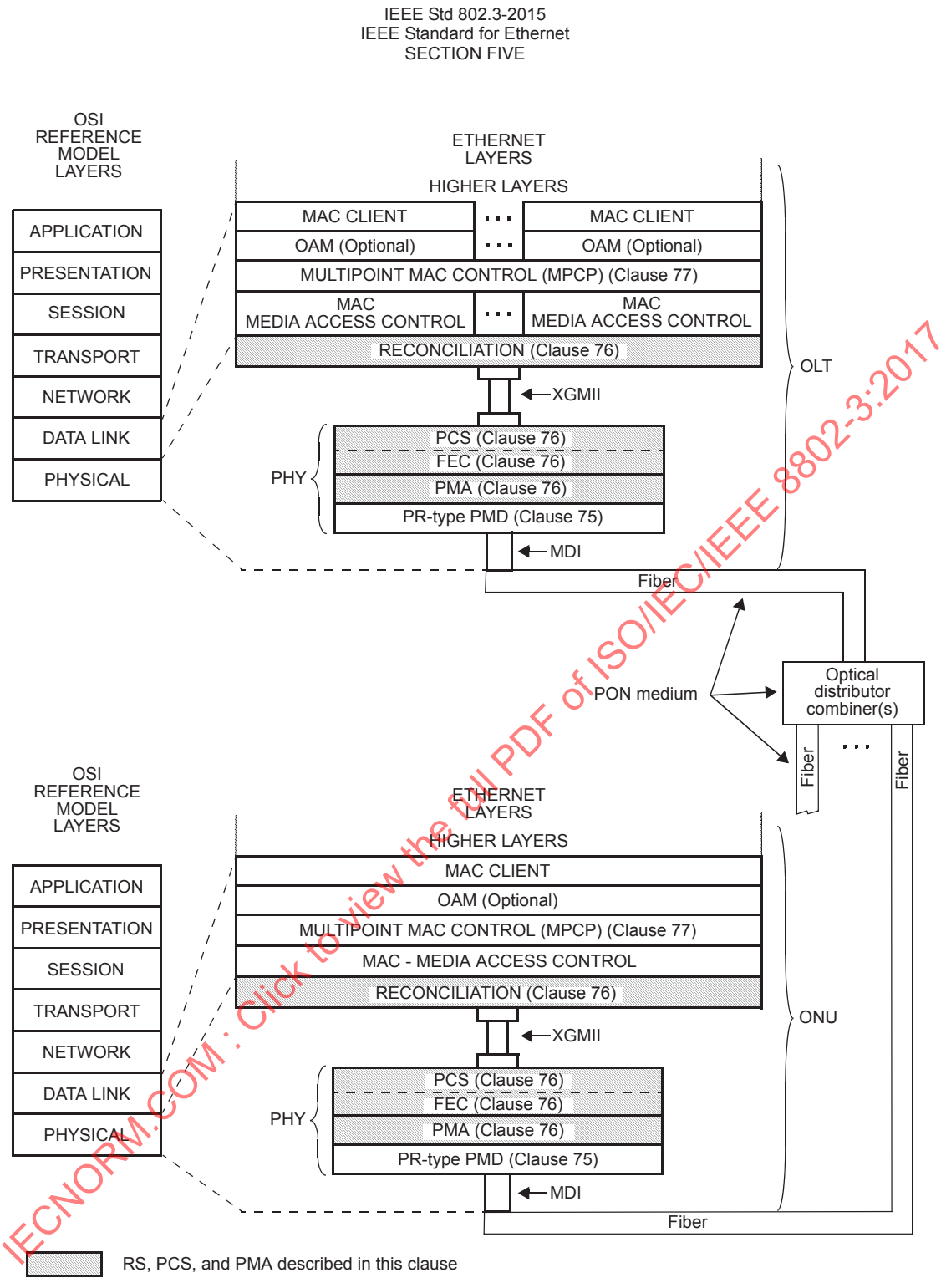

Figure 76–1—Relationship of 10/10G-EPON P2MP RS, PCS, and PMA to the ISO/IEC OSI reference model and the IEEE 802.3 Ethernet model

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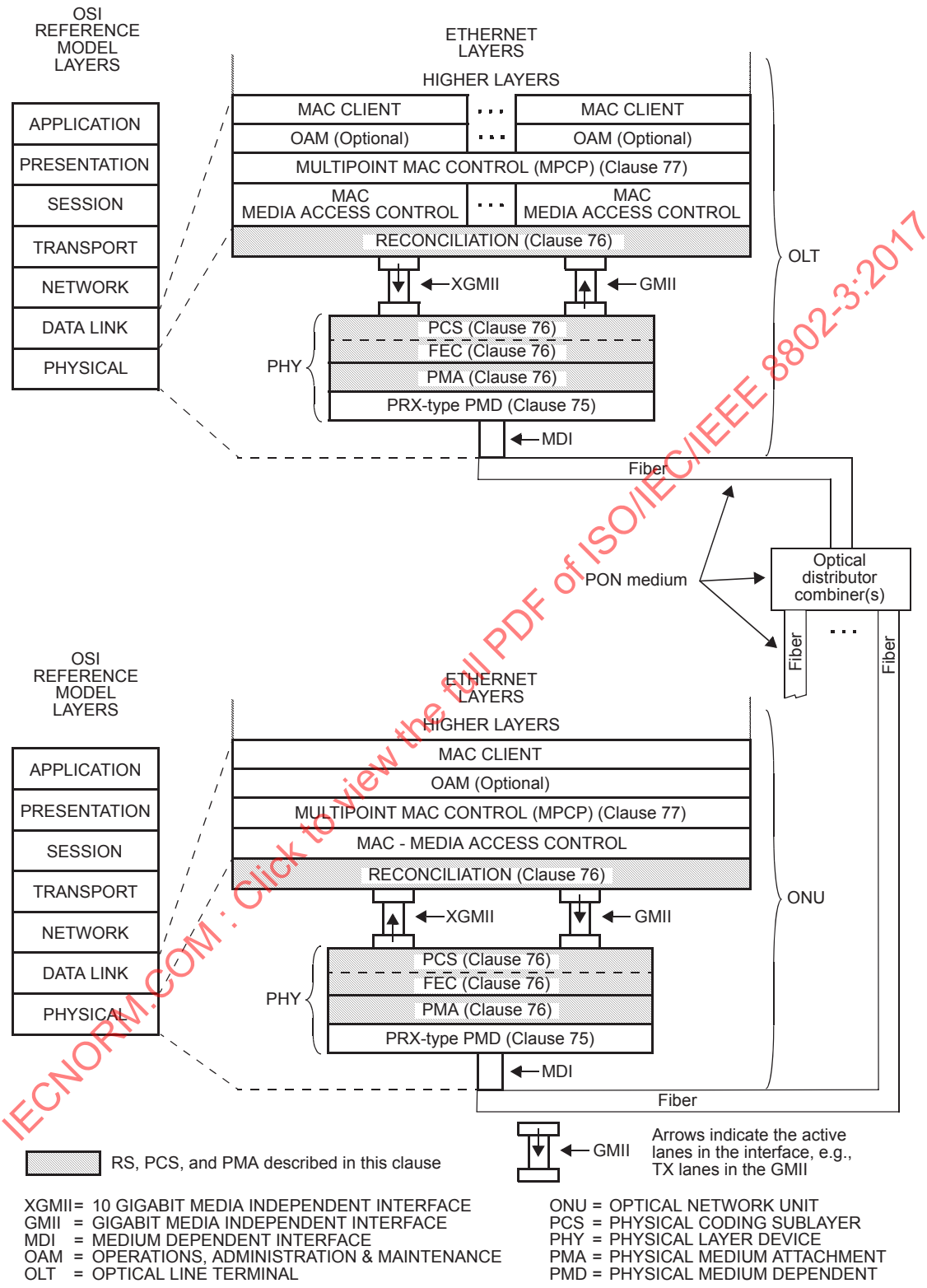

XGMII= 10 GIGABIT MEDIA INDEPENDENT INTERFACE
GMII = GIGABIT MEDIA INDEPENDENT INTERFACE
MDI = MEDIUM DEPENDENT INTERFACE
OAM = OPERATIONS, ADMINISTRATION & MAINTENANCE
OLT = OPTICAL LINE TERMINAL
ONU = OPTICAL NETWORK UNIT
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

Figure 76–2—Relationship of 10/1G-EPON P2MP RS, PCS, and PMA to the ISO/IEC OSI reference model and the IEEE 802.3 Ethernet model

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76.2.2 Dual-speed Media Independent Interface

In 1G-EPON architectures, the GMII is the interface used to transfer data between the RS and the PCS. For 10/10G-EPON architectures, the XGMII is the interface used to transfer data between the RS and the PCS. When using a 10/1G-EPON architecture, a combination of both GMII and XGMII is needed in order to support transmission and reception at different speeds. Through the parallel use of the GMII and XGMII, the following modes are supported:

— Symmetric-rate 10 Gb/s operation for transmit and receive data paths, utilizing all of the functionality of the XGMII defined in Clause 46.
— Symmetric-rate 1 Gb/s operation for transmit and receive data paths, utilizing all of the functionality of the GMII defined in Clause 35.
— Asymmetric-rate operation for transmit and receive data paths at the OLT, utilizing transmit path functionality of the XGMII defined in Clause 46 and receive path functionality of the GMII defined in Clause 35.
— Asymmetric-rate operation for transmit and receive data paths at the ONU, utilizing transmit path functionality of the GMII defined in Clause 35 and receive path functionality of the XGMII defined in Clause 46.
— Coexistence of various ONU types by utilizing different data paths within the OLT.

76.2.2.1 10/10G-EPON

Figure 76–3(a) depicts the data paths used in 10/10G-EPON.

76.2.2.2 10/1G-EPON

At the OLT, the transmit path uses XGMII signals TXD<31:0>, TXC<3:0> and TX_CLK, while the receive path uses GMII signals RXD<7:0>, RX_ER, RX_CLK, and RX_DV. At the ONU, the transmit path uses GMII signals TXD<7:0>, TX_EN, TX_ER, and GTX_CLK, while the receive path uses XGMII signals RXD<31:0>, RXC<3:0> and RX_CLK.

Figure 76–3(b) depicts the data paths used in 10/1G-EPON.

76.2.2.3 Dual-rate mode

To support coexistence of 10/10G-EPON, 10/1G-EPON, and 1G-EPON ONUs on the same outside plant, the OLT may optionally support dual-rate mode. Dual-rate mode supports transmission and reception at both 10 Gb/s and 1 Gb/s. When operating in a dual-rate mode, a combination of XGMII and GMII data paths are used for transmission and reception. Figure 76–4 depicts the data paths used in an OLT operating in a dual-rate mode.

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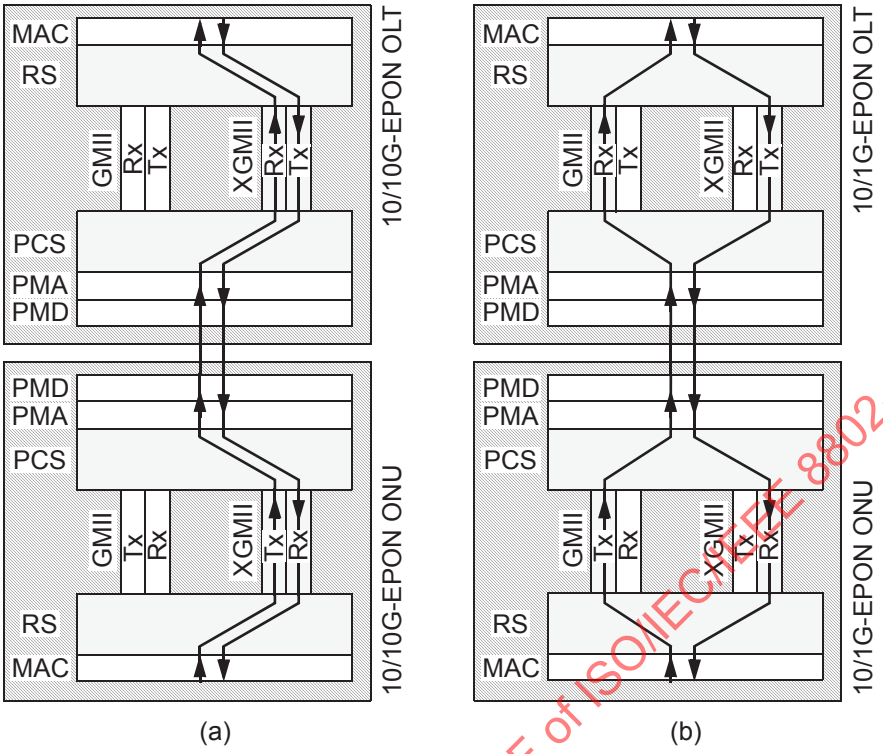

Figure 76–3—10/10G-EPON (a) and 10/1G-EPON (b) operation of OLT and ONU

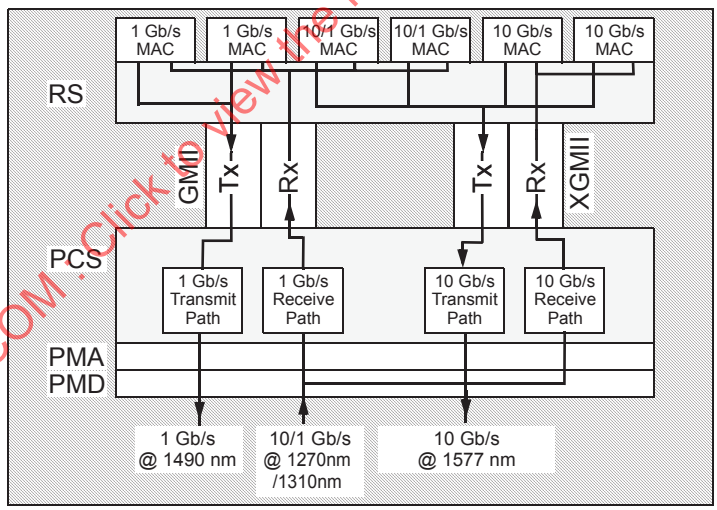

Figure 76–4—PCS and Reconciliation Sublayer for dual rate mode at OLT

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76.2.2.4 Mapping of XGMII and GMII primitives

The mapping of XGMII/GMII signals to the PLS_DATA.request and PLS_DATA.indication primitives is described in 76.2.6. Additional details are provided in Table 76–1, which shows the mapping of PLS_DATA.request primitives to transmit interface signals for different types of OLTs and ONUs. Table 76–2 shows the mapping of PLS_DATA.indication primitives to receive interface signals for different types of OLTs and ONUs.

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76.2.3 Summary of major concepts

A successful registration process, described in 77.3.3, results in the assignment of values to the MODE and LLID variables associated with a MAC. This may be one of many MACs in an OLT or a single MAC in an ONU. The MODE and LLID variables are used to identify a packet transmitted from that MAC and how received packets are directed to that MAC. The RS in the OLT shall operate in unidirectional mode as defined in 66.4.

As described in 77.1.2, multiple MACs within an OLT are bound to a single XGMII in the case of a 10/10G-EPON OLT, or to an XGMII transmit path and a GMII receive path in the case of a 10/1G-EPON OLT. Only one PLS_DATA.request primitive is active at any time.

At the ONU, the MAC is either bound to an XGMII in the case of a 10/10G-EPON ONU, or to an XGMII receive path and a GMII transmit path in case the of an 10/1G-EPON ONU.

In the transmit direction, the RS maps the active PLS_DATA.request to either the GMII signals (TXD<7:0>, TX_EN, TX_ER, and GTX_CLK) or the XGMII signals (TXD<31:0>, TXC<3:0>, and TX_CLK) according to the MAC instance generating the request. The RS replaces octets of preamble with the values of the transmitting MAC's MODE and LLID variables.

In the receive direction, the MODE and LLID values embedded within the preamble identify the MAC to which this packet should be directed. The RS establishes a temporal mapping of either the GMII signals (RXD<7:0>, RX_ER, RX_CLK, and RX_DV) or the XGMII signals (RXD<31:0>, RXC<3:0> and RX_CLK) to the correct PLS_DATA.indication and PLS_DATA_VALID.indication primitives.

76.2.3.1 Application

This subclause applies to the interface between the MAC and PHY in an OLT or an ONU. The physical implementation of the interface is primarily intended to be chip-to-chip, but may also be used as a logical interface between ASIC logic modules within an integrated circuit. These interfaces are used to provide media independence, so that an identical media access controller may be used with all 10GBASE-PR and 10/1GBASE-PRX PHY types.

76.2.4 GMII structure

See Clause 35.

76.2.5 XGMII structure

The XGMII structure is discussed in 46.1.6, and Figure 46–2 depicts a schematic view of the RS inputs and outputs.

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76.2.6 Mapping of XGMII and GMII signals to PLS service primitives

Except as noted in Table 76–1 and Table 76–2, the mapping of the signals provided at the XGMII to the PLS service primitives is defined in 46.1.7.

Table 76–1—Mapping of PLS_DATA.request primitive

MAC location	MAC operating speed	Transmit interface	Signals
OLT	1G-EPON (Tx: 1 Gb/s)	GMII	TXD<7:0>, TX_EN, TX_ER, GTX_CLK
OLT	10/10G-EPON (Tx: 10 Gb/s)	XGMII	TXD<31:0>, TXC<3:0>, TX_CLK
OLT	10/1G-EPON (Tx: 10 Gb/s)	XGMII	TXD<31:0>, TXC<3:0>, TX_CLK
ONU	1G-EPON (Tx: 1 Gb/s)	GMII	TXD<7:0>, TX_EN, TX_ER, GTX_CLK
ONU	10/10G-EPON (Tx: 10 Gb/s)	XGMII	TXD<31:0>, TXC<3:0>, TX_CLK
ONU	10/1G-EPON (Tx: 1 Gb/s)	GMII	TXD<7:0>, TX_EN, TX_ER, GTX_CLK

Table 76–2—Mapping of PLS_DATA.indication primitive

MAC location	MAC operating speed	Receive interface	Signals
OLT	1G-EPON (Rx: 1 Gb/s)	GMII	RXD<7:0>, RX_ER, RX_DV, RX_CLK
OLT	10/10G-EPON (Rx: 10 Gb/s)	XGMII	RXD<31:0>, RXC<3:0>, RX_CLK
OLT	10/1G-EPON (Rx: 1 Gb/s)	GMII	RXD<7:0>,RX_ER,RX_DV,RX_CLK
ONU	1G-EPON (Rx: 1 Gb/s)	GMII	RXD<7:0>, RX_ER, RX_DV, RX_CLK
ONU	10/10G-EPON (Rx: 10 Gb/s)	XGMII	RXD<31:0>, RXC<3:0>, RX_CLK
ONU	10/1G-EPON (Rx: 10 Gb/s)	XGMII	RXD<31:0>, RXC<3:0>, RX_CLK

76.2.6.1 Functional specifications for multiple MACs

76.2.6.1.1 Variables

The variables of 65.1.3.1 are inherited except as shown below.

logical_link_id
: Value: 15 bits
This variable shall be set to the broadcast value of 0x7FFE for the unregistered ONU MAC.
Enabled OLT MACs may use any value for this variable. If the optional multicast LLID feature is supported, the OLT may use a multicast_link_id along with the mode bit set to 0.
Registered ONU MACs may use any value other than the reserved values listed in Table 76–4 or a multicast_link_id for this variable.

76.2.6.1.2 RS Transmit function

The transmit function is described in 65.1.3.2 except as noted below in Table 76–3, which shows the replacement mapping for 10G-EPON. The XGMII transmit function is described in 46.3.1.

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Table 76–3—Preamble/SFD replacement mapping

Column	Lane	Field	Preamble/SFD	Modified preamble/SFD
0	0	—	0x55	Same
	1	—	0x55	Same
	2	SLD	0x55	0xd5
	3	—	0x55	Same
1	0	—	0x55	Same
	1	LLID[15:8]	0x55	<mode, logical_link_id[14:8]>[a]
	2	LLID[7:0]	0x55	<logical_link_id[7:0]>[b]
	3	CRC8	0xd5	The 8 bit CRC calculated over column 0 lane 2 through column 1 lane 2

[a]mode maps to TXD[15], logical_link_id[14] maps to TXD[14], logical_link_id[8] maps to TXD[8].
[b]logical_link_id[7] maps to TXD[23], logical_link_id[0] maps to TXD[16].

76.2.6.1.3 RS Receive function

The receive function is described in 65.1.3.3 except as noted below.

Table 65–2 is not applicable to 10G-EPON.

76.2.6.1.3.1 SLD

The 10 Gb/s RS transmit function maintains an alignment for its start control character to lane 0. The SLD is transmitted as the third octet and therefore is aligned to lane 2 in the same column containing the start control character. This is the only possibility considered when parsing the incoming octet stream for the SLD. If the SLD field is not found then the packet shall be discarded. If the packet is transferred, the SLD shall be replaced with a normal preamble octet and the two octets preceding the SLD and the one octet following the SLD are passed without modification. See Table 76–3.

76.2.6.1.3.2 LLID

This subclause supersedes the stipulations of 65.1.3.3.2.

The third and fourth octets following the SLD contain the mode and logical_link_id values. OLTs and ONUs act upon these values in a different manner.

If the device is an OLT, then the following comparison is made:

a) The received mode bit is ignored.
b) If the received logical_link_id value matches 0x7FFF or 0x7FFE and an enabled MAC exists with a logical_link_id variable with the same value, then the comparison is considered a match to that MAC.
c) If the received logical_link_id has a value other than 0x7FFF or 0x7FFE and an enabled MAC exists with a mode variable with a value of 0 and a logical_link_id variable matching the received logical_link_id value, then the comparison is considered a match to that MAC.

If the device is an ONU then the following comparison is made:

d) If the received mode bit is equal to 0 and the received logical_link_id value matches the logical_link_id variable, then the comparison is considered a match.

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e) If the received mode bit is equal to 1 and the received logical_link_id value does not match the logical_link_id variable, or the received logical_link_id matches 0x7FFE, then the comparison is considered a match.
f) If the received logical_link_id value matches one of the assigned multicast LLIDs, then the comparison is considered a match.

If no match is found, then the packet shall be discarded within the RS. If a match is found, then the packet is intended to be transferred. If the packet is transferred, then both octets of the LLID field shall be replaced with normal preamble octets.

If the packet is transferred, the one octet preceding the LLID is passed without modification. A number of LLIDs have been reserved (see Figure 76–4) for various purposes including downstream broadcast, discovery messages, and upstream registration request messages. An additional block of LLIDs has been set aside for future use and definition. A registered ONU shall not transmit frames with one of these reserved LLIDs.

Table 76–4—Reserved LLID values

LLID value	Used in RS	Purpose
0x7FFF	1000BASE-PX	Downstream: 1 Gb/s SCB Upstream: ONU registration at 1 Gb/s
0x7FFE	10/1GBASE-PRX	Downstream: 10 Gb/s SCB Upstream: ONU registration at 1 Gb/s
	10GBASE-PR	Downstream: 10 Gb/s SCB Upstream: ONU registration at 10 Gb/s
0x7FFD–0x7F00	—	Reserved for future use

76.2.6.1.3.3 CRC-8

The CRC-8 field is as described in 65.1.3.3.3.

76.3 Physical Coding Sublayer (PCS) for 10G-EPON

76.3.1 Overview

This subclause defines the physical coding sublayers 10GBASE-PR and 10/1GBASE-PRX, supporting burst mode operation over the point-to-multipoint physical medium. The 10GBASE-PR PCS is specified to support 10/10G EPON, where both the receive and transmit paths operate at 10 Gb/s rate. The 10/1GBASE-PRX PCS supports 10/1G-EPON, in which OLT transmit path and ONU receive path operate at 10 Gb/s, while the ONU transmit path and the OLT receive path operate at 1 Gb/s rate.

This subclause also specifies a forward error correction (FEC) mechanism to increase the optical link budget or the fiber distance. Figure 76–1 and Figure 76–2 show the relationship between the PCS sublayer and the ISO/IEC OSI reference model.

76.3.1.1 10/1GBASE-PRX PCS

Conceptually, the 10/1GBASE-PRX PCS represents a combination of transmit and receive functions defined in the 10GBASE-PR PCS (specified in this clause) and the 1000BASE-PX PCS (specified in Clause 65). At the OLT, the 10/1GBASE-PRX consists of the 10GBASE-PR transmit function and the 1000BASE-PX

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receive function (see Figure 76–5). Reciprocally, at the ONU, the 10/1GBASE-PRX PCS consists of the 10GBASE-PR receive function and the 1000BASE-PX transmit function (see Figure 76–6).

Deriving a specification for the 10/1GBASE-PRX PCS from the 10GBASE-PR PCS and the 1000BASE-PX PCS specifications as described previously is a straightforward process; therefore, no further explicit specification for the 10/1GBASE-PRX PCS is necessary.

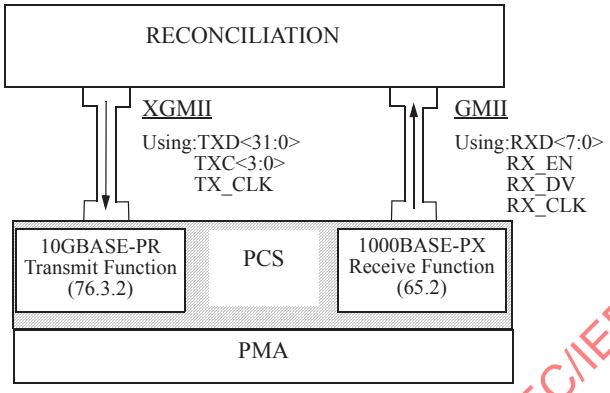

Figure 76–5—Conceptual diagram of 10/1GBASE-PRX PCS, OLT Side

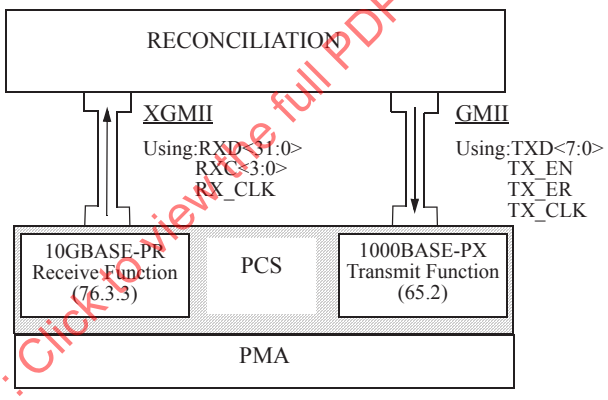

Figure 76–6—Conceptual diagram of 10/1GBASE-PRX PCS, ONU Side

76.3.1.2 10GBASE-PR PCS

The 10GBASE-PR PCS extends the physical coding sublayer described in Clause 49 to support burst mode operation over the point-to-multipoint physical medium. Figure 76–7 illustrates the functional block diagram of the downstream path and Figure 76–8 shows the functional block diagram of the upstream path.

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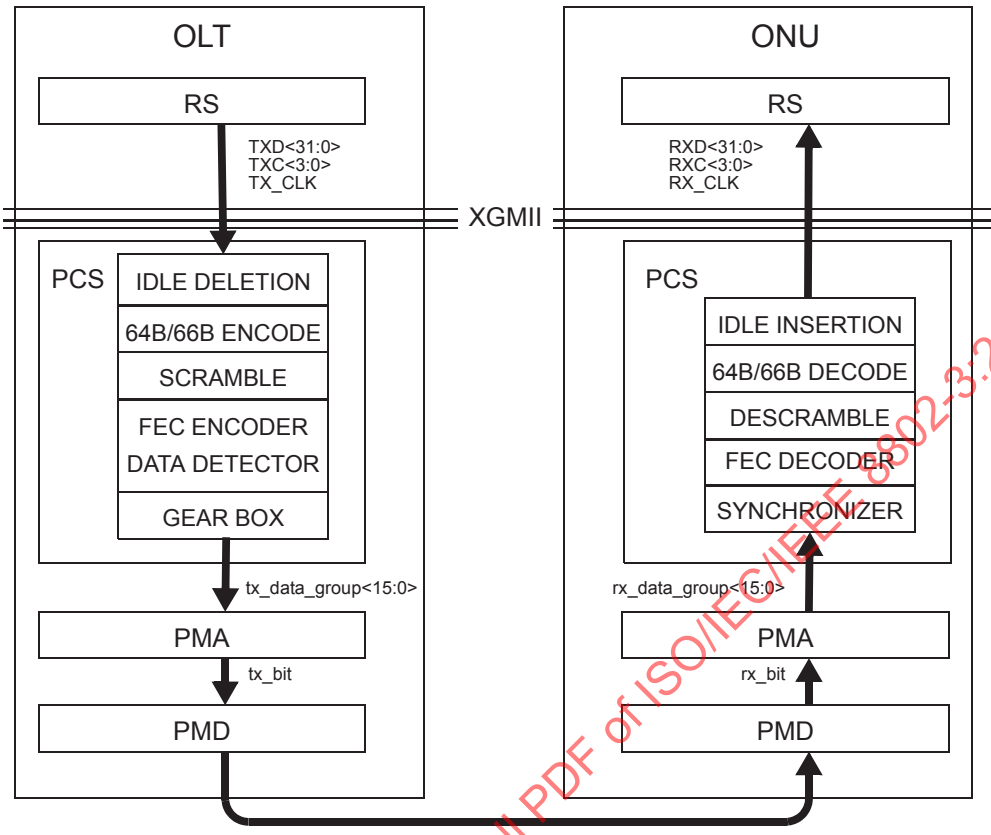

Figure 76–7—PCS functional block diagram, downstream path

76.3.2 PCS transmit function

This subclause defines the transmit direction of the physical coding sublayers for 10GBASE-PR and 10/1GBASE-PRX. In the OLT, the PCS transmit function operates at a 10 Gb/s rate in a continuous mode. In the ONU, the PCS transmit function may operate at a 10 Gb/s rate, as specified herein (10GBASE-PR), or at a 1 Gb/s rate, as specified in Clause 65 (10/1GBASE-PRX). For both 10GBASE-PR and 10/1GBASE-PRX, the ONU PCS always operates in a burst mode in the transmit direction. When operating at the 10 Gb/s rate, the PCS includes a mandatory FEC encoder. Figure 76–7 illustrates the transmit direction of OLT PCS. Figure 76–8 illustrates the transmit direction of the ONU PCS.

76.3.2.1 Idle control character deletion

The Idle Deletion process is responsible for deleting excess Idle characters to allow the parity data to be inserted without increasing the PMD line rate. This process deletes four 72 bit vectors containing Idle characters per every thirty-one 72 bit vectors received from the XGMII. The MPCP function ensures that sufficient Idle characters occur so that the minimum IPG is always preserved between two adjacent packets.

The Idle Deletion process is depicted in Figure 76–9 for OLTs and in Figure 76–10 for ONUs.

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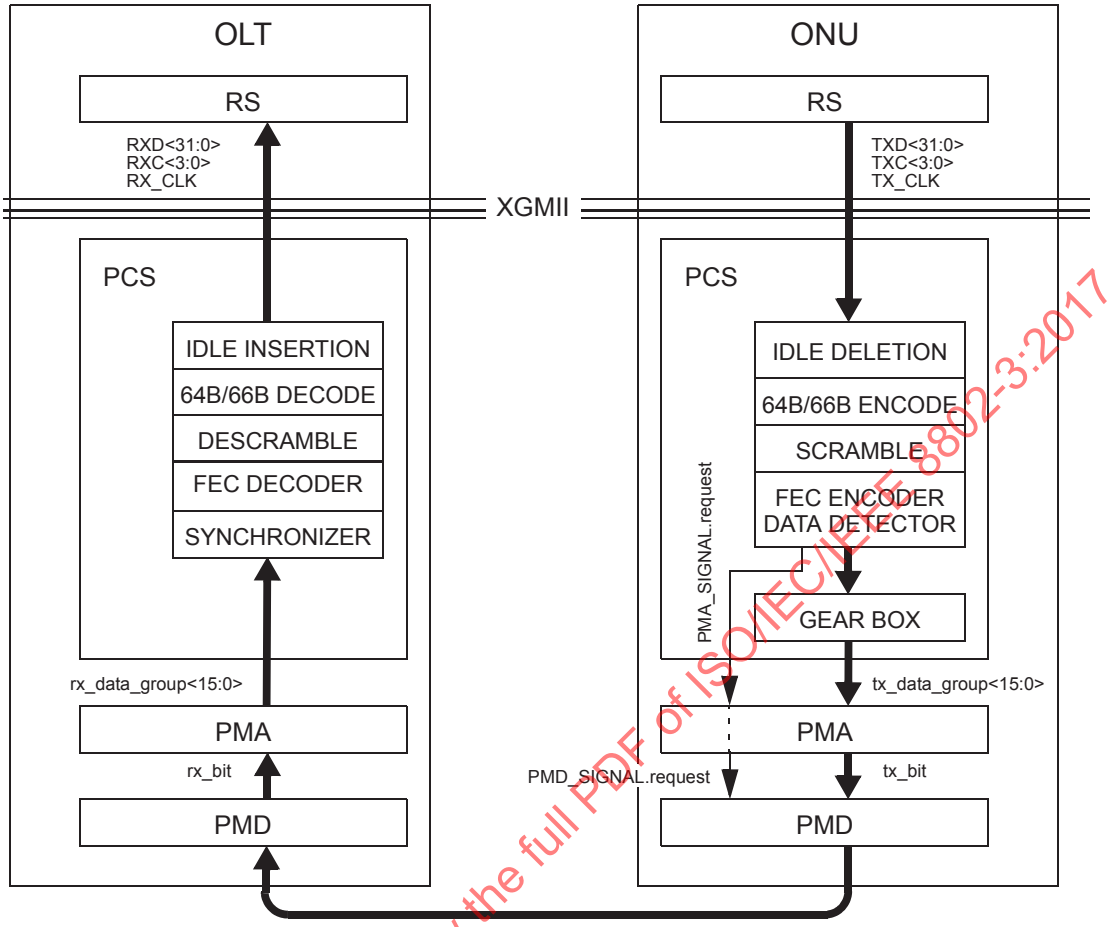

Figure 76–8—PCS functional block diagram, upstream path

76.3.2.1.1 Constants

FEC_DSize
: TYPE: 16 bit unsigned
The number of 72 bit vectors constituting a payload of a FEC codeword. To normalize pre-FEC data rate, the Idle Deletion function removes FEC_PSize vectors per every FEC_DSize vectors transferred to the 64B/66B encoder.
Value: 27

FEC_PSize
: TYPE: 16 bit unsigned
The number of 72 bit vectors constituting parity portion of a FEC codeword. To normalize pre-FEC data rate, the Idle Deletion function removes FEC_PSize vectors per every FEC_DSize vectors transferred to the 64B/66B encoder.
Value: 4

76.3.2.1.2 Variables

BEGIN
: TYPE: Boolean

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This variable is used when initiating operation of the state diagram. It is set to true following initialization and every reset.

DelayBound
TYPE: 16 bit unsigned
This value represents the delay sufficient to initiate the laser and to stabilize the receiver at the OLT (i.e., the maximum FIFO size expressed in 66 bit blocks). The value includes LaserOnTime (77.3.3.2), $T_{receiver_settling}$, T_{CDR}, Burst Delimiter, and the two 66 bit blocks containing Idles, that precede the first packet in the burst. This variable is used only by the ONU.

tx_raw<71:0>
This variable is defined in 49.2.13.2.2.

tx_raw_out<71:0>
72 bit vector sent from the output of the Idle Deletion function to the 64B/66B encoder. The vector contains two XGMII transfers mapped as shown for tx_raw<71:0>.

76.3.2.1.3 Functions

T_TYPE(tx_raw<71:0>)
This function is defined in 49.2.13.2.3.

76.3.2.1.4 Counters

DelCount
TYPE: 16 bit unsigned
Counts the number of 72 bit vectors that need to be deleted.

IdleCount
TYPE: 16 bit unsigned
Counts the number of 72 bit vectors containing Idle control characters or other control vectors.

VectorCount
TYPE: 16 bit unsigned
Counts the number of 72 bit vectors transmitted.

76.3.2.1.5 State diagrams

The OLT PCS shall perform the Idle Deletion process as shown in Figure 76–9. The ONU PCS shall perform the Idle Deletion process as shown in Figure 76–10. Should there be a discrepancy between a state diagrams and descriptive text, the state diagrams prevail.

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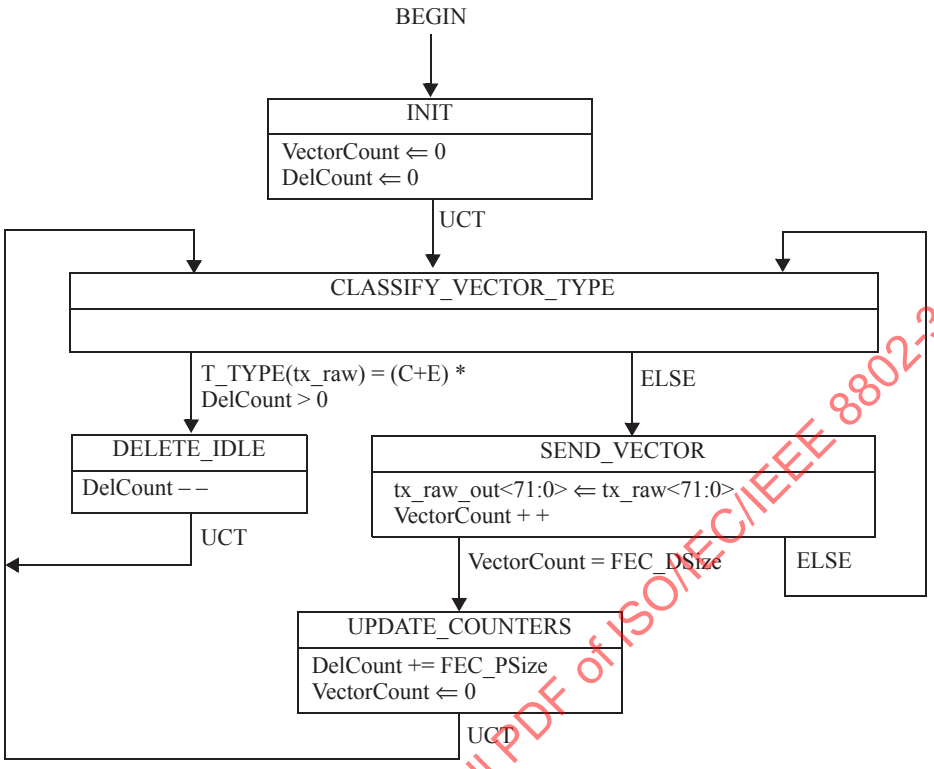

Figure 76–9—OLT Idle Deletion state diagram

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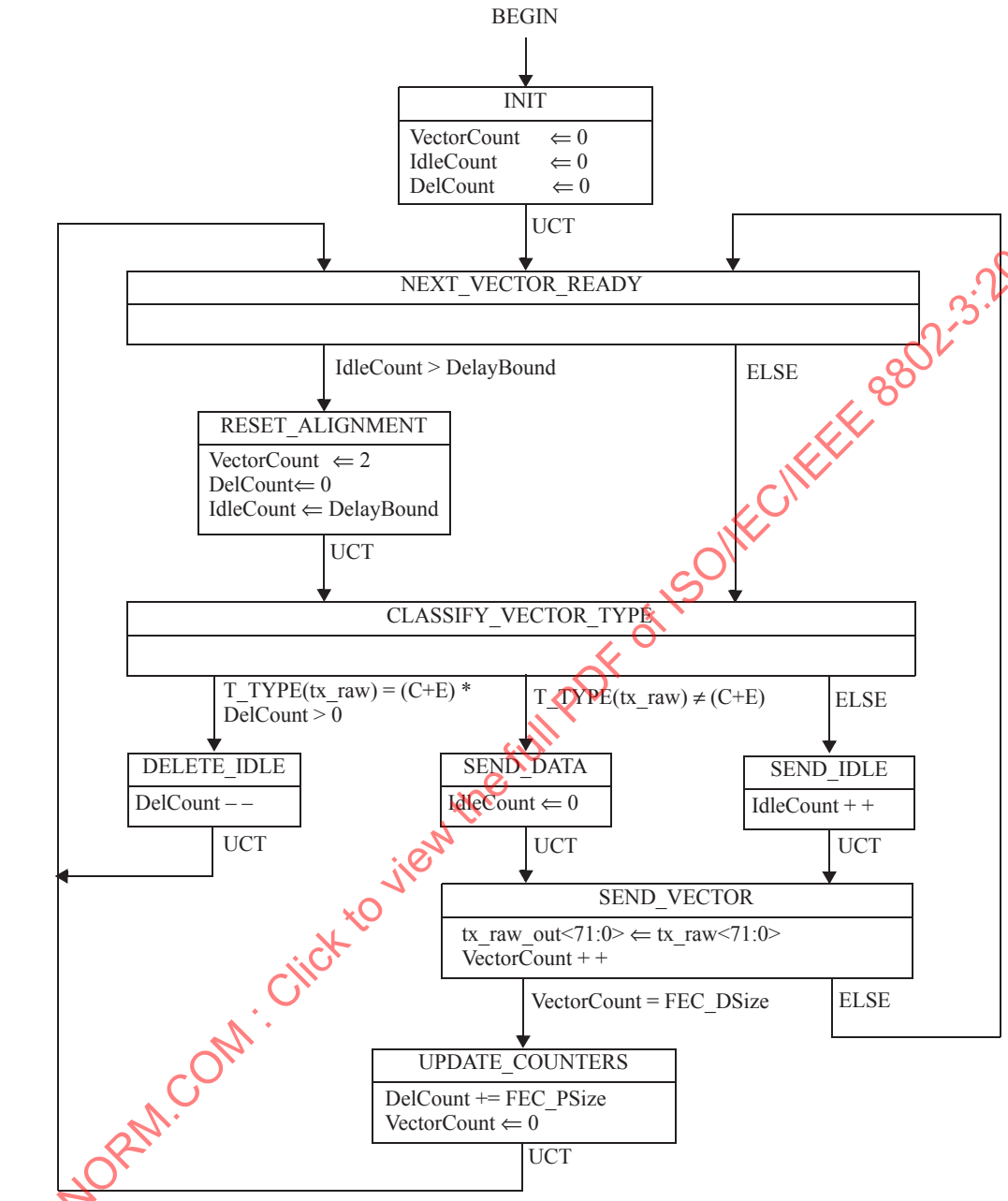

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Figure 76–10—ONU Idle Deletion state diagram

76.3.2.2 64B/66B Encode

See 49.2.4 64B/66B transmission code. The encoder shall perform the functions specified in the state diagram shown in Figure 49–16.

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76.3.2.3 Scrambler

See 49.2.6 Scrambler.

76.3.2.4 FEC encoding

The 10GBASE-PR-D, 10GBASE-PR-U, and 10/1GBASE-PRX-D PCS shall encode the transmitted data stream using Reed-Solomon code (255,223). Annex 76A gives an example of RS(255,223) FEC Encoding.

76.3.2.4.1 FEC Algorithm [RS(255,223)]

The FEC code used for 10GBASE-PR links is a linear cyclic block code—the Reed-Solomon code (255, 223) over the Galois Field of GF(2^8)—a code operating on 8 bit symbols. The code encodes 223 information symbols and adds 32 parity symbols. The code is systematic, meaning that the information symbols are not disturbed in any way in the encoder and the parity symbols are added separately to each block.

The code is based on the generating polynomial shown in Equation (76-1).

$$G(Z) = \prod_{i=0}^{31}(Z - \alpha^i) = A_{32}Z^{32} + A_{31}Z^{31} + \ldots + A_0Z^0 \qquad (76\text{–}1)$$

where

α is a root of the binary primitive polynomial $x^8 + x^4 + x^3 + x^2 + 1$ and is represented as 0x02
A is a series representing the resulting polynomial coefficients of $G(Z)$, (A_{32} is equal to 0x01)
Z corresponds to an 8 bit GF(2^8) symbol
x corresponds to a bit position in a GF(2^8) symbol

The parity calculation shall produce the same result as the shift register implementation shown in Figure 76–11. Before calculation begins, the shift register shall be initialized to zero. The contents of the shift register are transmitted without inversion.

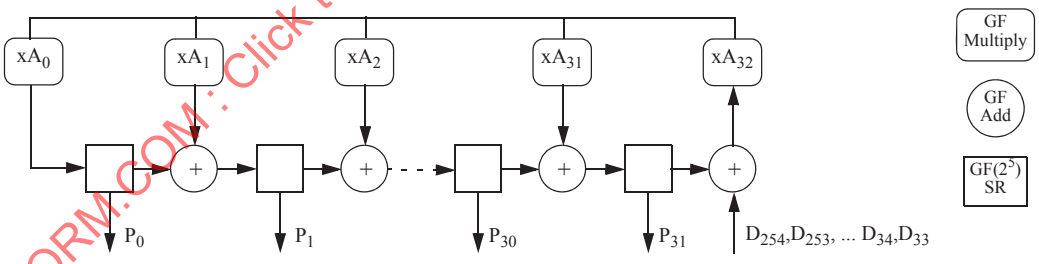

Figure 76–11—Circuit for generating FEC parity vector

A FEC parity vector is represented by Equation (76-2).

$$P(Z) = D(Z) \bmod G(Z) \qquad (76\text{–}2)$$

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where

$D(Z)$ is the data vector $D(Z) = D_{222}Z^{254} + D_{221}Z^{253} + \ldots + D_0Z^{32}$. D_{222} is the first data octet and D_0 is the last.

$P(Z)$ is the parity vector $P(Z) = P_{31}Z^{31} + P_{30}Z^{30} \ldots + P_0Z^0$. P_{31} is the first parity octet and P_0 is the last.

A data octet $(d_7, d_6, \ldots, d_1, d_0)$ is identified with the element: $d_7\alpha^7 + d_6\alpha^6 + \ldots + d_1\alpha^1 + d_0$ in GF(2^8), the finite field with 2^8 elements. The code has a correction capability of up to sixteen symbols.

NOTE—For the (255,223) Reed-Solomon code, the symbol size equals one octet. The d_0 is identified as the LSB and d_7 is identified as the MSB for all octets in accordance with the conventions of 3.1.1.

Bit ordering shall be as illustrated in Figure 76–12.

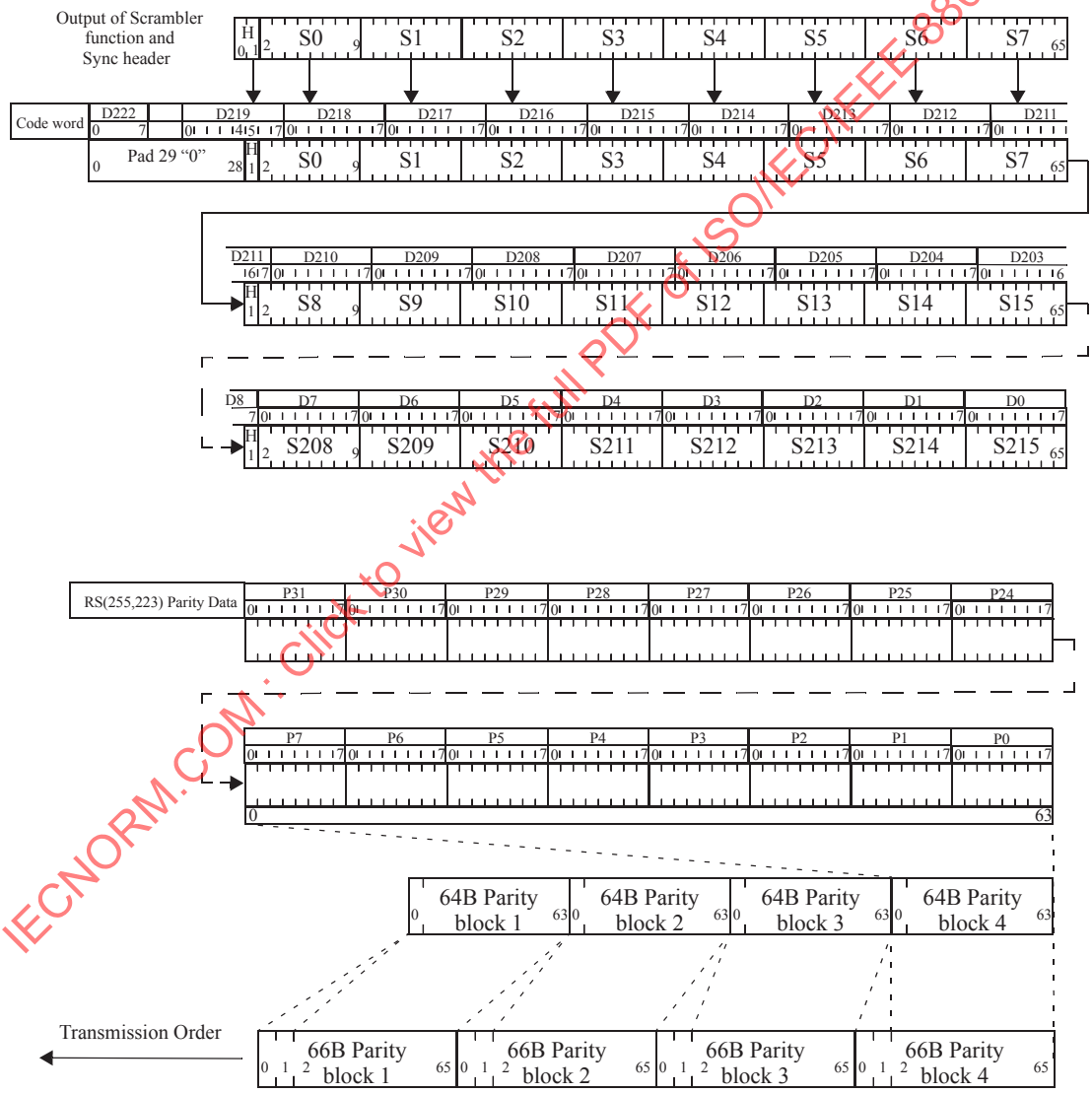

Figure 76–12—Bit ordering in FEC codeword generation

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76.3.2.4.2 Parity calculation

Padding of FEC codewords and appending FEC parity octets in the 10GBASE-PR and 10/1GBASE-PRX OLT PCS transmitter is illustrated in Figure 76–13. The 64B/66B encoder and scrambler produce 66 bit blocks. The FEC encoder accumulates 27 of these 66 bit blocks to form the basis of an FEC codeword, removing the redundant first bit (i.e., sync header bit <0>) of each block (the first bit is guaranteed to be the complement of the second bit).

The FEC encoder then prepends 29 padding bits (binary 0) to the 27 blocks (65 bits each) to form the 223-octet payload portion of an FEC codeword. This data is then FEC-encoded, resulting in the 32-octet parity portion of the FEC codeword. The 223-octet payload portion and 32-octet parity portion combine to form the 255-octet Reed-Solomon codeword. The padding is used to generate the FEC codeword but is not transmitted.

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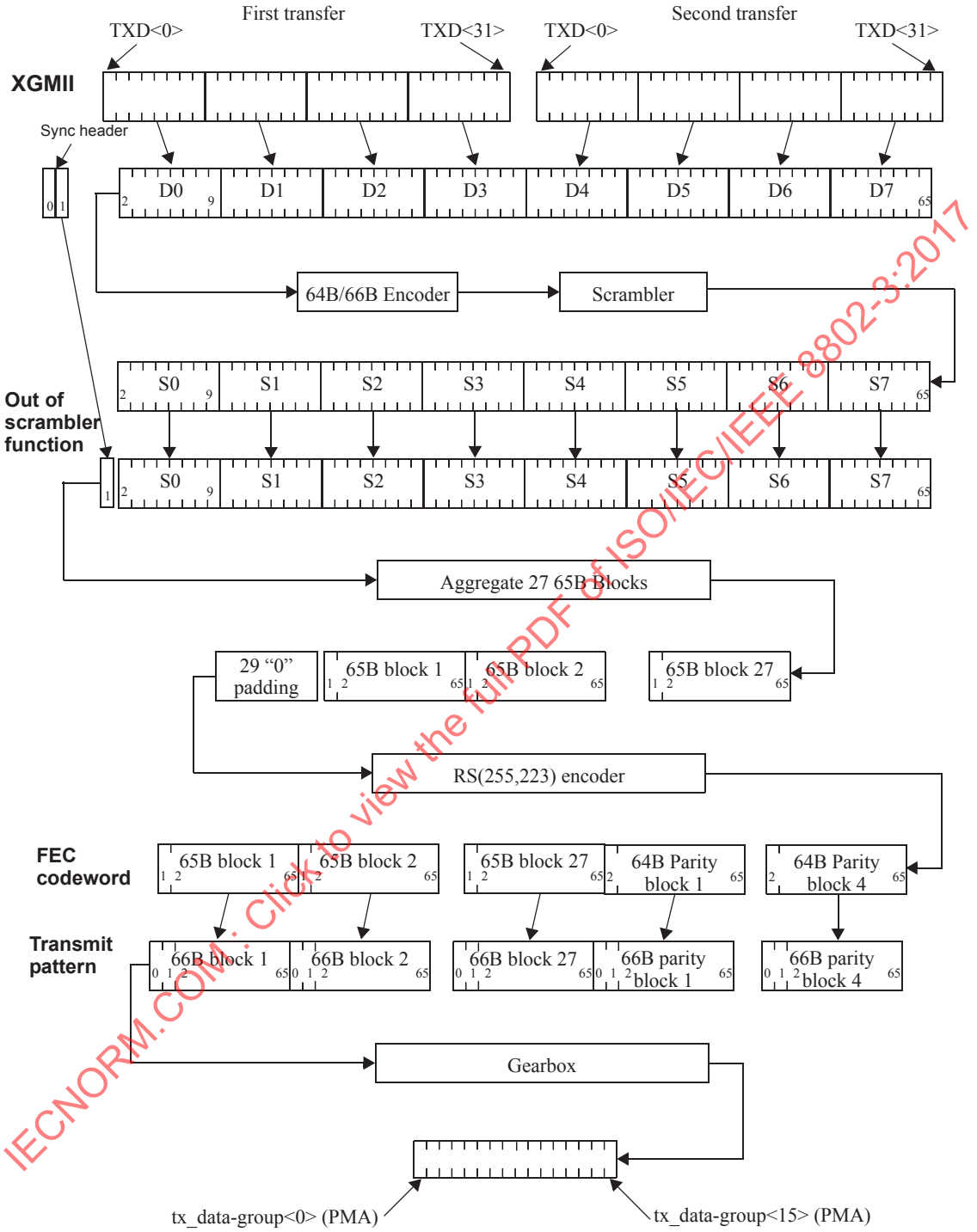

Figure 76–13—PCS Transmit bit ordering

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76.3.2.4.3 FEC Transmission Block Formatting

As shown in Figure 76–13, after the Reed-Solomon codeword has been computed, the FEC encoder constructs the transmittable FEC codeword with the original sequence of twenty-seven 66 bit blocks (including the redundant sync bit, but not including the 29 “0” padding bits). The FEC encoder prepends a 2 bit sync header to each group of 64 parity bits to construct a properly formed 66 bit codeword, according to the predefined sync header pattern for the four 64 bit parity blocks: 00 11 11 00. Finally the four 66 bit parity blocks are appended following the twenty-seven 66 bit data blocks and transmitted to the PMA.

76.3.2.5 Data Detector

The 10GBASE-PR-D, 10GBASE-PR-U, and 10/1GBASE-PRX-D PCS transmit path includes the Data Detector process. This process contains a delay line (FIFO_DD buffer) that stores the 66 bit blocks to allow insertion of the FEC parity data into the transmitted data stream. The length of the FIFO_DD buffer should be large enough to hold the amount of data equal to the maximum amount of parity data that may be inserted within the transmission time of one packet of a maximum length (i.e., at most forty 66 bit blocks of parity data).

76.3.2.5.1 Burst Mode operation (ONU only)

In addition to inserting the parity data into the data stream, the Data Detector process in the 10GBASE-PR-U PCS generates the PMA_SIGNAL.request(tx_enable) primitive to turn the laser on and off at the correct times.

Upon initialization, the laser is turned off. When the first 66 bit block containing data arrives at the buffer, the Data Detector sets the PMA_SIGNAL.request(tx_enable) primitive to the value ON, instructing the PMD sublayer to start the process of turning the laser on.

When the buffer becomes empty (i.e., contains only 66 bit blocks with Idle characters), the Data Detector sends the End of Burst Delimiter and after that sets the PMA_SIGNAL.request(tx_enable) primitive to the value OFF, instructing the PMD sublayer to start the process of turning the laser off. Between packets, Idle blocks arrive at the buffer. If the number of these Idle blocks is insufficient to fill the buffer then the laser is not turned off.

The length of the FIFO_DD buffer at the ONU shall be chosen such that the delay introduced by the buffer together with any delay introduced by the PMA sublayer is long enough to turn the laser on and to allow a laser synchronization pattern, Burst Delimiter pattern, and a predefined number of Idle blocks to be transmitted. The laser synchronization pattern allows the receiving optical detector to adjust its gain ($T_{receiver_settling}$) and synchronize its receive clock (T_{CDR}). The Burst Delimiter allows the receiver to easily identify the beginning of FEC protected portion of the ONU transmission. The Idle control characters are used to synchronize the descrambler and establish start-of-packet delineation.

Figure 76–14 illustrates the details of the ONU burst transmission. In particular, this figure shows the details of the synchronization time and the FEC protected portions of the burst transmission.

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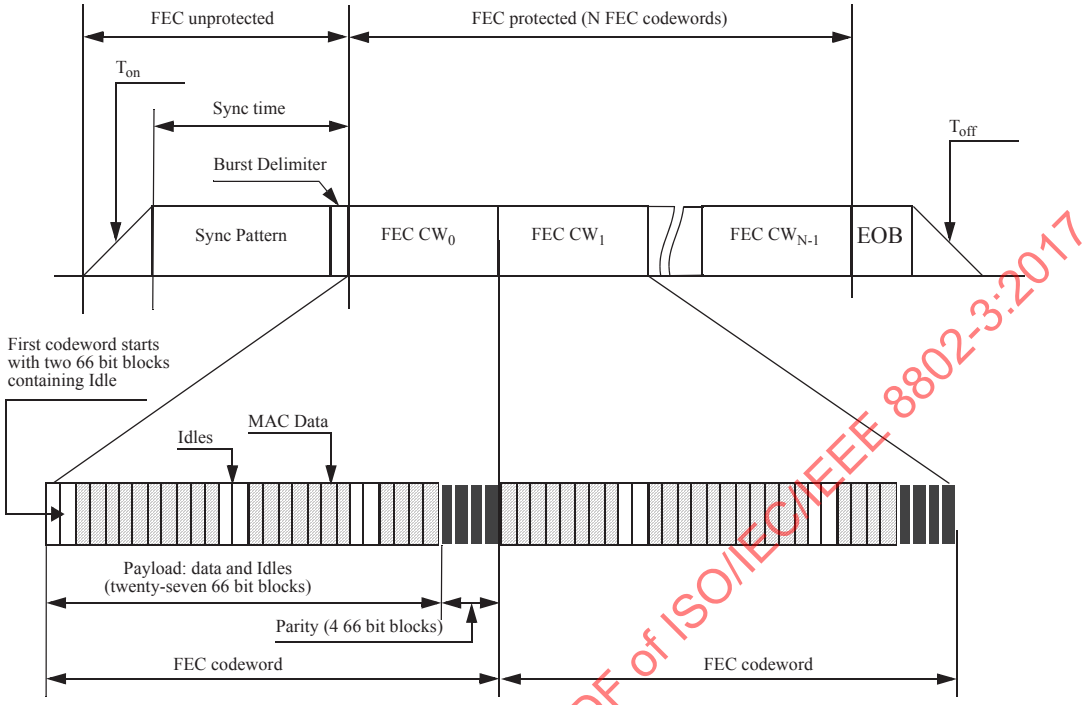

Figure 76–14—Details of burst composition

The ONU burst transmission begins with a Synchronization Pattern (see 76.3.2.5.2), which facilitates receiver clock recovery and gain control at the OLT. To facilitate FEC codeword synchronization, the ONU transmits a 66 bit BURST_DELIMITER (see Figure 76–15). When received at the OLT, the BURST_DELIMITER allows for FEC codeword alignment on the incoming data stream, even in the presence of bit errors. The BURST_DELIMITER is followed by two 66 bit blocks containing Idle codes. The first 66 bit block is used to synchronize the descrambler and a second 66 bit block is needed to provide packet delineation at the RS layer of the OLT. These two 66 bit Idle blocks are part of the first FEC codeword.

The ONU burst transmission ends with an END_BURST_DELIMITER (EOB) pattern of length TERMINATOR_LENGTH (see Figure 76–15). When received at the OLT, the burst terminator allows for the rapid reset of the OLT FEC synchronizer, so that it can search for the next burst. The burst terminator is not part of the last FEC codeword.

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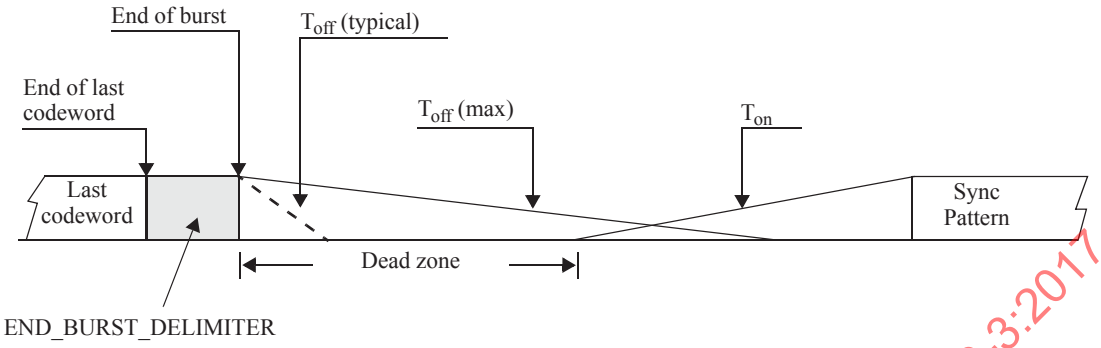

Figure 76–15—ONU burst transmission termination

The body of this subclause comprises state diagrams, including the associated definitions of variables, constants, and functions pertinent to the 10GBASE-PR and 10/1GBASE-PRX OLT PCS transmitters. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails. The notation used in the state diagrams in this clause follows the conventions in 21.5. State diagram variables follow the conventions of 21.5.2 except when the variable has a default value.

76.3.2.5.2 Constants

BURST_DELIMITER
: TYPE: 66 bit unsigned
A 66 bit value used to find the beginning of the first FEC codeword in the upstream burst.
Value: binary 01 followed by 0x 6B F8 D8 12 D8 58 E4 AB (transmission bit sequence: 01 1101 0110 0001 1111 0001 1011 0100 1000 0001 1011 0001 1010 0010 0111 1101 0101)

END_BURST_DELIMITER
: TYPE: 66 bit unsigned
A 66 bit value used to identify the end of the upstream burst transmission.
Value: binary 10 followed by 0x 55 55 55 55 55 55 55 55 (transmission bit sequence of 10 1010 1010 1010 1010 1010 1010 1010 1010 1010 1010 1010 1010 1010 1010 1010 1010)

FEC_DSize
: See 76.3.2.1.1.

FEC_PSize
: See 76.3.2.1.1.

SP
: Type: 66 bit unsigned
A 66 bit value used to for the burst mode synchronization pattern.
Value: binary 10 followed by 0x BF 40 18 E5 C5 49 BB 59 (transmission bit sequence 10 1111 1101 0000 0010 0001 1000 1010 0111 1010 0011 1001 0010 1101 1101 1001 1010)

TERMINATOR_LENGTH
: Type: 8 bit unsigned
Number of END_BURST_DELIMITER blocks that are transmitted at the end of each burst.
Value: 3

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SH_DATA
Type: 2-bit unsigned
The value of synchronization header indicating that the given 66-bit block is a data block, as defined in 49.2.4.3.
Value: 0x02 (binary representation 10)

SH_CTRL
Type: 2-bit unsigned
The value of synchronization header indicating that the given 66-bit block is a control block, as defined in 49.2.4.3.
Value: 0x01 (binary representation 01)

NOTE—The binary representation of the sync header in here is different than that in Clause 49. In Clause 49, binary values are shown with the first transmitted bit (the LSB) on the left.

76.3.2.5.3 Variables

CLK
TYPE: Boolean
This Boolean is true on every negative edge of TX_CLK (See 46.3.1) and represents instances of time at which a 66 bit block should be passed from Data Detector to the GearBox. This variable is reset to false upon read.

DelayBound
This variable is defined in 76.3.2.1.2.

FIFO_DD
TYPE: Array of 66 bit unsigned elements
A FIFO array used to store tx_coded<65:0> blocks while the parity is inserted and while burst preamble is generated (at the ONU only).

FifoSize
TYPE: 16 bit unsigned
Variable representing a number of elements stored in FIFO_DD.

SyncLength
TYPE: 16 bit unsigned
Required number of sync blocks per burst. The value of this variable is derived from the syncTime (excluding BURST_DELIMITER) and laserOnTime parameters defined in 77.3.3.

Transmitting
TYPE: Boolean
Boolean variable indicating whether the device is transmitting or not. At the ONU, the default value of Transmitting is false. At the OLT, this variable is always set to true.

tx_coded<65:0>
TYPE: 66 bit unsigned
66 bit block containing the output of the scrambler. The format for this vector is shown in Figure 49–7. The left-most bit in the figure is tx_coded<0> and the right-most bit is tx_coded<65>.

tx_coded_out<65:0>
TYPE: 66 bit unsigned

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66 bit block containing the output of Data Detector being passed to the Gearbox. The format for this vector is shown in Figure 49–7. The left-most bit in the figure is tx_coded<0> and the right-most bit is tx_coded<65>.

76.3.2.5.4 Functions

RemoveFifoHead()

This function removes the first block in FIFO_DD and decrements the variable FifoSize by 1.

```
RemoveFifoHead()
    {
        // shift FIFO_DD forward
        FIFO_DD[0] = FIFO_DD[1]
        FIFO_DD[1] = FIFO_DD[2]
            ...
        FIFO_DD[FifoSize-2] = FIFO_DD[FifoSize-1]
        FifoSize --
    }
```

76.3.2.5.5 Messages

PMA_SIGNAL.request(tx_enable)

This primitive is used to turn the laser on and off at the PMD sublayer. In the OLT, this primitive shall always take the value ON. In the ONU, the value of this variable is controlled by the Data detector state diagram (see Figure 76–17).

SCRAMBLER_UNITDATA.request(tx_coded<65:0>)

A primitive generated by the SCRAMBLER transmit process conveying the next 66 bit block to be transmitted.

SUDR

Alias for SCRAMBLER_UNITDATA.request(tx_coded<65:0>).

76.3.2.5.6 Counters

IdleBlockCount

TYPE: 32 bit unsigned

The number of consecutive non-data blocks ending with the most recently received block. The non-data blocks are represented by sync header 10 (binary).

ParityBlockCount

TYPE: 8 bit unsigned

The number of parity blocks transmitted in a current FEC codeword. After reaching the full parity size (FEC_PSize=4), this counter is reset to 0.

ProtectedBlockCount

TYPE: 8 bit unsigned

The number of blocks added to a payload of a current FEC codeword. After reaching the full payload size (FEC_DSize = 27), this counter is reset to 0.

SyncBlockCount

TYPE: 16 bit unsigned

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The number of synchronization blocks transmitted in current burst.

76.3.2.5.7 State diagrams

The OLT and the ONU shall implement the Data Detector input process as depicted in Figure 76–16. The OLT shall implement the Data Detector output process as depicted in Figure 76–17(a). The ONU shall implement the Data Detector output process as depicted in Figure 76–17(b).

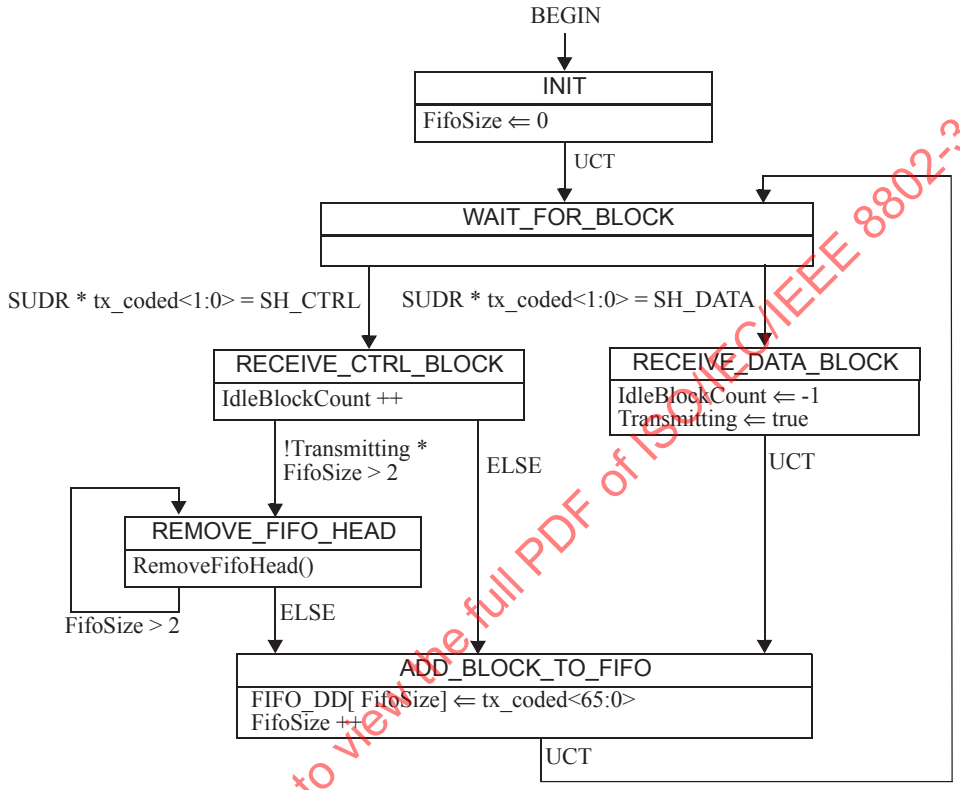

Figure 76–16—Data Detector, input process state diagram

76.3.2.6 Gearbox

See 49.2.7 Gearbox.

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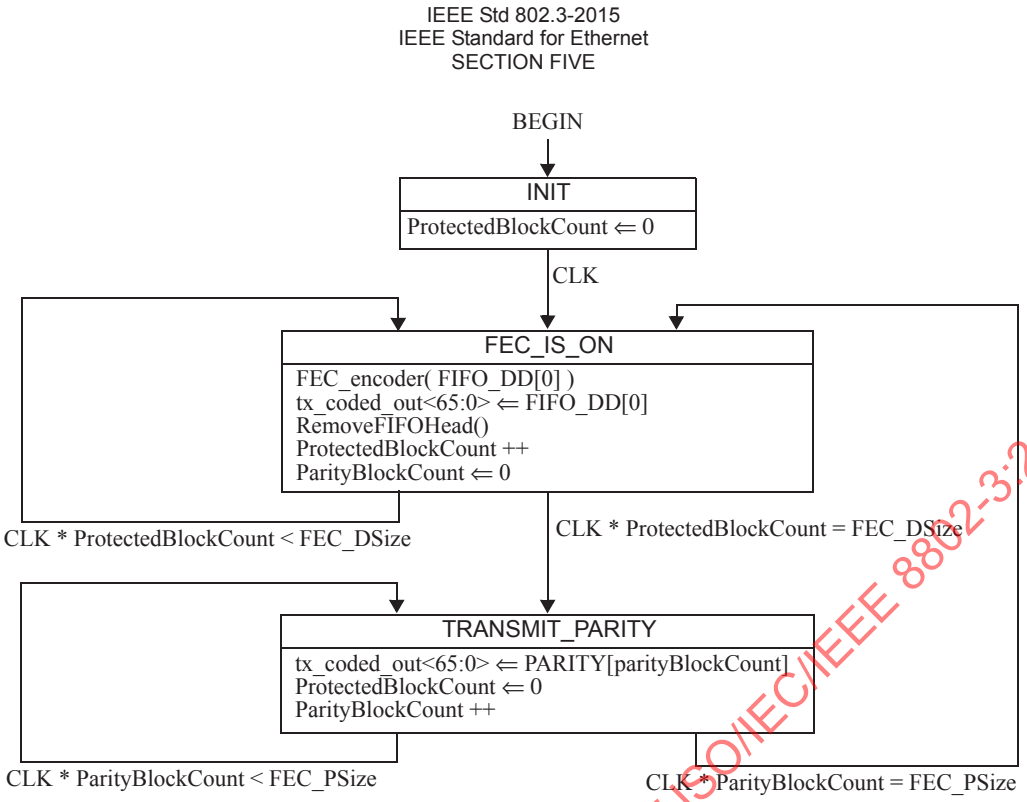

(a) OLT state diagram

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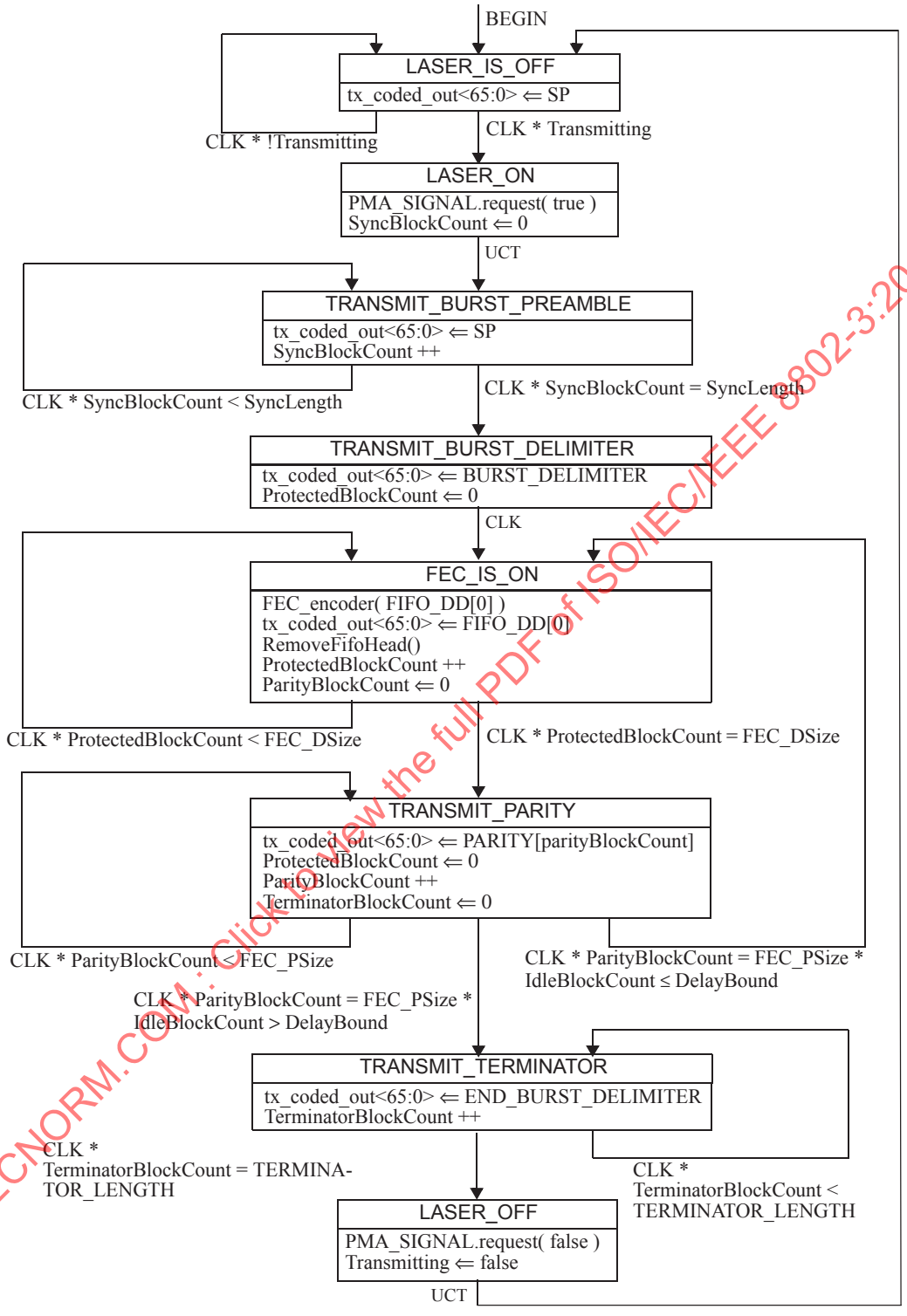

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(b) ONU state diagram

Figure 76–17—Data Detector, output process state diagram

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76.3.3 PCS receive Function

This subclause defines the receive direction of physical coding sublayers for 10GBASE-PR and 10/1GBASE-PRX. In the ONU, the PCS operates at a 10 Gb/s rate in a continuous mode. In the OLT, the PCS may operate at a 10 Gb/s rate, as specified herein (10GBASE-PR), or at a 1 Gb/s rate, compliant with Clause 65 (10/1GBASE-PRX). For both 10GBASE-PR and 10/1GBASE-PRX, the OLT PCS always operates in burst mode. When operating at the 10 Gb/s rate, the PCS includes a mandatory FEC decoder. The receive direction of ONU PCS is illustrated in Figure 76–7 and receive direction for the OLT PCS is illustrated in Figure 76–8.

76.3.3.1 OLT synchronizer

The OLT codeword synchronization function receives data via the 16 bit PMA_UNITDATA.indication primitive.

The OLT synchronizer forms a bit stream from the primitives by concatenating requests with the bits of each primitive in order from rx_data-group<0> to rx_data-group<15> (see Figure 76–18). It obtains lock to the thirty-one 66 bit blocks in the bit stream by looking for the burst delimiter. Lock is obtained as specified in the codeword lock state diagram shown in Figure 76–18. While in codeword lock, the synchronizer copies the FEC-protected bits from each data block and the parity bits of the codeword into an input buffer. When the codeword is complete, the FEC decoder is triggered, and the input buffer is freed for the next codeword. When in codeword lock, the state diagram looks for the end of the burst. When this is observed, then the state diagram deasserts codeword lock. The state diagram then goes back to searching for the burst delimiter.

76.3.3.1.1 Variables

BD_valid
: TYPE:Boolean
Indication that is set true if received block rx_coded matches the BURST_DELIMITER with less than 12 bits difference, and de-asserted otherwise.

cword_lock
: TYPE: Boolean
Boolean variable that is set true when receiver acquires codeword delineation.

CurrentBlock<65:0>
: TYPE: 66 bit vector
The last 66 bit block received. This variable has an initial value of 0.

decode_success
: TYPE: Boolean
Indication that is set true if the codeword was successfully decoded by the FEC algorithm, and false otherwise.

EOB_valid
: TYPE: Boolean
Indication that is set true if:

$$\text{DistanceFromEob}(\text{CurrentBlock}) + \text{DistanceFromEob}(\text{PreviousBlock}) < 11$$

It is set to false otherwise.

inbuffer
: TYPE: bit array
An array of 2040 bits that holds the input to the FEC decoder.

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input_buffer_location
TYPE: integer
An integer that points to the next appending location in the input buffer.

persist_dec_fail
TYPE: Boolean
Indication that is set when three consecutive decoding failures have occurred.

PreviousBlock<65:0>
TYPE: 66 bit vector
The 66 bit block received previous to the current block. This variable has an initial value of 0.

reset
This variable is inherited from 49.2.13.2.2.

rx_coded<65:0>
This variable is inherited from 49.2.13.2.2.

signal_ok
This variable is inherited from 49.2.13.2.2.

76.3.3.1.2 Counters

decode_failures
TYPE:
Counter that holds the number of consecutive decoding failures.

sh_wndw_cnt
Count of the number of sync headers checked within the current 62-block window (composed of 2 codewords of 31 blocks each).

76.3.3.1.3 Functions

Append_inbuffer()
Appends the newly arrived 66 bit block into the input buffer of the FEC decoding algorithm, taking care to only insert the bits to be protected, and discarding the unwanted bits.

```
Append_inbuffer()
{
   BlockFromPMA()
   if (sh_wndw_cnt<27)
   {
      inbuffer[input_buffer_location]=rx_coded<1>
      input_buffer_location++
   }
   for(i=2, i<66, i++)
   {
      inbuffer[input_buffer_location]=rx_coded<i>
      input_buffer_location++
   }
}
```

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BlockFromPMA()

Function that accepts the next received data from the PMA. Conceptually, this function serializes the 16 bit rx_data_group<15:0> to a bit stream at 10.3125 Gb/s, and then deserializes the resulting bit stream into a 66 bit wide rx_coded<65:0> block of data. It does not return until 66 bits have been transferred. Note that the internal design by which this function is accomplished is an implementation choice; however, the design operates such that a new 66 bit block is made available at the regular interval of 6.4 ns, and the transfers are made synchronous to the XGMII clock.

Decode()

Triggers the FEC decoding algorithm to accept the contents of the input buffer, and do its decoding work. Note that this function is not blocking, and returns immediately. It is assumed that the FEC decoding algorithm copies the input buffer contents into its own internal memory, so that the input buffer is released to accept the next codeword.

DecodeWhenReady()

Determines if the inbuffer contains a full codeword, and if so, it triggers the Decode function, and then clears the inbuffer for the next codeword.

```
DecodeWhenReady()
{
   if (sh_wndw_cnt=0 or sh_wndw_cnt=31)
   {
      if (cword_lock)
      {
         Decode();
      }
      Flush_inbuffer();
   }
}
```

DistanceFromEob(block<65:0>)

Returns the Hamming distance between the supplied block and the END_BURST_DELIMITER

Flush_inbuffer()

Flushes the input buffer of the FEC decoding algorithm block.

```
Flush_inbuffer()
{
   for(i=0, i<2040, i++)
   {
      inbuffer[i]=0
   }
   input_buffer_location = 29
}
```

SLIP_One_Bit

Causes the next candidate block sync position to be tested. The next candidate is exactly one bit later than the previous candidate – no burst alignments may be skipped. Following the conceptual model mentioned in “BlockFromPMA,” this function transfers one more bit from the 16 bit serializer to the 66 bit deserializer.

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76.3.3.1.4 State diagram

The OLT Synchronizer shall implement the state diagram as depicted in Figure 76–18. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

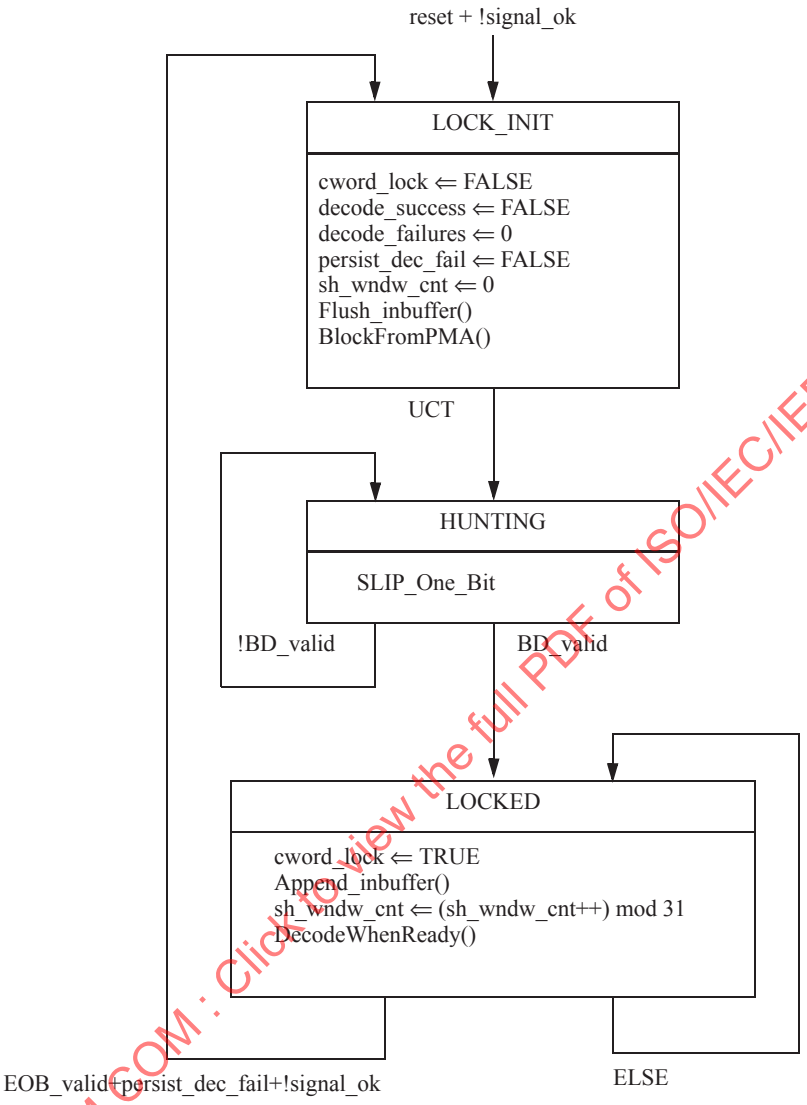

Figure 76–18—OLT Synchronizer state diagram

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76.3.3.2 ONU Synchronizer

The codeword synchronization function receives data via the 16 bit PMA_UNITDATA.indication primitive.

The synchronizer forms a bit stream from the primitives by concatenating requests with the bits of each primitive in order from rx_data-group<0> to rx_data-group<15> (see Figure 76–19). It obtains lock to the thirty-one 66 bit blocks in the bit stream using the sync headers and outputs 2040 bit codewords to the FEC decoder function.

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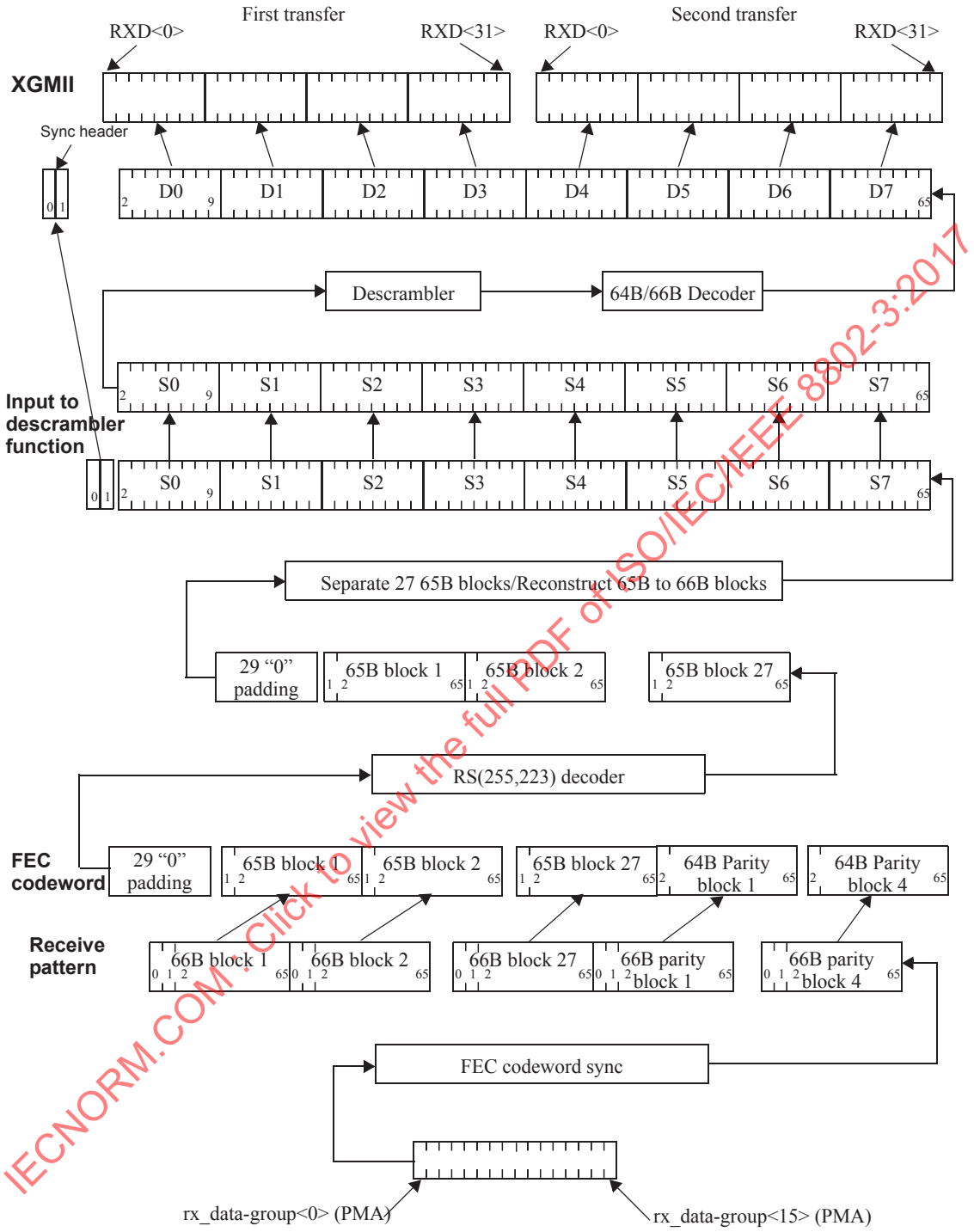

Figure 76–19—PCS Receive bit ordering

The incoming sync header pattern is 27 conventional (Clause 49) sync headers (binary 01 or 10), and then binary 00, 11, 11, and finally binary 00. The ONU synchronizer attempts to match this pattern to the

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received data stream, and when it finds a perfect match of two full codewords (62 blocks), it then asserts codeword lock.

While in codeword lock, the synchronizer copies the FEC-protected bits from each data block and the parity bits of the codeword into an input buffer. When the codeword is complete, the FEC decoder is triggered, and the input buffer is freed for the next codeword.

When in codeword lock, the state diagram continues to check for sync header validity. If 16 or more sync headers in a codeword pair (62 blocks) are invalid, then the state diagram deasserts codeword lock. In addition, if the persist_dec_fail signal becomes set, then codeword lock is deasserted (this check ensures that certain false-lock cases are not persistent.)

76.3.3.2.1 Constants

All the relevant constants defined in 49.2.13.2.1 are inherited. In addition, the following items are defined.

SH_CW_PATTERN
: TYPE: array of 8 bit unsigned
31 element array of codeword sync header bit counts, where each element is set to the value 1 except for:
Value:
SH_CW_PATTERN[27]=0
SH_CW_PATTERN[28]=2
SH_CW_PATTERN[29]=2
SH_CW_PATTERN[30]=0

76.3.3.2.2 Variables

cword_lock
: See 76.3.3.1.1.

decode_success
: See 76.3.3.1.1.

persist_dec_fail
: See 76.3.3.1.1.

reset
: This variable is inherited from 49.2.13.2.2.

sh_valid
: TYPE: Boolean array
Indication that is set true if received block rx_coded has valid sync header bits for the supposed current position in the FEC codeword. That is, sh_valid[i] is asserted if (rx_coded<0> + rx_coded<1>) = SH_CW_PATTERN[i mod 31] and de-asserted otherwise.

signal_ok
: This variable is inherited from 49.2.13.2.2.

slip_done
: This variable is inherited from 49.2.13.2.2.

test_sh
: This variable is inherited from 49.2.13.2.2.

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76.3.3.2.3 Counters

decode_failures
See 76.3.3.1.2.

FEC_cnt
TYPE: 8 bit unsigned
This counter keeps track of the parity sync header index that is currently being tested.

sh_wndw_cnt
See 76.3.3.1.2.

sh_valid_cnt
This counter is inherited from 49.2.13.2.4.

76.3.3.2.4 Functions

Append_inbuffer()
See 76.3.3.1.3.

DecodeWhenReady()
See 76.3.3.1.3.

SLIP
This function is inherited from 49.2.13.2.3.

76.3.3.2.5 State diagram

The ONU Synchronizer shall implement the state diagram as depicted in Figure 76–20. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

76.3.3.3 FEC decoding process

The 10GBASE-PR-D, 10GBASE-PR-U, and 10/1GBASE-PRX-U PCS shall correct errors in the received data stream using Reed-Solomon code (255,223). The FEC decoder corrects or confirms the correctness of the twenty-seven 66 bit blocks contained in the FEC codeword based on the four 66 bit blocks of parity information. The FEC decoding process then forwards the 66 bit data blocks to the descrambler and discards the parity blocks. The FEC decoding process is also responsible for setting bit 0 of the sync header to the inverse of bit 1 of the sync header. The handling of data leaving the FEC decoder and going to the descrambler is specified in the FEC decoding process state diagram shown in Figure 76–21. Implementations shall be capable of correcting up to 16 symbols in a codeword and detecting uncorrectable codewords.

The synchronizer state diagram accumulates a full codeword in a buffer. If the synchronizer is locked, then the FEC decoding process is triggered. The FEC algorithm then processes the buffer. The algorithm produces two outputs: the decode_success signal and (if successful) the corrected buffer. The data portion of the buffer is then read out to the descrambler logic in 66 bit blocks, as normal. Note that the rate of 66 bit transfers here is reduced due to the removal of the FEC parity blocks. This is corrected in the Idle Insertion step (see Figure 76–23).

If decode_success is false, then a counter is incremented (see 45.2.3.40). If there are three decoding failures in a row, then the Persist_dec_fail signal is asserted. This signal then resets the synchronizer.

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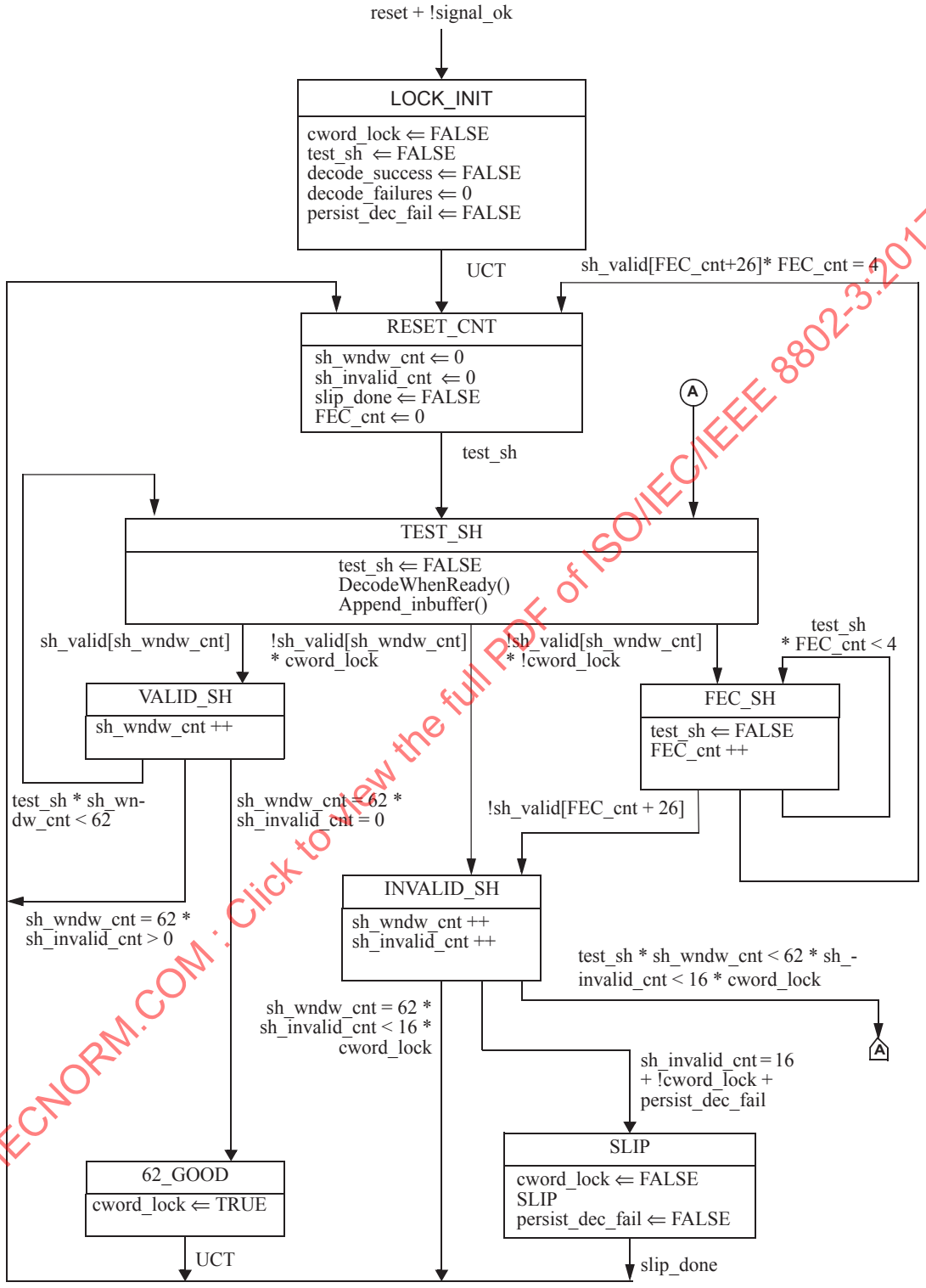

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Figure 76–20—ONU Synchronizer state diagram

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The FEC decoding process shall provide a user option to indicate an uncorrectable FEC codeword (due to an excess of symbols containing errors) to higher layers. If this option is set to be true, the FEC decoding process checks for the value of decode_success. If the variable decode_success is set to false, then each sync header of the received payload blocks in the FEC codeword is set to a value of binary 00. However, the data blocks are nevertheless passed to the descrambler to maintain descrambling synchronization. When this option is set to FALSE and decode_success is FALSE then each received payload block is passed unchanged.

76.3.3.3.1 Variables

decode_done
: TYPE: Boolean
Indication that is transiently set when the FEC decoder algorithm has completed its processing and the corrected data is present in the output buffer.

decode_success
: See 76.3.3.1.1.

mark_uncorrectable
: TYPE: Boolean
Control variable that is set to true if the uncorrectable errors are to be marked.
Default: TRUE

outbuffer
: TYPE: bit array
An array of 2040 bits that holds the output of the FEC decoder.

persist_dec_fail
: See 76.3.3.1.1.

rx_code_corrected
: Type: 66 bit vector
The next block of data to be sent to the scrambler.

76.3.3.3.2 Counters

decode_failures
: See 76.3.3.1.2.

corrected_FEC_codewords_counter
: A corrected block is an FEC codeword that was received with one or more errored symbols, and that has been corrected by the FEC decoder.
corrected_FEC_codewords_counter counts once for each corrected FEC codeword processed. This is a 32 bit counter. This variable is provided by a management interface that may be mapped to the 45.2.3.39 register (3.76, 3.77).

FEC_uncorrected_blocks_counter
: An uncorrected block is an FEC codeword that was received with 17 or more errored symbols, and that has not been corrected by the FEC decoder.
FEC_uncorrected_blocks_counter counts once for each uncorrected FEC codeword processed. This is a 32 bit counter. This variable is provided by a management interface that may be mapped to the 45.2.3.40 register (3.78, 3.79).

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76.3.3.3.3 Functions

All the relevant functions defined in 49.2.13.2.3 are inherited. In addition, the following items are defined.

BlockFromPMA()
See 76.3.3.1.3.

BlockToDescrambler()
Function that sends the next rx_coded_corrected<65:0> block to the descrambler. It does not return until the transfer is completed, and each transfer takes 6.4 ns and is synchronized to the XGMII clock.

Flush_inbuffer()
See 76.3.3.1.3.

Read_outbuffer(i)
Passes output buffer contents to the descrambler, with the appropriate format.

```
Read_outbuffer[i]
{
   int offset = 29+i*65
   for(j=0, j<65, j++)
   {
      rx_coded_corrected<j+1> = outbuffer[j+offset]
   }
   if (!decode_success AND mark_uncorrectable)
   {
      rx_coded_corrected<0> = 0
      rx_coded_corrected<1> = 0
   }
   else
   {
      rx_coded_corrected<0> = !rx_coded_corrected<1>
   }
   BlockToDescrambler()
}
```

SLIP
This function is inherited from 49.2.13.2.3.

76.3.3.3.4 State diagrams

The body of this subclause comprises state diagrams, including the associated definitions of variables, constants, and functions pertinent to the 10GBASE-PR-D, 10GBASE-PR-U, and 10/1GBASE-PRX-U PCS receivers. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails. The notation used in the state diagrams in this clause follows the conventions in 21.5.

The FEC decoding process shall be implemented in the PCS as depicted in Figure 76–21. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

76.3.3.4 BER monitor

The BER monitor is described in Figure 76–22. This BER monitor function operates on the uncorrected incoming data stream.

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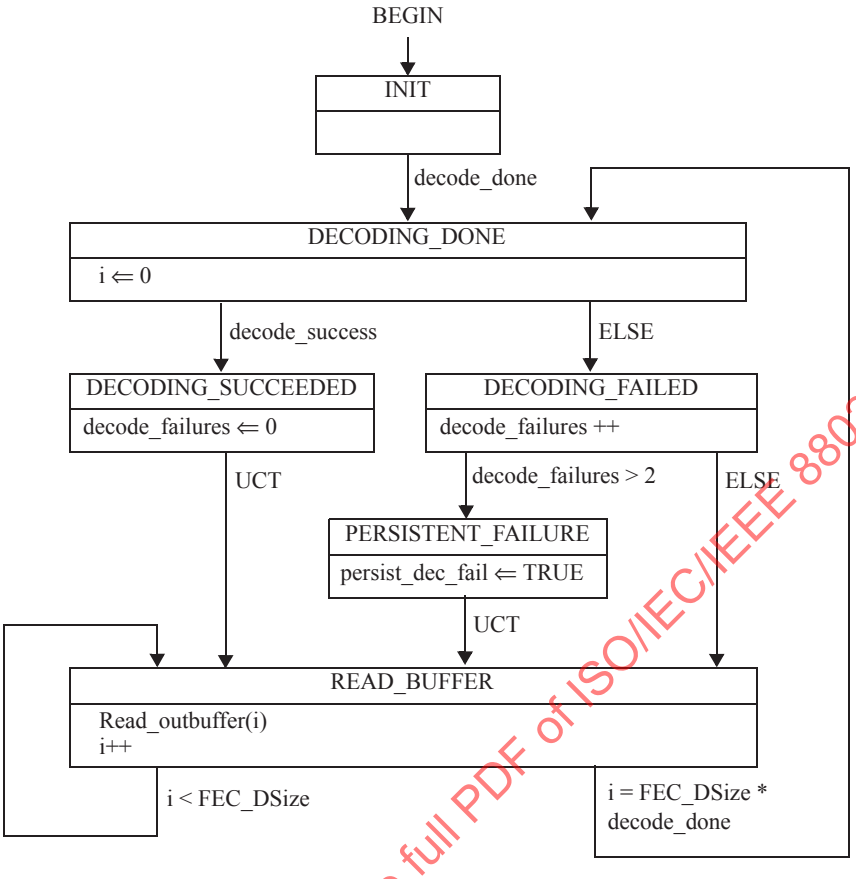

Figure 76–21—FEC decoding process state diagram

76.3.3.4.1 Variables

BER_Monitor_Interval
: Indicates the time window associated with the BER monitor function. The timers in the BER monitor state diagram depend on this configurable variable. This value is reflected in MDIO register 3.80.

ber_test_sh
: This variable is inherited from 49.2.13.2.2.

BER_Threshold
: Indicates the threshold value of invalid sync headers associated with the BER monitor function. When BER_Threshold bad sync headers are encountered within the BER Monitor_Interval period, the BER monitor raises the hi_ber flag. When the number of bad sync headers encountered within the BER_Monitor_interval period less than the BER_Threshold, the hi_ber flag is turned off. This value is reflected in MDIO register 3.82.

hi_ber
: This variable is inherited from 49.2.13.2.2.

reset
: This variable is inherited from 49.2.13.2.2.

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ber_test_sh
: This variable is inherited from 49.2.13.2.2.

76.3.3.4.2 Timers

State diagram timers follow the conventions of 14.2.3.2.

interval_timer
: Timer that is triggered every BER_monitor_interval µs +1%, –25%.

76.3.3.4.3 Counters

ber_cnt
: This counter is inherited from 49.2.13.2.4.

76.3.3.4.4 State diagrams

The BER monitor state diagram is present only in the ONU. It is shown in Figure 76–22.

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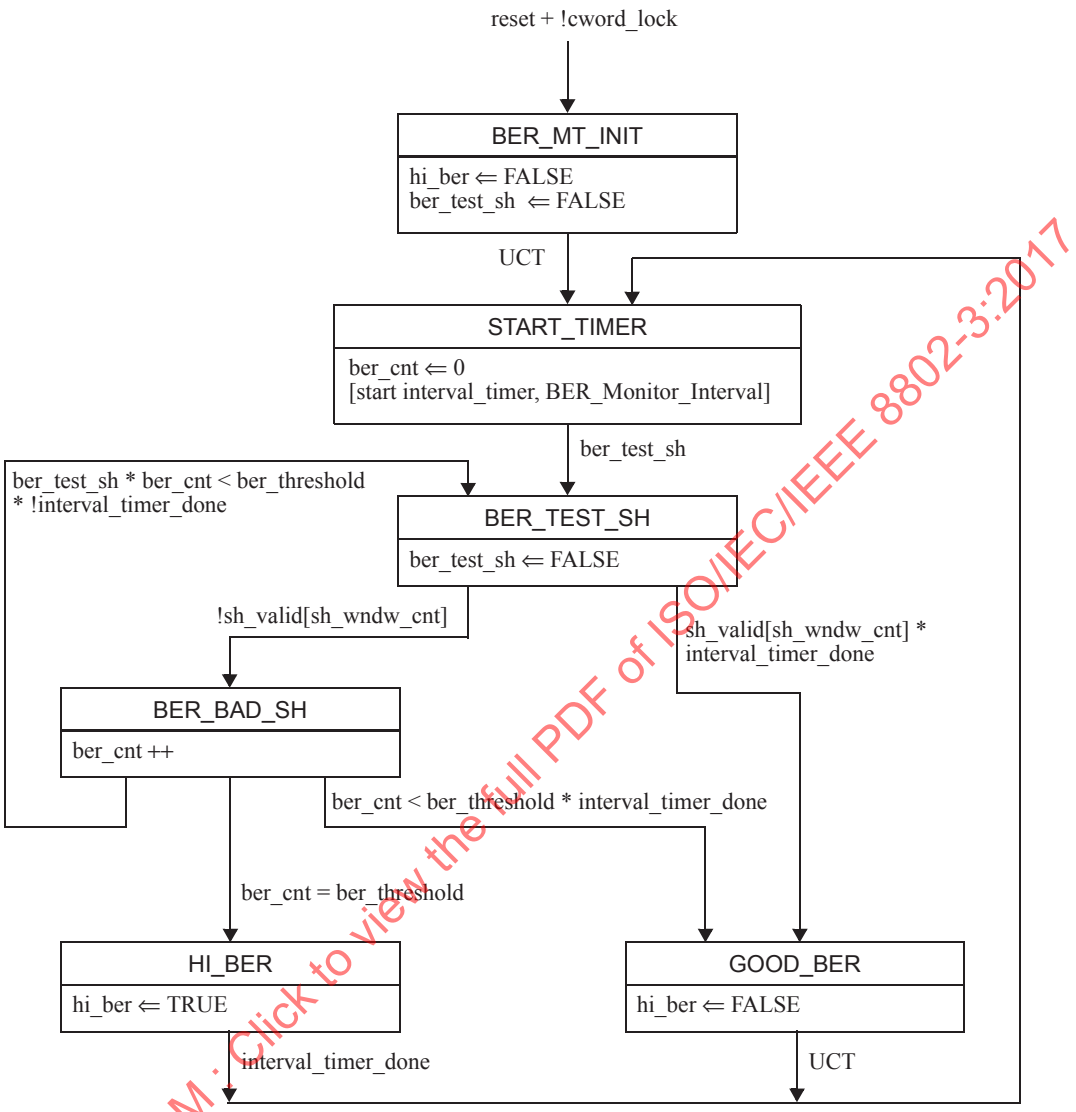

Figure 76–22—BER monitor state diagram (ONU only)

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76.3.3.5 Descrambler

See 49.2.10 Descrambler.

76.3.3.6 64B/66B Decode

See 49.2.11 Receive process. The decoder shall perform functions specified in the state diagram shown in Figure 49–17.

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76.3.3.7 Idle Insertion

The receiving PCS inserts the Idle control characters to compensate for the removed FEC parity octets. The Idle Insertion function (see Figure 76–23) receives 72 bit vectors from the 64B/66B decoder and writes them into the Idle Insertion FIFO (called FIFO_II) and reads 72 bit vectors from the FIFO_II and transfers them to the XGMII.

The Idle Insertion process receives 72 bit vectors at a slower rate than the nominal XGMII rate due to the fact that the FEC parity blocks are removed by the FEC decoder and not put through the descrambler and 64B/66B decoder. The Idle Insertion process outputs 72 bit vectors at the nominal XGMII rate. To match the input and output rates, the Idle Insertion process inserts additional 72 bit vectors containing Idle codes. The additional blocks are inserted between packets and not necessarily at the same locations where parity blocks have been removed.

The body of this subclause comprises state diagrams, including the associated definitions of variables, constants, and functions pertinent to the 10GBASE-PR-D, 10GBASE-PR-U and 10/1GBASE-PRX-U PCS receivers. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails. The notation used in the state diagrams in this clause follows the conventions in 21.5.

76.3.3.7.1 Constants

FEC_DSize
: This constant is defined in 76.3.2.1.1.

FEC_PSize
: This constant is defined in 76.3.2.1.1.

FIFO_II_SIZE
: TYPE: 16 bit unsigned
This constant represents the size of Idle Insertion FIFO buffer. This buffer should be able to accommodate the number of 66 bit blocks sufficient to fill the gap introduced by removing the parity blocks from a maximum size MAC frame.
Value: 42

IDLE_VECTOR
: TYPE: 72 bit binary
This constant represents a 72 bit vector containing Idle characters.

LBLOCK_R
: This constant is defined in 49.2.13.2.1.

76.3.3.7.2 Variables

FIFO_II
: TYPE: Array of 72 bit vectors received from 64B/66B decoder.
This FIFO is internal to the Idle Insertion process. Upon initialization, all elements of this array are filled with IDLE_VECTORs. FIFO_II is a zero-based array of size FIFO_II_SIZE (see 76.3.3.7.1).

RX_CLK
: TYPE: Boolean
This variable represents the RX_CLK signal defined in 46.3.2.1.

rx_raw_in<71:0>
: TYPE: 72 bit binary

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Vector received from the output of the 64B/66B decoder. RXD<0> through RXD<31> for the second transfer are placed in rx_raw<40> through rx_raw<71>, respectively.

rx_raw_out<71:0>
TYPE: 72 bit binary
72 bit vector passed from the Idle Insertion process to XGMII. The vector is mapped to two XGMII transfers as follows:
Bits rx_raw<3:0> are mapped to RXC<3:0> for the first transfer;
Bits rx_raw<7:4> are mapped to RXC<3:0> for the second transfer;
Bits rx_raw<39:8> are mapped to RXD<31:0> for the first transfer;
Bits rx_raw<71:40> are mapped to RXD<31:0> for the second transfer.

VectorCount
TYPE: 16 bit unsigned
This variable tracks the number of 72 bit vectors stored in the FIFO_II.

76.3.3.7.3 Functions

T_TYPE(rx_raw)
This function is defined in 49.2.13.2.3.

76.3.3.7.4 Messages

DECODER_UNITDATA.indicate(rx_raw_in<71:0>)
A signal sent by the PCS Receive process conveying the next received 72 bit vector.

DUDI
Alias for DECODER_UNITDATA.indicate(rx_raw_in<71:0>).

76.3.3.7.5 State diagrams

The PCS Idle Insertion function shall implement the state diagram as shown in Figure 76–23. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

76.4 10GBASE-PR and 10/1GBASE-PRX PMA

The 10GBASE-PR PMA is derived from the 10GBASE-R PMA defined in Clause 51. This clause specifies 10GBASE-R extensions necessary to support P2MP operation. The 10/1GBASE-PRX PMA conceptually consists of a combination of transmit and receive functions specified for 10GBASE-PR and 1000BASE-PX defined in 65.3.2, as shown in Table 76–5.

76.4.1 Extensions for 10GBASE-PR-U and 10/1GBASE-PRX-U

76.4.1.1 Physical Medium Attachment (PMA) sublayer interfaces

In addition to the primitives of Clause 51, the following primitive is defined:

PMA_SIGNAL.request(tx_enable)
This primitive is mapped to PMD_SIGNAL.request(tx_enable). It is generated by the PCS's Data Detector. The effect of reception of PMD_SIGNAL.request(tx_enable) is defined in 75.3.1.4.

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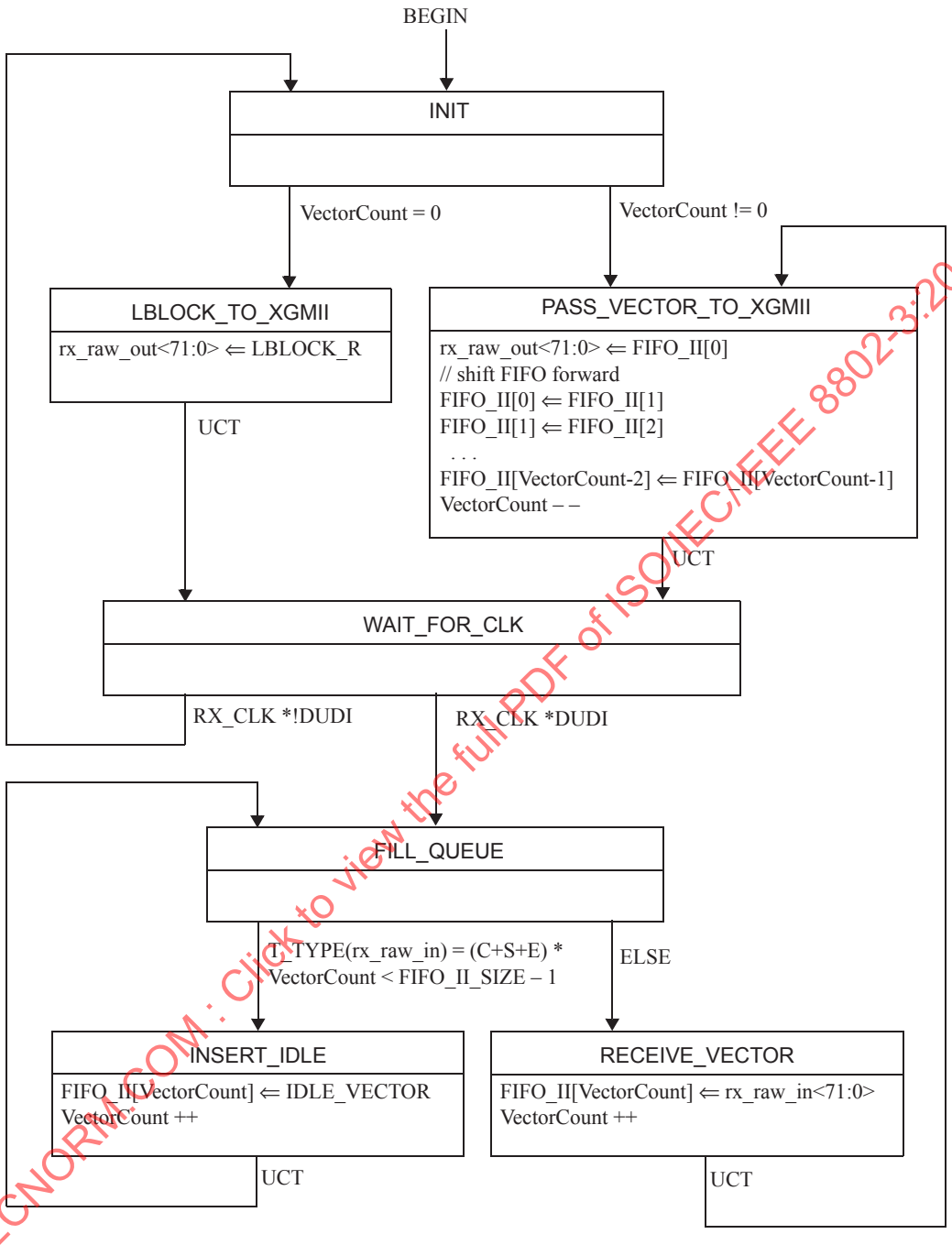

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Figure 76–23—PCS Idle Insertion

tx_enable

The tx_enable parameter can take one of two values, ON or OFF.

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Table 76–5—Derivation of PMA transmit and receive functions for 10GBASE-PR and 10/1GBASE-PRX

PMA	Transmit function	Receive function
10GBASE-PR-U	As specified in Clause 51 with extensions defined in 76.4.1.	
10/1GBASE-PRX-U	Identical to 1000BASE-PX-U. See 65.3.1.	Identical to 10GBASE-PR-U. See 76.4.1.
10GBASE-PR-D	As specified in Clause 51 with extensions defined in 76.4.2.	
10/1GBASE-PRX-D	Identical to 10GBASE-PR-D.	Identical to 1000BASE-PX-D. See 65.3.2.

76.4.1.2 Loop-timing specifications for ONUs

ONUs shall operate at the same time basis as the OLT, i.e., the ONU TX clock tracks the ONU RX clock, which in turn locks to OLT TX clock. Jitter transfer masks are defined in 75.7.

For the 10/1GBASE-PRX-U devices, the received clock PMA_RX_CLK is 644.53125 MHz (10.3125 GBd/16), however, the transmit clock PMA_TX_CLK is 125 MHz (1.25 GBd/10). The loop timing is achieved by multiplying the PMA_RX_CLK by 32 and dividing by 165.

76.4.2 Extensions for 10GBASE-PR-D and 10/1GBASE-PRX-D

76.4.2.1 CDR lock timing measurement for the upstream direction

CDR lock time (denoted T_{CDR}) is defined as a time interval required by the receiver to acquire phase lock on the incoming data stream. T_{CDR} is measured as the time elapsed from the moment when the electrical signal after the PMD at TP8, as illustrated in Figure 75–3, reaches the conditions specified in 75.7.15 for receiver settling time to the moment when the signal phase is recovered and jitter is maintained for a network with BER of no more than 10^{-3}.

A PMA instantiated in an OLT becomes synchronized at the bit level within 400 ns (T_{CDR}) after the appearance of a valid synchronization pattern (as defined in 76.3.2.5.2) at TP8.

76.4.2.1.1 Test specification

The test of the OLT PMA receiver T_{CDR} time assumes that there is an optical PMD transmitter at the ONU with well known T_{on} time as defined in 75.7.14, and an optical PMD receiver at the OLT with well-known $T_{receiver_settling}$ time as defined in 75.7.15. After T_{on} + $T_{receiver_settling}$ time, the parameters at TP8 reach within 15% of their steady state values, measure T_{CDR} as the time from the TX_ENABLE assertion, minus the known T_{on} + $T_{receiver_settling}$ time, to the time the electrical signal at the output of the receiving PMA reaches up to the phase difference from the input signal of the transmitting PMA assuring BER of 10^{-3}, and maintaining its jitter specifications. The signal throughout this test is the synchronization pattern, as illustrated in Figure 76–14.

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76.5 Protocol implementation conformance statement (PICS) proforma for Clause 76, Reconciliation Sublayer, Physical Coding Sublayer, and Physical Media Attachment for 10G-EPON[33]

76.5.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 76, Reconciliation Sublayer, Physical Coding Sublayer and Physical Media Attachment for 10G-EPON, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

76.5.2 Identification

76.5.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

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[33]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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76.5.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 76, Reconciliation Sublayer (RS), Physical Coding Sublayer (PCS), and Physical Media Attachment (PMA) for point-to-point media, types 10GBASE–PR and 10/1GBASE–PRX
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	
Date of Statement	

76.5.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*OLT	OLT functionality	76.2.1	Device supports functionality required for OLT	O.1	Yes [ ] No [ ]
*ONU	ONU functionality	76.2.1	Device supports functionality required for ONU	O.1	Yes [ ] No [ ]

76.5.4 PICS proforma tables for Reconciliation Sublayer (RS), Physical Coding Sublayer (PCS), and Physical Media Attachment (PMA) for point-to-multipoint media, types 10GBASE–PR and 10/1GBASE–PRX

76.5.4.1 Operating modes of OLT MACs

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	Unidirectional mode	76.2.3	Device operates in unidirectional transmission mode	OLT:M	Yes [ ]
OM2	Dual-rate mode	76.2.2.3	Device operates in dual-rate mode	OLT:O	Yes [ ] No [ ]

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76.5.4.2 ONU and OLT variables

Item	Feature	Subclause	Value/Comment	Status	Support
FS1	enable variable	65.1.3.1	True for ONU MAC, TRUE for OLT MAC if enabled, FALSE for OLT MAC if not enabled	M	Yes [ ]
FS2	mode variable	65.1.3.1	0 for ONU MAC, 0 or 1 for enabled OLT MAC	M	Yes [ ]
FS3	logical_link_id variable	76.2.6.1.1	Set to 0x7FFE until ONU MAC is registered Set to any value for enabled OLT MAC. Set to any value other then 0x7FFE for registered ONU MAC	M	Yes [ ]
FS4	multicast LLID support	76.2.6.1.1	Supports multicast LLID, multicast_link_id variable	O	Yes [ ] No [ ]

76.5.4.3 Preamble mapping and replacement

Item	Feature	Subclause	Value/Comment	Status	Support
PM1	CRC-8 generation	65.1.3.2	CRC calculation produces same result as serial implementation	M	Yes [ ] No [ ]
PM2	CRC-8 initial value	65.1.3.2	CRC shift register initialized to 0x00 before each new calculations	M	Yes [ ] No [ ]
PM3	SLD parsing	76.2.6.1.3.1	If SLD is not found then discard packet	M	Yes [ ] No[ ]
PM4	SLD replacement	76.2.6.1.3.1	Replace SLD with preamble	M	Yes [ ] No [ ]
PM5	LLID matching	76.2.6.1.3.2	If LLID does not match then discard packet	M	Yes [ ] No [ ]
PM6	multicast LLID matching	76.2.6.1.3.2	If multicast LLID matches accept the packet	*FS4 :M	Yes [ ] No [ ]
PM7	LLID replacement	76.2.6.1.3.2	Replace LLID with preamble	M	Yes [ ] No [ ]
PM8	Reserved LLID	76.2.6.1.3.2	registered ONU shall not transmit frames with a reserved LLID	M	Yes [ ] No [ ]
PM9	CRC-8 checking	65.1.3.3.3	If CRC does not match then discard packet	M	Yes [ ] No [ ]
PM10	CRC-8 replacement	65.1.3.3.3	Replace CRC with preamble	M	Yes [ ] No [ ]

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76.5.4.4 Coding Rules

Item	Feature	Subclause	Value/Comment	Status	Support
C1	Encoder implements the code as specified	76.3.2.2		M	Yes [ ] No [ ]
C2	Decoder implements the code as specified	76.3.3.6		M	Yes [ ] No [ ]

76.5.4.5 Data detection

Item	Feature	Subclause	Value/Comment	Status	Support
DD1	Buffer depth	76.3.2.5.1	Depth sufficient to turn on laser and send laser synchronization pattern, Burst Delimiter pattern and a predefined number of Idle control character (receiver settle).	ONU:M	Yes [ ] No [ ]
DD2	OLT laser control	76.3.2.5.5	Always takes the value ON	OLT:M	Yes [ ] No [ ]
DD3	ONU State diagrams	76.3.2.5.7	Meets the requirements of Figure 76–16 and Figure 76–17	ONU:M	Yes [ ] No[ ]
DD4	OLT State diagrams	76.3.2.5.7	Meets the requirements of Figure 76–16 and Figure 76–17	OLT:M	Yes [ ] No[ ]

76.5.4.6 Idle control character deletion

Item	Feature	Subclause	Value/Comment	Status	Support
AIC1	Idle Deletion function implementation in ONU	76.3.2.1.5	Meets the requirements of Figure 76–10	ONU:M	Yes [ ] No [ ]
AIC2	Idle Deletion function implementation in OLT	76.3.2.1.5	Meets the requirements of Figure 76–9	OLT:M	Yes [ ] No [ ]

76.5.4.7 FEC requirements

Item	Feature	Subclause	Value/Comment	Status	Support
FE1	FEC Encoder	76.3.2.4	RS(255,223)	M	Yes [ ] No [ ]
FE2	FEC Decoder	76.3.3.3	RS(255,223)	M	Yes [ ] No [ ]

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Item	Feature	Subclause	Value/Comment	Status	Support
FE3	Uncorrectable block indication	76.3.3.3	When activated, mark all 66 bit blocks in an uncorrectable block by setting all sync headers for the received payload blocks of the FEC codeword to the value of 00.	M	Yes [ ] No [ ]
FE4	Correctable codewords	76.3.3.3	Correct up to 16 symbols in a codeword and detect uncorrectable codewords	M	Yes [ ] No [ ]

76.5.4.8 FEC state diagrams

Item	Feature	Subclause	Value/Comment	Status	Support
SM1	Transmit	76.3.2.4.1	Meets the requirements of Figure 76–12	M	Yes [ ]
SM2	ONU synchronization	76.3.3.2.5	Meets the requirements of Figure 76–20	ONU:M	Yes [ ] No [ ]
SM3	OLT synchronization	76.3.3.1.4	Meets the requirements of Figure 76–18	OLT:M	Yes [ ] No [ ]
SM4	FEC decoding process	76.3.3.3.4	Meets the requirements of Figure 76–21	M	Yes [ ] No [ ]

76.5.4.9 PCS Idle Insertion

Item	Feature	Subclause	Value/Comment	Status	Support
PI1	Idle Insertion	76.3.3.7.5	Meets the requirements of Figure 76–23	M	Yes [ ] No [ ]

76.5.4.10 PMA

Item	Feature	Subclause	Value/Comment	Status	Support
BMC1	Loop timing	76.4.1.2	ONU RX clock tracks OLT TX clock	ONU:M	Yes [ ] No [ ]

76.5.4.11 Delay variation

Item	Feature	Subclause	Value/Comment	Status	Support
DV1	Delay variation	76.1.2	Combined delay variation through RS, PCS, and PMA sublayers is limited to 1 time_quantum	M	Yes [ ] No [ ]

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77. Multipoint MAC Control for 10G–EPON

77.1 Overview

This clause deals with the mechanism and control protocols required in order to reconcile the 10 Gb/s P2MP topology into the Ethernet framework. The P2MP medium is a passive optical network (PON), an optical network with no active elements in the signal's path from source to destination. The only interior elements used in a PON are passive optical components, such as optical fiber, splices, and splitters. When combined with the Ethernet protocol, such a network is referred to as Ethernet passive optical network (EPON).

P2MP is an asymmetric medium based on a tree (or tree-and-branch) topology. The DTE connected to the trunk of the tree is called optical line terminal (OLT) and the DTEs connected at the branches of the tree are called optical network units (ONU). The OLT typically resides at the service provider's facility, while the ONUs are located at the subscriber premises.

In the downstream direction (from the OLT to an ONU), signals transmitted by the OLT pass through a 1:N passive splitter (or cascade of splitters) and reach each ONU. In the upstream direction (from the ONUs to the OLT), the signal transmitted by an ONU would only reach the OLT, but not other ONUs. To avoid data collisions and increase the efficiency of the subscriber access network, the ONU's transmissions are arbitrated. This arbitration is achieved by allocating a transmission window (grant) to each ONU. An ONU defers transmission until its grant arrives. When the grant arrives, the ONU transmits frames at wire speed during its assigned time slot.

A simplified P2MP topology example is depicted in Figure 77–1. Clause 67 provides additional examples of P2MP topologies.

Topics dealt with in this clause include allocation of upstream transmission resources to different ONUs, discovery and registration of ONUs into the network, and reporting of congestion to higher layers to allow for dynamic bandwidth allocation schemes and statistical multiplexing across the PON.

This clause does not deal with topics including bandwidth allocation strategies, authentication of end-devices, quality-of-service definition, provisioning, or management.

This clause specifies the multipoint control protocol (MPCP) to operate an optical multipoint network by defining a Multipoint MAC Control sublayer as an extension of the MAC Control sublayer defined in Clause 31, and supporting current and future operations as defined in Clause 31and annexes.

Each PON consists of a node located at the root of the tree assuming the role of OLT, and multiple nodes located at the tree leaves assuming roles of ONUs. The network operates by allowing only a single ONU to transmit in the upstream direction at a time. The MPCP located at the OLT is responsible for timing the different transmissions. Reporting of congestion by the different ONUs may assist in optimally allocating the bandwidth across the PON.

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Automatic discovery of end stations is performed, culminating in registration through binding of an ONU to an OLT port by allocation of a Logical Link ID (see LLID in 76.2.6.1.3.2), and dynamic binding to a MAC connected to the OLT.

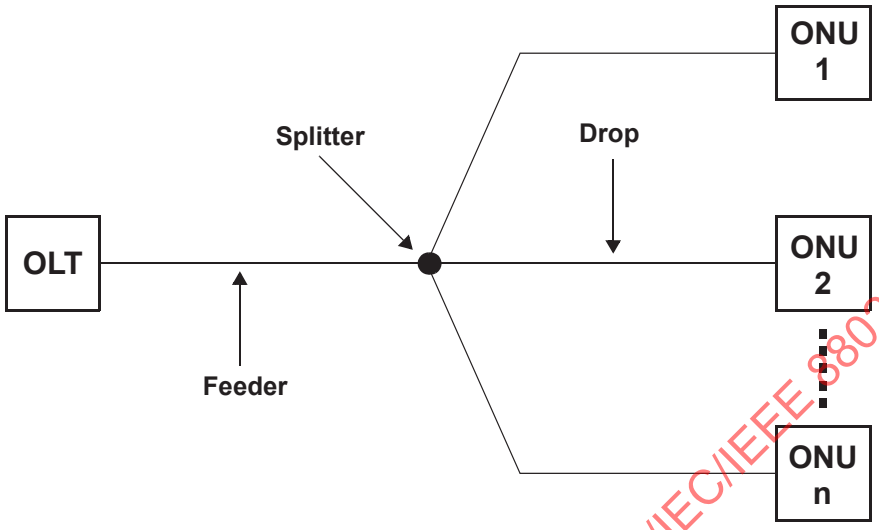

Figure 77–1—PON topology example

The Multipoint MAC Control functionality shall be implemented for subscriber access devices containing point-to-multipoint Physical Layer devices defined in Clause 75.

77.1.1 Goals and objectives

The goals and objectives of this clause are the definition of a point-to-multipoint Ethernet network utilizing an optical medium.

Specific objectives met include the following:

a) Support of point-to-point Emulation (P2PE) as specified
b) Support multiple LLIDs and MAC Clients at the OLT
c) Support a single LLID per ONU
d) Support a mechanism for single copy broadcast
e) Flexible architecture allowing dynamic allocation of bandwidth
f) Use of 32 bit timestamp for timing distribution
g) MAC Control based architecture
h) Ranging of discovered devices for improved network performance
i) Continuous ranging for compensating round trip time variation

77.1.2 Position of Multipoint MAC Control within the IEEE 802.3 hierarchy

Multipoint MAC Control defines the MAC control operation for optical point-to-multipoint networks. Figure 77–2 and Figure 77–3 depict the architectural positioning of the Multipoint MAC Control sublayer with respect to the MAC and the MAC Control client. The Multipoint MAC Control sublayer takes the place of the MAC Control sublayer to extend it to support multiple clients and additional MAC control functionality.

Multipoint MAC Control is defined using the mechanisms and precedents of the MAC Control sublayer. The MAC Control sublayer has extensive functionality designed to manage the real-time control and manipulation of MAC sublayer operation. This clause specifies the extension of the MAC Control

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mechanism to manipulate multiple underlying MACs simultaneously. This clause also specifies a specific protocol implementation for MAC Control.

The Multipoint MAC Control sublayer is specified such that it can support new functions to be implemented and added to this standard in the future. MultiPoint Control Protocol (MPCP), the management protocol for P2MP is one of these protocols. Non-real-time, or quasi-static control (e.g., configuration of MAC operational parameters) is provided by Layer Management. Operation of the Multipoint MAC Control sublayer is transparent to the MAC.

As depicted in Figure 77–2 and Figure 77–3, the layered system instantiates multiple MAC entities, using a single Physical Layer. The individual MAC instances offer a point-to-point emulation service between the OLT and the ONU. An additional MAC is instantiated to communicate to all 10G–EPON ONUs at once. This instance takes maximum advantage of the broadcast nature of the downstream channel by sending a single copy of a frame that is received by all 10G–EPON ONUs. This MAC instance is referred to as Single Copy Broadcast (SCB).

The ONU only requires one MAC instance since frame filtering operations are done at the RS layer before reaching the MAC. Therefore, MAC and layers above are emulation-agnostic at the ONU (see 76.2.6.1.3).

Although Figure 77–2 and Figure 77–3 and supporting text describe multiple MACs within the OLT, a single unicast MAC address may be used by the OLT. Within the EPON Network, MACs are uniquely identified by their LLIDs, which are dynamically assigned by the registration process.

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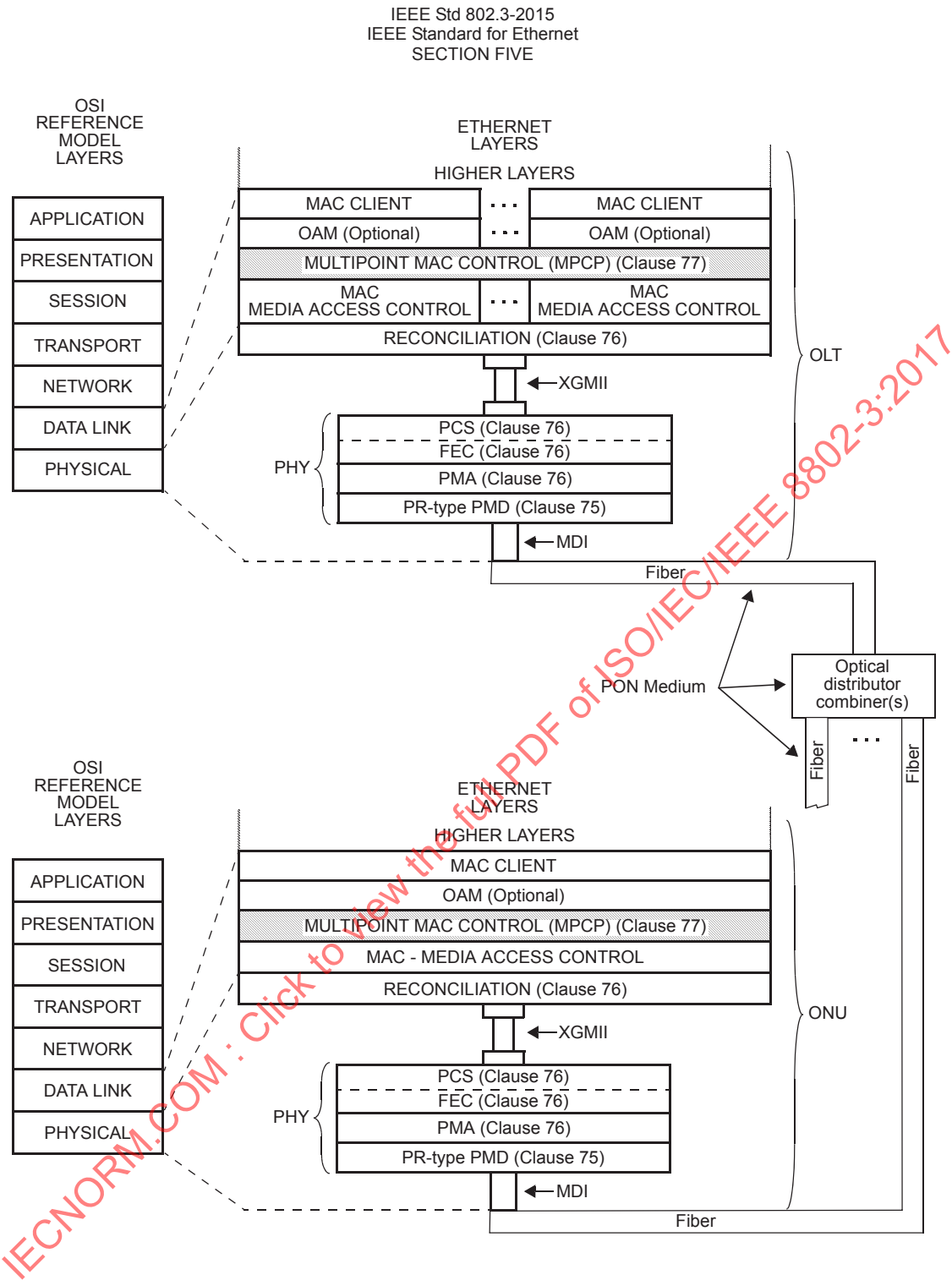

Figure 77–2—Relationship of Multipoint MAC Control and the OSI protocol stack for 10/10G–EPON (10 Gb/s downstream and 10 Gb/s upstream)

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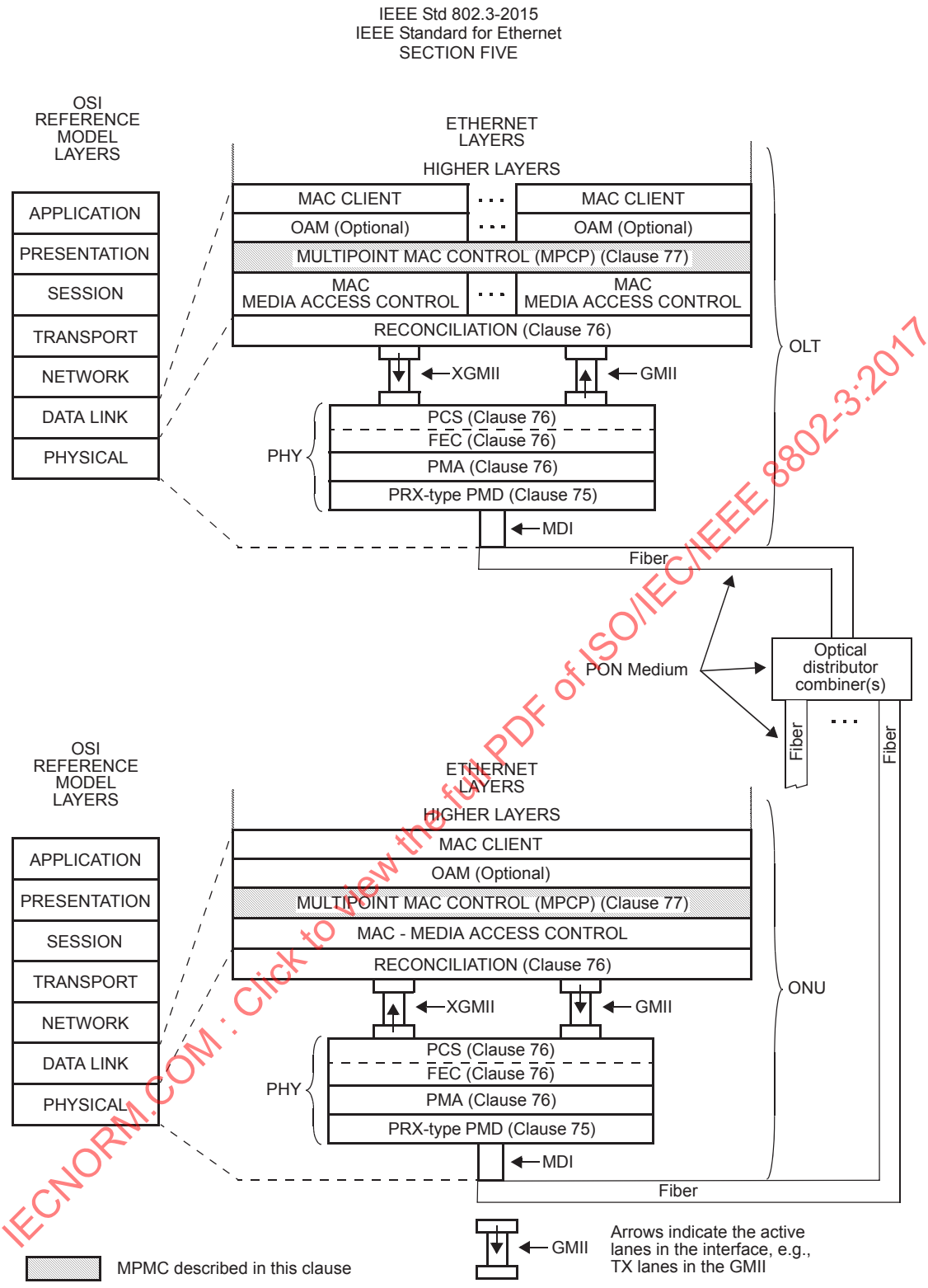

XGMII= 10 GIGABIT MEDIA INDEPENDENT INTERFACE
GMII = GIGABIT MEDIA INDEPENDENT INTERFACE
MDI = MEDIUM DEPENDENT INTERFACE
OAM = OPERATIONS, ADMINISTRATION & MAINTENANCE
OLT = OPTICAL LINE TERMINAL
ONU = OPTICAL NETWORK UNIT
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

Figure 77–3—Relationship of Multipoint MAC Control and the OSI protocol stack for 10/1G–EPON (10 Gb/s downstream and 1 Gb/s upstream)

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77.1.3 Functional block diagram

Figure 77–4 provides a functional block diagram of the Multipoint MAC Control architecture.

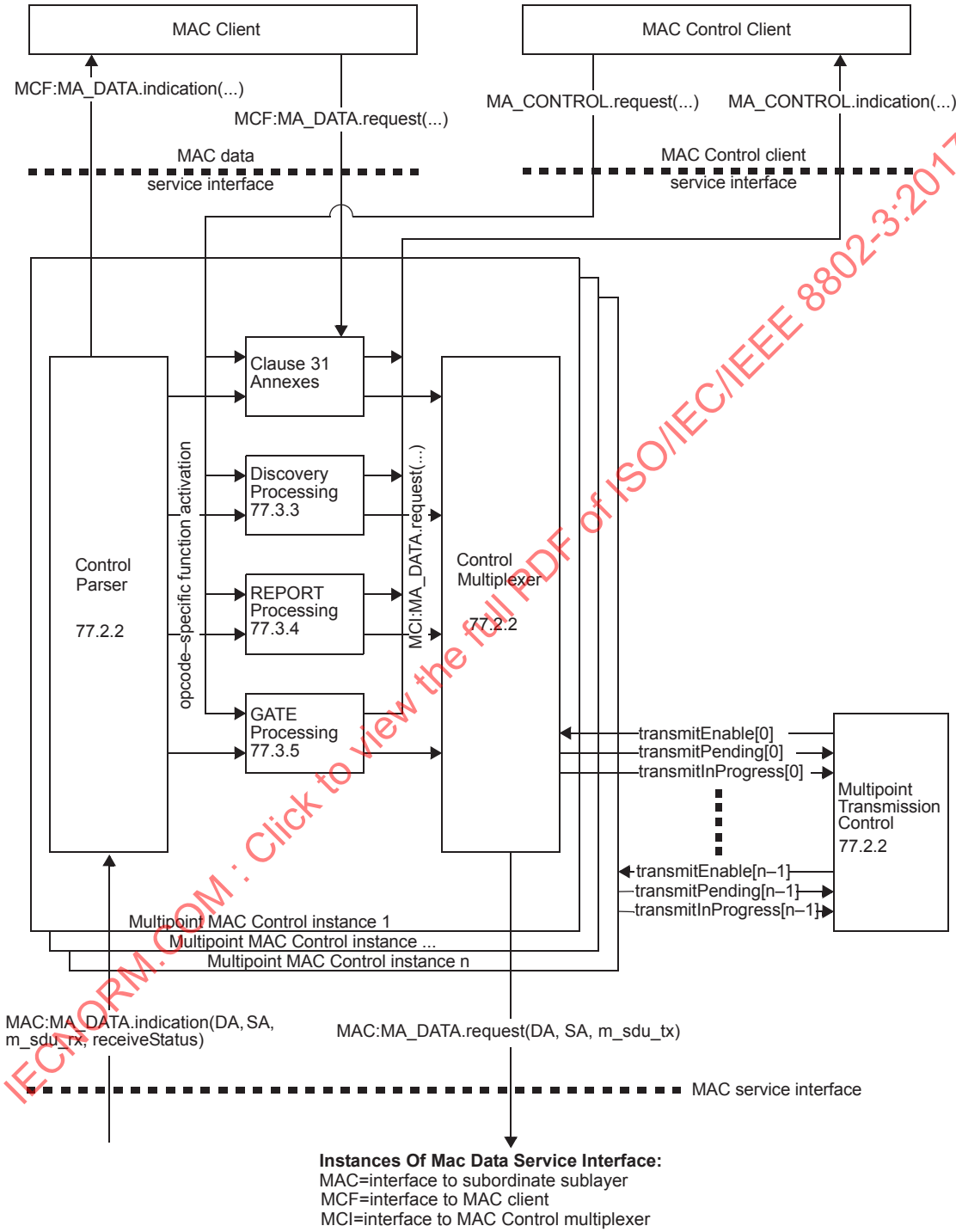

Figure 77–4—Multipoint MAC Control functional block diagram

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77.1.4 Service interfaces

The MAC Client communicates with the Control Multiplexer using the standard service interface specified in 2.3. Multipoint MAC Control communicates with the underlying MAC sublayer using the standard service interface specified in Annex 4A.3.2. Similarly, Multipoint MAC Control communicates internally using primitives and interfaces consistent with definitions in Clause 31.

77.1.5 State diagram conventions

The body of this standard comprises state diagrams, including the associated definitions of variables, constants, and functions. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails.

The notation used in the state diagrams follows the conventions of 21.5. State diagram timers follow the conventions of 14.2.3.2 augmented as follows:

a) [start x_timer, y] sets expiration of *y* to timer *x_timer*.
b) [stop x_timer] aborts the timer operation for *x_timer* asserting *x_timer_not_done* indefinitely.

The state diagrams use an abbreviation MACR as a shorthand form for MA_CONTROL.request and MACI as a shorthand form for MA_CONTROL.indication.

The vector notations used in the state diagrams for bit vector use 0 to mark the first received bit and so on (for example data[0:15]), following the conventions of 3.1 for bit ordering. When referring to an octet vector, 0 is used to mark the first received octet and so on (for example m_sdu[0..1]).

a < *b*: A function that is used to compare two (cyclic) time values. Returned value is true when *b* is larger than *a* allowing for wrap around of *a* and *b*. The comparison is made by subtracting *b* from *a* and testing the MSB. When MSB(*a*–*b*) = 1 the value true is returned, else false is returned. In addition, the following functions are defined in terms of *a* < *b*:
a > *b* is equivalent to !(*a* < *b* or *a* = *b*)
a ≥ *b* is equivalent to !(*a* < *b*)
a ≤ *b* is equivalent to !(*a* > *b*)

77.2 Multipoint MAC Control operation

As depicted in Figure 77–4, the Multipoint MAC Control functional block comprises the following functions:

a) *Multipoint Transmission Control*. This block is responsible for synchronizing Multipoint MAC Control instances associated with the Multipoint MAC Control. This block maintains the Multipoint MAC Control state and controls the multiplexing functions of the instantiated MACs.
b) *Multipoint MAC Control Instance n*. This block is instantiated for each MAC and respective MAC and MAC Control clients associated with the Multipoint MAC Control. It holds all the variables and state associated with operating all MAC Control protocols for the instance.
c) *Control Parser*. This block is responsible for parsing MAC Control frames, and interfacing with Clause 31 entities, the opcode specific blocks, and the MAC Client.
d) *Control Multiplexer*. This block is responsible for selecting the source of the forwarded frames.
e) *Clause 31 annexes*. This block holds MAC Control actions as defined in Clause 31 annexes for support of legacy and future services.
f) *Discovery, Report, and Gate Processing*. These blocks are responsible for handling the MPCP in the context of the MAC.

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77.2.1 Principles of Multipoint MAC Control

As depicted in Figure 77–4, Multipoint MAC Control sublayer may instantiate multiple Multipoint MAC Control instances in order to interface multiple MAC and MAC Control clients above with multiple MACs below. A unique unicast MAC instance is used at the OLT to communicate with each ONU. The individual MAC instances utilize the point-to-point emulation service between the OLT and the ONU as defined in 76.2.

At the ONU, a single MAC instance is used to communicate with a MAC instance at the OLT. In that case, the Multipoint MAC Control contains only a single instance of the Control Parser/Multiplexer function.

Multipoint MAC Control protocol supports several MAC and client interfaces. Only a single MAC interface and Client interface is enabled for transmission at a time. There is a tight mapping between a MAC service interface and a Client service interface. In particular, the assertion of the MAC:MA_DATA.indication primitive in MAC *j* leads to the assertion of the MCF:MA_DATA.indication primitive to Client *j*. Conversely, the assertion of the request service interface in Client *i* leads to the assertion of the MAC:MA_DATA.request primitive of MAC *i*. Note that the Multipoint MAC sublayer need not receive and transmit packets associated with the same interface at the same time. Thus the Multipoint MAC Control acts like multiple MAC Controls bound together with common elements.

The scheduling algorithm is implementation dependent, and is not specified for the case where multiple transmit requests happen at the same time.

The reception operation is as follows. The Multipoint MAC Control instances generate MAC:MA_DATA.indication service primitives continuously to the underlying MAC instances. Since these MACs are receiving frames from a single PHY only one frame is passed from the MAC instances to Multipoint MAC Control. The MAC instance responding to the MAC:MA_DATA.indication is referred to as the enabled MAC, and its service interface is referred to as the enabled MAC interface. The MAC passes to the Multipoint MAC Control sublayer all valid frames. Invalid frames, as specified in 3.4, are not passed to the Multipoint MAC Control sublayer in response to a MAC:MA_DATA.indication service primitive.

The enabling of a transmit service interface is performed by the Multipoint MAC Control instance in collaboration with the Multipoint Transmission Control. Frames generated in the MAC Control are given priority over MAC Client frames, in effect, prioritizing the MA_CONTROL primitive over the MCF:MA_DATA primitive, and for this purpose MCF:MA_DATA.request primitives may be delayed, discarded or modified in order to perform the requested MAC Control function. For the transmission of this frame, the Multipoint MAC Control instance enables forwarding by the MAC Control functions, but the MAC Client interface is not enabled. The reception of a frame in a MAC results in generation of the MAC:MA_DATA.indication primitive on that MAC's interface. Only one receive MAC interface is enabled at any given time since there is only one PHY interface.

The information of the enabled interfaces is stored in the controller state variables, and accessed by the Multiplexing Control block.

The Multipoint MAC Control sublayer uses the services of the underlying MAC sublayer to exchange both data and control frames.

Receive operation (MAC:MA_DATA.indication) at each instance:

a) A frame is received from the underlying MAC
b) The frame is parsed according to Length/Type field
c) MAC Control frames are demultiplexed according to opcode and forwarded to the relevant processing functions
d) Data frames (see 31.5.1) are forwarded to the MAC Client by asserting MCF:MA_DATA.indication primitives

Transmit operation (MAC:MA_DATA.request) at each instance:

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e) The MAC Client signals a frame transmission by asserting MCF:MA_DATA.request, or

f) A protocol processing block attempts to issue a frame, as a result of a previous MA_CONTROL.request or as a result of an MPCP event that generates a frame.

g) When allowed to transmit by the Multipoint Transmission Control block, the frame is forwarded.

77.2.1.1 Ranging and timing process

Both the OLT and the ONU have 32 bit counters that increment every 16 ns. These counters provide a local time stamp. When either device transmits an MPCPDU, it maps its counter value into the timestamp field. The time of transmission of the first octet of the MPCPDU frame from the MAC Control to the MAC is taken as the reference time used for setting the timestamp value.

When the ONU receives MPCPDUs, it sets its counter according to the value in the timestamp field in the received MPCPDU.

When the OLT receives MPCPDUs, it uses the received timestamp value to calculate or verify a round trip time between the OLT and the ONU. The Round Trip Time (RTT) is equal to the difference between the timer value and the value in the timestamp field. The calculated RTT is notified to the client via the MA_CONTROL.indication primitive. The client can use this RTT for the ranging process.

A condition of *timestamp drift error* occurs when the difference between OLT's and ONU's clocks exceeds some predefined threshold. This condition can be independently detected by the OLT or an ONU. The OLT detects this condition when an absolute difference between new and old RTT values measured for a given ONU exceeds the value of guardThresholdOLT (see 77.2.2.1), as shown in Figure 77–11. An ONU detects the timestamp drift error condition when absolute difference between a timestamp received in an MPCPDU and the localTime counter exceeds guardThresholdONU (see 77.2.2.1), as is shown in Figure 77–12.

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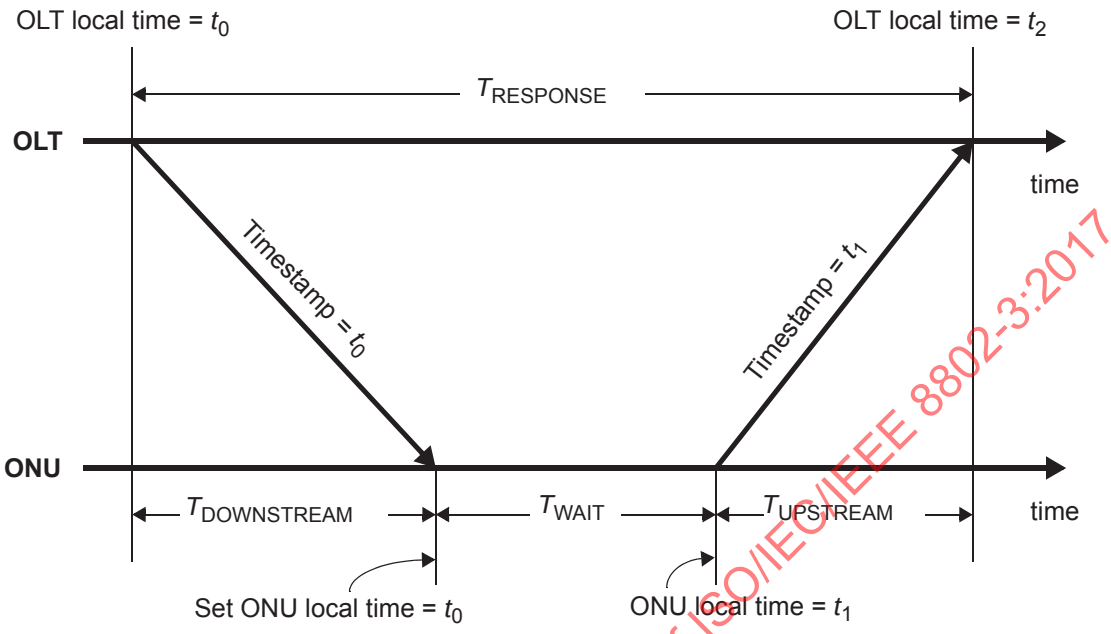

$T_{DOWNSTREAM}$ = downstream propagation delay

$T_{UPSTREAM}$ = upstream propagation delay

T_{WAIT} = wait time at ONU = $t_1 - t_0$

$T_{RESPONSE}$ = response time at OLT = $t_2 - t_0$

$$RTT = T_{DOWNSTREAM} + T_{UPSTREAM} = T_{RESPONSE} - T_{WAIT} = (t_2 - t_0) - (t_1 - t_0) = t_2 - t_1$$

Figure 77–5—Round trip time calculation

77.2.2 Multipoint transmission control, Control Parser, and Control Multiplexer

The purpose of the multipoint transmission control is to allow only one of the multiple MAC clients to transmit to its associated MAC and subsequently to the RS layer at one time by only asserting one transmitEnable signal at a time.

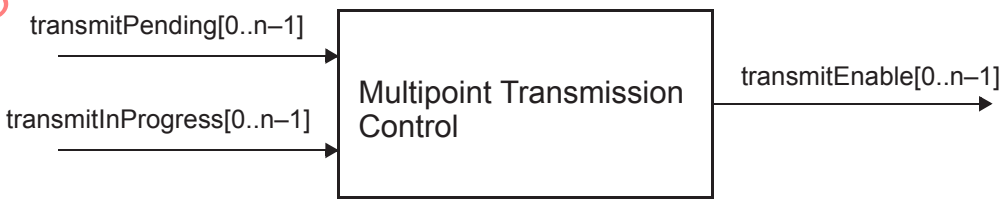

Figure 77–6—Multipoint Transmission Control service interfaces

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Multipoint MAC Control Instance n function block communicates with the Multipoint Transmission Control using transmitEnable[n], transmitPending[n], and transmitInProgress[n] state variables (see Figure 77–4).

The Control Parser is responsible for opcode independent parsing of MAC frames in the reception path. By identifying MAC Control frames, demultiplexing into multiple entities for event handling is possible. Interfaces are provided to existing Clause 31 entities, functional blocks associated with MPCP, and the MAC Client.

The Control Multiplexer is responsible for forwarding frames from the MAC Control opcode-specific functions and the MAC Client to the MAC. Multiplexing is performed in the transmission direction. Given multiple MCF:MA_DATA.request primitives from the MAC Client, and MA_CONTROL.request primitives from the MAC Control Clients, a single MAC:MA_DATA.request service primitive is generated for transmission. At the OLT, multiple MAC instances share the same Multipoint MAC Control, as a result, the transmit block is enabled based on an external control signal housed in Multipoint Transmission Control for transmission overlap avoidance. At the ONU, the Gate Processing functional block interfaces for upstream transmission administration.

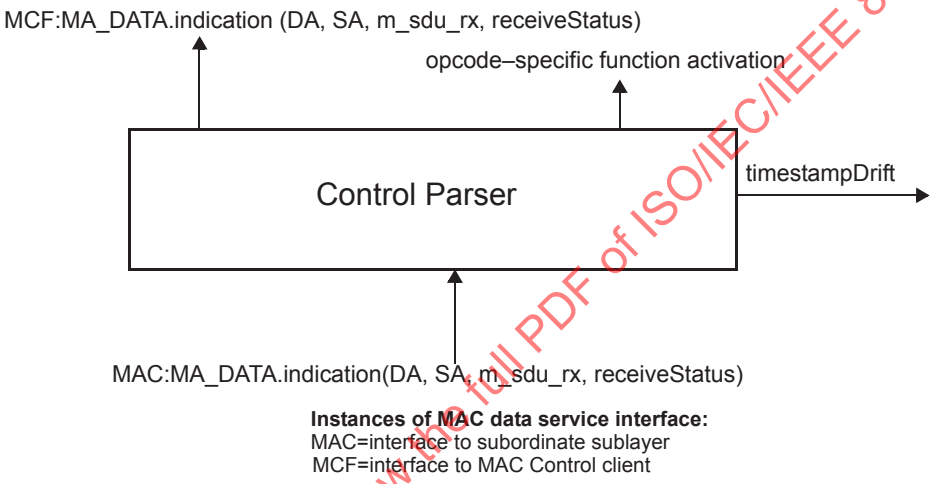
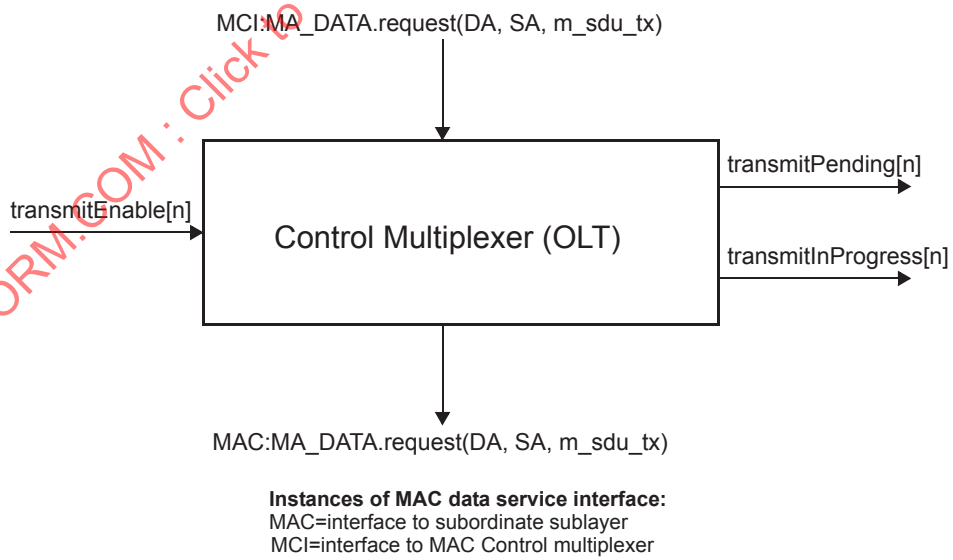


Figure 77–7—Control Parser service interfaces



NOTE—MAC:MA_DATA.request primitive may be issued from multiple MAC Control processing blocks.

Figure 77–8—OLT Control Multiplexer service interfaces

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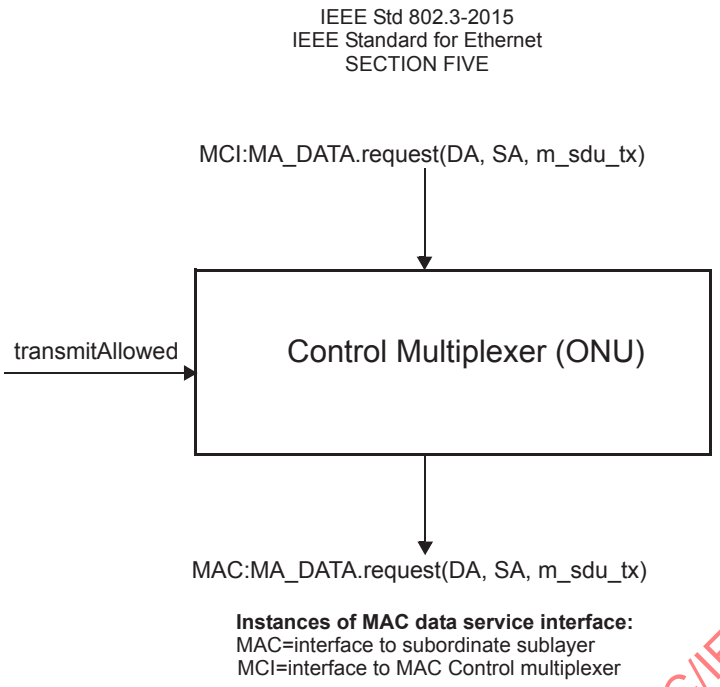

NOTE—MAC:MA_DATA.request primitive may be issued from multiple MAC Control processing blocks.

Figure 77–9—ONU Control Multiplexer service interfaces

77.2.2.1 Constants

FEC_CODEWORD_SIZE
TYPE: integer
This constant represents the size of FEC codeword in octets (FEC_PAYLOAD_SIZE + FEC_PARITY_SIZE).
Value: 248

FEC_PARITY_SIZE
TYPE: integer
This constant represents the size of FEC codeword parity field in octets.
Value: 32

FEC_PAYLOAD_SIZE
TYPE: integer
This constant represents the size of FEC codeword payload in octets.
VALUE: 216

guardThresholdOLT
TYPE: integer
This constant holds the maximum amount of drift allowed for a timestamp received at the OLT. This value is measured in units of time_quantum.
VALUE: 12

guardThresholdONU
TYPE: integer
This constant holds the maximum amount of drift allowed for a timestamp received at the ONU. This value is measured in units of time_quantum.
VALUE: 8

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MAC_Control_type
TYPE: integer
The value of the Length/Type field as defined in 31.4.1.3.
VALUE: 0x8808

tailGuard
TYPE: integer
This constant holds the value used to reserve space at the end of the upstream transmission at the ONU in addition to the size of last MAC service data unit (m_sdu) in units of octets. Space is reserved for the MAC overheads including: preamble, SFD, DA, SA, Length/Type, FCS, and minimum interpacket gap. The sizes of the above listed MAC overhead items are described in 3.1.1. The size of the minimum IPG is described in 4A.4.2.
VALUE: 38

time_quantum
This variable is defined in 64.2.2.1.

tqSize
TYPE: integer
This constant represents time_quantum in octet transmission times.
VALUE: 20

77.2.2.2 Counters

localTime
TYPE: 32 bit unsigned
This variable holds the value of the local timer used to control MPCP operation. This variable is advanced by a timer at 62.5 MHz, and counts in time_quanta. At the OLT the counter shall track the transmit clock, while at the ONU the counter shall track the receive clock. For accuracy of receive clock see 76.4.1.2. It is reloaded with the received timestamp value (from the OLT) by the Control Parser (see Figure 77–12). Changing the value of this variable while running using Layer Management is highly undesirable and is unspecified.

77.2.2.3 Variables

BEGIN
TYPE: Boolean
This variable is used when initiating operation of the functional block state diagram. It is set to true following initialization and every reset.

fecOffset
TYPE: 32 bit unsigned
A variable that advances by 1 after every 8 bit times. After reaching the value of FEC_CODEWORD_SIZE, this variable is reset to zero. In the OLT, this variable is initialized to 0 at system initialization. In the ONU, this variable is assigned in the ONU Control Multiplexer state diagram (see Figure 77–14).
NOTE—Notation fecOffset[1:0] refers to two least significant bits of this variable.

data_rx
TYPE: bit array
This variable represents a 0–based bit array corresponding to the payload of a received MPCPDU. This variable is used to parse incoming MPCPDU frames.

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data_tx
TYPE: bit array
This variable represents a 0-based bit array corresponding to the payload of an MPCPDU being transmitted. This variable is used to access payload of outgoing MPCPDU frames, for example to set the timestamp value.

grantStart
TYPE: Boolean
This variable indicates beginning of a grant transmission. It is set to true in the GATE Processing ONU Activation state diagram (see Figure 77–30) when a new grant activates. It is reset to false after the transmission of the first frame in the grant (see Figure 77–14). This variable is defined in ONU only.

IdleGapCount
TYPE: 32-bit unsigned
This variable represents length of gap between subsequent frames, expressed in the unit of octet time. This variable advances by 1 after every 8-bit times.

newRTT
TYPE: 16 bit unsigned
This variable temporary holds a newly–measured Round Trip Time to the ONU. The new RTT value is represented in units of time_quanta.

m_sdu_rx
TYPE: bit array
Equal to the concatenation of the Length/Type and data_rx variables.

m_sdu_tx
TYPE: bit array
Equal to the concatenation of the Length/Type and data_tx variables.

m_sdu_ctl
TYPE: bit array
Equal to the concatenation of the MAC_Control_type and data_tx variables.

OctetsRemaining
TYPE: 32 bit unsigned
This variable is an alias for the expression (((stopTime – localTime) × tqSize) – tqOffset). It denotes the number of octets that can be transmitted between the current time and the end of the grant.

OctetsRequired
TYPE: 16 bit unsigned
This variable represents a total transmission time of next packet and is used to check whether the next packet fits in the remainder of ONU's transmission window. The value of OctetsRequired includes packet transmission time, tailGuard defined in 77.2.2.1, and FEC parity data overhead. This variable is measured in units of octets.

opcode_rx
TYPE: 16 bit unsigned
This variable holds an opcode of the last received MPCPDU.

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opcode_tx
TYPE: 16 bit unsigned
This variable holds an opcode of an outgoing MPCPDU.

packet_initiate_delay
TYPE: 16 bit unsigned
This variable is used to set the time–out interval for packet_initiate_timer defined in 77.2.2.5. The packet_initiate_delay value is represented in units of octets.

ResetBound
TYPE: 32-bit unsigned
This variable represents the value of DelayBound (see 76.3.1.2) expressed in units of octet time (i.e., ResetBound = 8 * DelayBound).

RTT
TYPE: 16 bit unsigned
This variable holds the measured Round Trip Time to the ONU. The RTT value is represented in units of time_quanta.

stopTime
TYPE: 32 bit unsigned
This variable holds the value of the localTime counter corresponding to the end of the nearest grant. This value is set by the Gate Processing function as described in 77.3.5.

timestamp
TYPE: 32 bit unsigned
This variable holds the value of timestamp of the last received MPCPDU frame.

timestampDrift
TYPE: Boolean
This variable is used to indicate whether an error is signaled as a result of uncorrectable timestamp drift.

tqOffset
TYPE: 8 bit unsigned
This variable denotes the offset (in octet times) of the current actual time from the localTime variable (which maintains the current time in units of time_quanta).

transmitAllowed
TYPE: Boolean
This variable is used to control PDU transmission at the ONU. It is set to true when the transmit path is enabled, and is set to false when the transmit path is being shut down. transmitAllowed changes its value according to the state of the Gate Processing functional block.

transmitEnable
TYPE: Boolean array
This array contains one element per each Multipoint MAC Control instance. Elements of this array are used to control the transmit path in the Multipoint MAC Control instance at the OLT. Setting an element to TRUE indicates that the selected instance is permitted to transmit a frame. Setting it to FALSE inhibits the transmission of frames in the selected instance. Only one element of transmitEnable should be set to TRUE at a time.

transmitInProgress
TYPE: Boolean array

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This array contains one element per each Multipoint MAC Control instance. The element *j* of this array set to on indicates that the Multipoint MAC Control instance *j* is in the process of transmitting a frame.

transmitPending
TYPE: Boolean array
This array contains one element per each Multipoint MAC Control instance. The element *j* of this array set to on indicates that the Multipoint MAC Control instance *j* is ready to transmit a frame.

77.2.2.4 Functions

abs(n)
This function returns the absolute value of the parameter n.

Opcode–specific function(opcode)
Functions exported from opcode specific blocks that are invoked on the arrival of a MAC Control message of the appropriate opcode.

CheckGrantSize(length)
This function calculates the future time at which the transmission of the current frame (including the FEC parity overhead) is completed.

$$\text{CheckGrantSize}(\text{length}) = \left\lceil \frac{\text{fecOffset} + \text{length}}{\text{FEC_PAYLOAD_SIZE}} \right\rceil \times \text{FEC_CODEWORD_SIZE} - \text{fecOffset}$$

NOTE—The notation $\lceil x \rceil$ represents a *ceiling* function, which returns the value of its argument *x* rounded up to the nearest integer.

FEC_Overhead(length)
This function calculates the additional amount of time (in octet times) that the MPCP control multiplexer waits following transmission of a frame of size 'length' by the MAC. The additional time is added to allow the insertion of parity data into the frame by the PHY layer. As described in 76.3.2.4, FEC encoder adds 32 parity octets for each block of 216 data or control octets. FEC_Overhead() returns the number of octets that the PHY inserts during transmission of a particular packet and its subsequent IPG. Parameter 'length' represents the size of an entire frame including preamble, SFD, DA, SA, Length/Type, FCS, and IPG. The following formula is used to calculate the overhead:

$$\text{FEC_Overhead}(\text{length}) = 12 + \text{FEC_PARITY_SIZE} \times \left\lfloor \frac{\text{fecOffset} + \text{length}}{\text{FEC_PAYLOAD_SIZE}} \right\rfloor$$

NOTE—The notation $\lfloor x \rfloor$ represents a *floor* function, which returns the value of its argument *x* rounded down to the nearest integer.

select()
This function selects the next Multipoint MAC Control instance allowed to initiate transmission of a frame. The function returns an index to the transmitPending array for which the value is not false. The selection criteria in the presence of multiple active elements in the list is implementation dependent.

SelectFrame()
This function enables the interface, which has a pending frame. If multiple interfaces have frames waiting at the same time, only one interface is enabled. The selection criteria is not specified, except for the case when some of the pending frames have Length/Type = MAC_Control. In this case, one of the interfaces with a pending MAC Control frame shall be enabled.

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sizeof(sdu)
This function returns the size of the sdu in octets.

transmissionPending()
This function returns true if any of the Multipoint MAC Control instances has a frame waiting to be transmitted. The function can be represented as:

```
transmissionPending() =
   transmitPending[0] +
   transmitPending[1] +
   ... +
   transmitPending[n-1]
```

where n is the total number of Multipoint MAC Control instances.

77.2.2.5 Timers

packet_initiate_timer
This timer is used to delay frame transmission from MAC Control to avoid variable MAC delay while MAC enforces IPG after a previous frame. In addition, this timer increases interframe spacing just enough to accommodate the extra parity data to be added by the FEC encoder.

77.2.2.6 Messages

MAC:MA_DATA.indication(DA, SA, m_sdu, receiveStatus)
The service primitive is defined in 31.3.

MCF:MA_DATA.indication(DA, SA, m_sdu, receiveStatus)
The service primitive is defined in 31.3.

MAC:MA_DATA.request (DA, SA, m_sdu)
The service primitive is defined in 31.3. The action invoked by this service primitive is not considered to end until the transmission of the frame by the MAC has concluded. The ability of the MAC control layer to determine this is implementation dependent.

MCF:MA_DATA.request (DA, SA, m_sdu)
The service primitive is defined in 31.3.

77.2.2.7 State diagrams

The Multipoint transmission control function in the OLT shall implement state diagram shown in Figure 77–10. Control parser function in the OLT shall implement state diagram shown in Figure 77–11. Control parser function in the ONU shall implement state diagram shown in Figure 77–12. Control multiplexer function in the OLT shall implement state diagram shown in Figure 77–13. Control multiplexer function in the ONU shall implement state diagram shown in Figure 77–14.

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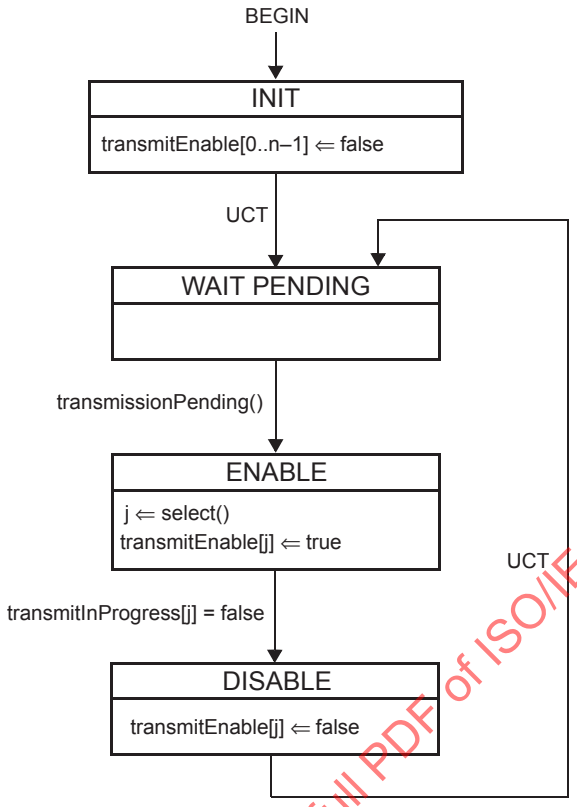

Figure 77–10—OLT Multipoint Transmission Control state diagram

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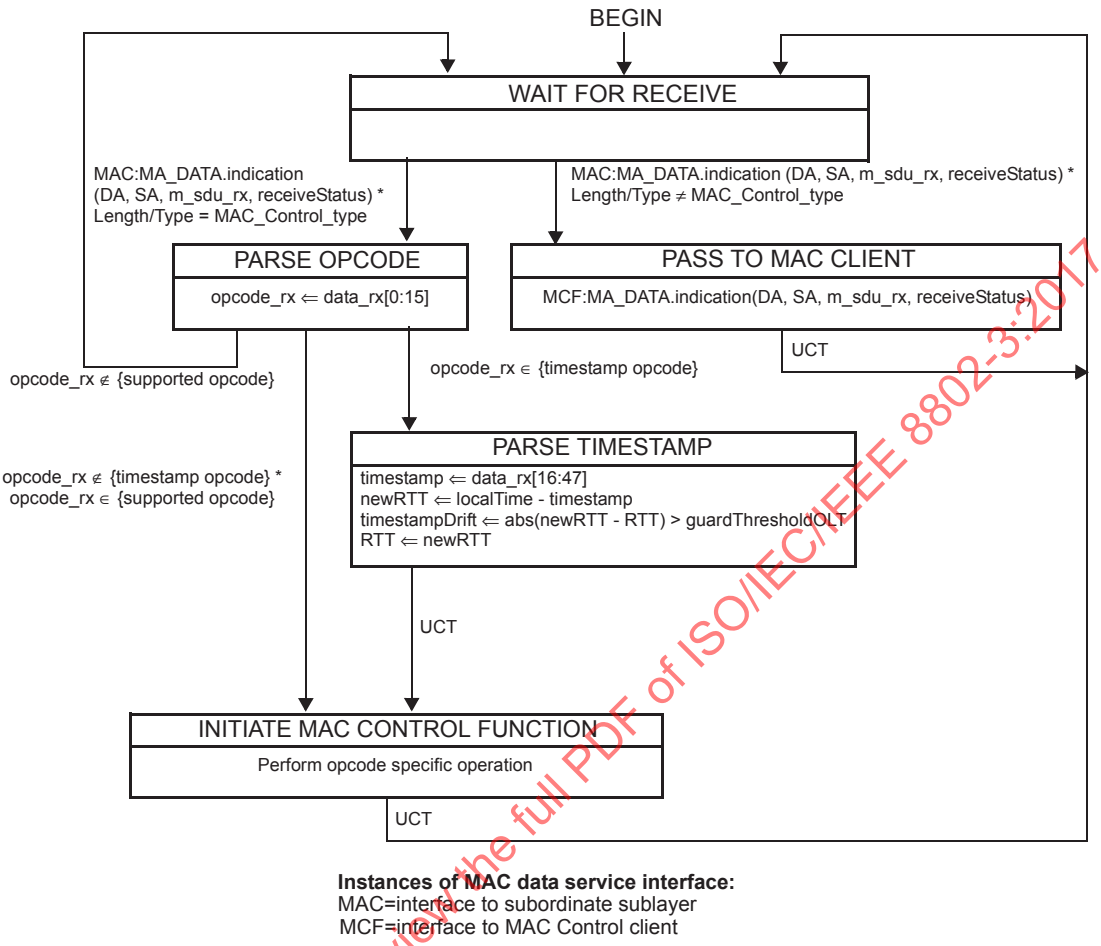

Instances of MAC data service interface:
MAC=interface to subordinate sublayer
MCF=interface to MAC Control client

NOTE—The opcode–specific operation is launched as a parallel process by the MAC Control sublayer, and not as a synchronous function. Progress of the generic MAC Control Receive state diagram (as shown in this figure) is not implicitly impeded by the launching of the opcode specific function.

Refer to Annex 31A for list of supported opcodes and timestamp opcodes.

Figure 77–11—OLT Control Parser state diagram

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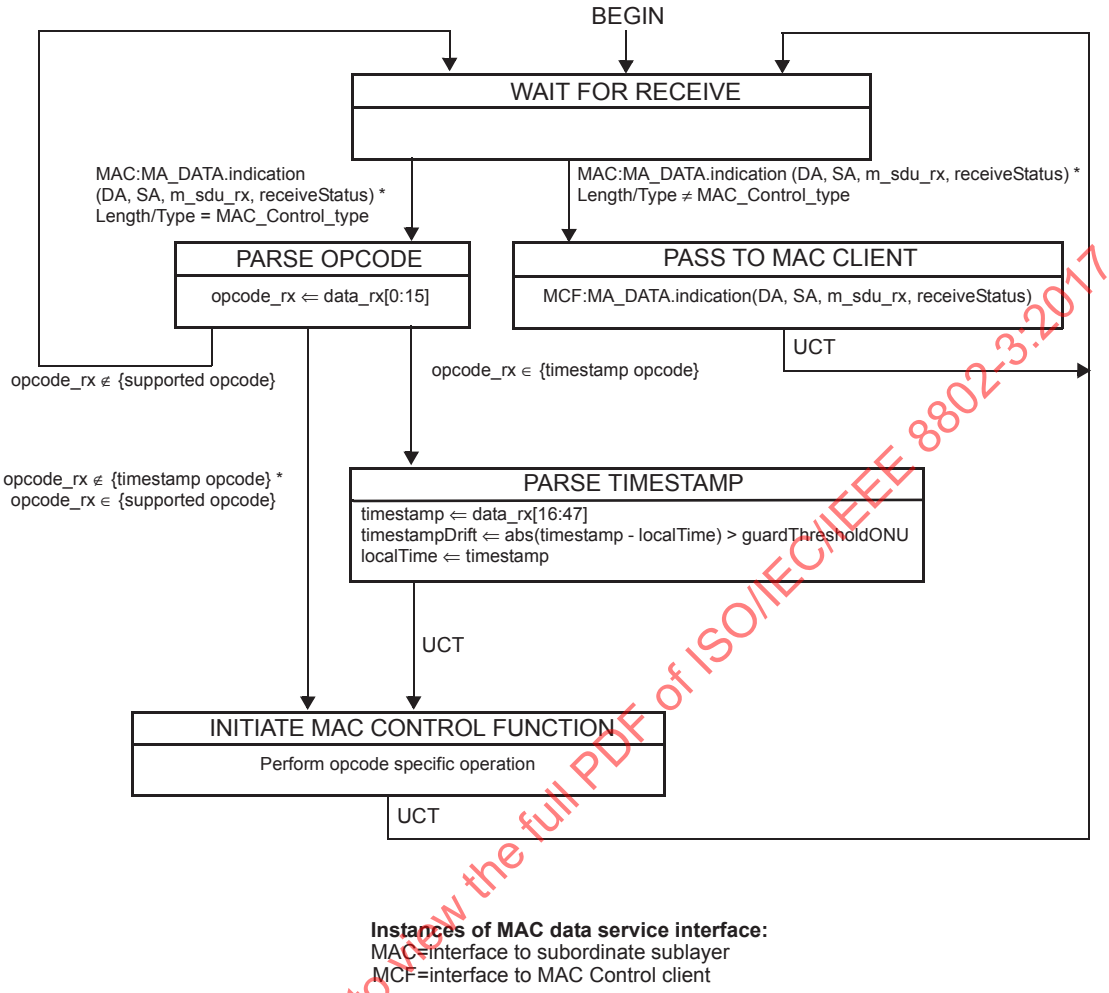

Instances of MAC data service interface:
MAC=interface to subordinate sublayer
MCF=interface to MAC Control client

NOTE—The opcode–specific operation is launched as a parallel process by the MAC Control sublayer, and not as a synchronous function. Progress of the generic MAC Control Receive state diagram (as shown in this figure) is not implicitly impeded by the launching of the opcode specific function.

Refer to Annex 31A for list of supported opcodes and timestamp opcodes.

Figure 77–12—ONU Control Parser state diagram

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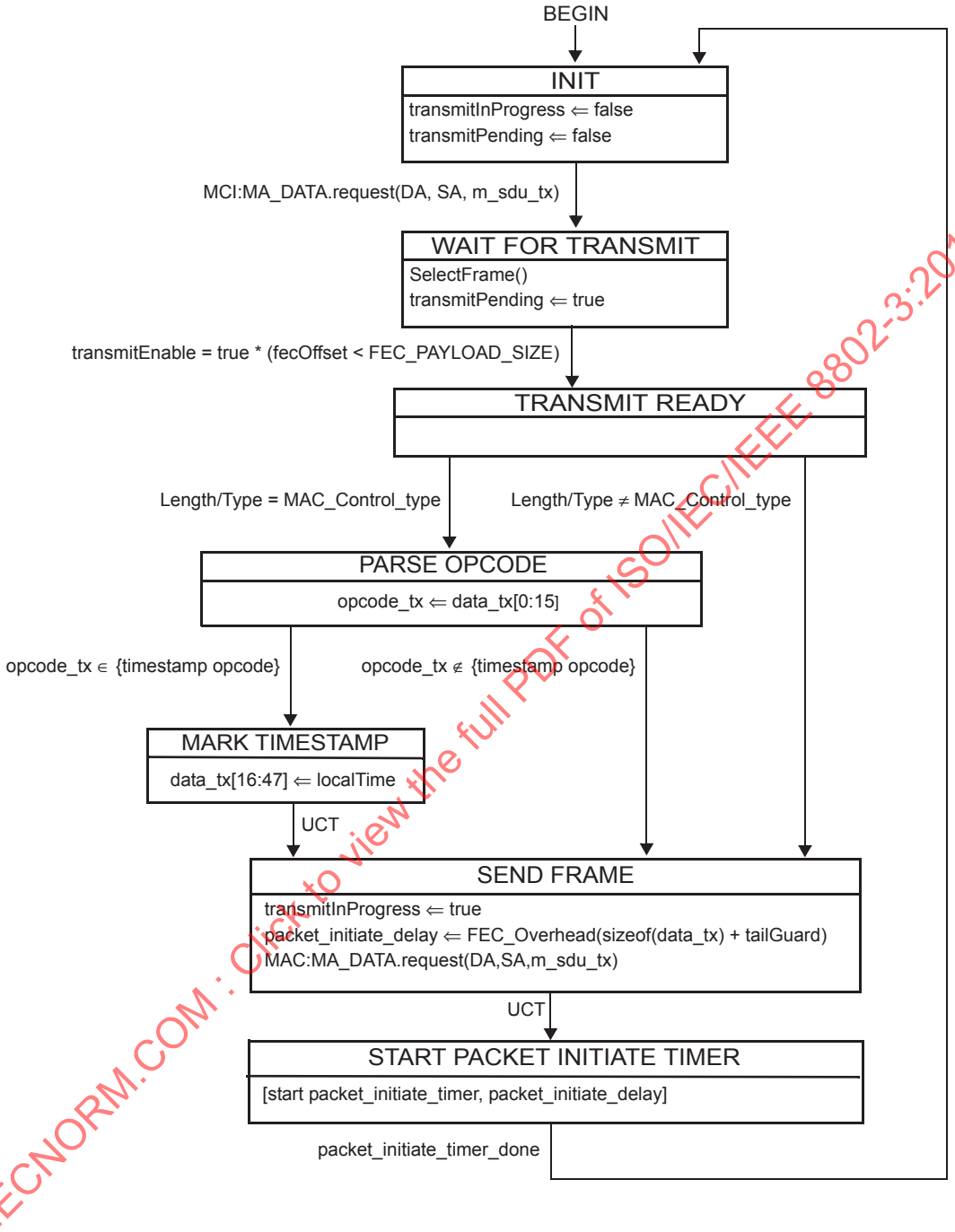

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Instances of MAC data service interface:
MAC=interface to subordinate sublayer
MCI=interface to MAC Control multiplexer

Figure 77–13—OLT Control Multiplexer state diagram

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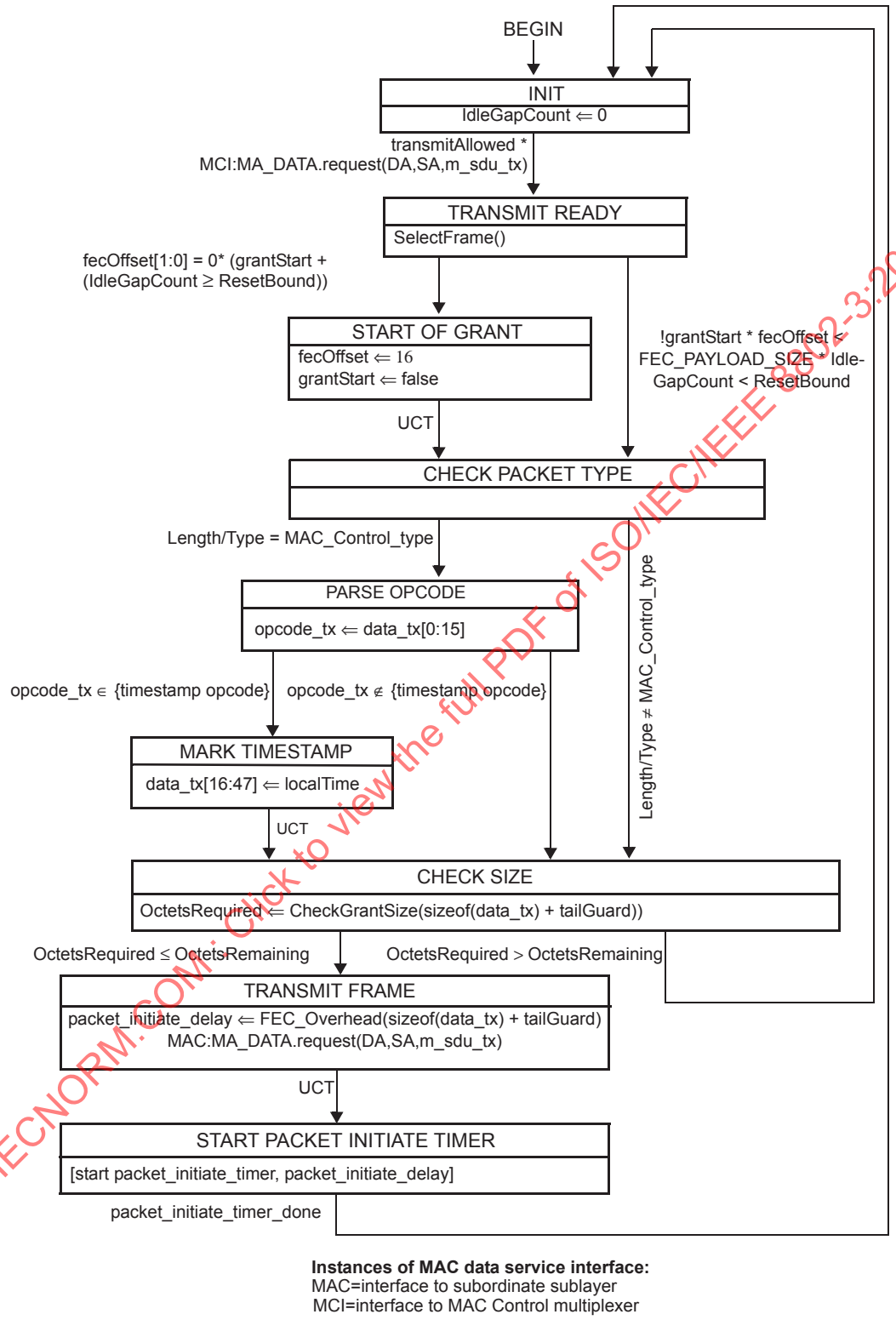

Instances of MAC data service interface:
MAC=interface to subordinate sublayer
MCI=interface to MAC Control multiplexer

Figure 77–14—ONU Control Multiplexer state diagram

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77.3 Multipoint Control Protocol (MPCP)

As depicted in Figure 77–4, the Multipoint MAC Control functional block comprises the following functions:

a) *Discovery Processing*. This block manages the discovery process, through which an ONU is discovered and registered with the network while compensating for RTT.
b) *Report Processing*. This block manages the generation and collection of report messages, through which bandwidth requirements are sent upstream from the ONU to the OLT.
c) *Gate Processing*. This block manages the generation and collection of gate messages, through which multiplexing of multiple transmitters is achieved.

As depicted in Figure 77–4, the layered system may instantiate multiple MAC entities, using a single Physical Layer. Each instantiated MAC communicates with an instance of the opcode specific functional blocks through the Multipoint MAC Control. In addition some global variables are shared across the multiple instances. Common state control is used to synchronize the multiple MACs using MPCP procedures. Operation of the common state control is generally considered outside the scope of this document.

77.3.1 Principles of Multipoint Control Protocol

Multipoint MAC Control enables a MAC Client to participate in a point-to-multipoint optical network by allowing it to transmit and receive frames as if it was connected to a dedicated link. In doing so, it employs the following principles and concepts:

a) A MAC client transmits and receives frames through the Multipoint MAC Control sublayer.
b) The Multipoint MAC Control decides when to allow a frame to be transmitted using the client interface Control Multiplexer.
c) Given a transmission opportunity, the MAC Control may generate control frames that would be transmitted in advance of the MAC Client's frames, utilizing the inherent ability to provide higher priority transmission of MAC Control frames over MAC Client frames.
d) Multiple MACs operate on a shared medium by allowing only a single MAC to transmit upstream at any given time across the network using a time-division multiple access (TDMA) method.
e) Such gating of transmission is orchestrated through the Gate Processing function.
f) New devices are discovered in the network and allowed transmission through the Discovery Processing function.
g) Fine control of the network bandwidth distribution can be achieved using feedback mechanisms supported in the Report Processing function.
h) The operation of P2MP network is asymmetric, with the OLT assuming the role of master, and the ONU assuming the role of slave.

77.3.2 Compatibility considerations

77.3.2.1 PAUSE operation

Even though MPCP is compatible with flow control, optional use of flow control may not be efficient in the case of large propagation delay. If flow control is implemented, then the timing constraints in Annex 31B supplement the constraints found at 77.3.2.4.

NOTE—MAC at an ONU can receive frames from unicast channel and SCB channel. If the SCB channel is used to broadcast data frames to multiple ONUs, the ONU's MAC may continue receiving data frames from SCB channel even after the ONU has issued a PAUSE request to its unicast remote-end.

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77.3.2.2 Optional Shared LAN emulation

By combining P2PE, suitable filtering rules at the ONU, and suitable filtering and forwarding rules at the OLT, it is possible to emulate an efficient shared LAN. Support for shared LAN emulation is optional, and requires an additional layer above the MAC, which is out of scope for this document. Thus, shared LAN emulation is introduced here for informational purposes only.

Specific behavior of the filtering layer at the RS is specified in 76.2.6.1.3.2.

77.3.2.3 Multicast and single copy broadcast support

In the downstream direction, the PON is a broadcast medium. In order to make use of this capability for forwarding broadcast frames from the OLT to multiple recipients without multiple duplication for each ONU, the SCB and multicast LLID support is introduced.

The OLT has at least one MAC associated with every ONU. In addition one more MAC at the OLT is marked as the SCB MAC. Moreover, the OLT has a multicast MAC associated with each defined multicast LLID. The SCB MAC handles all downstream broadcast traffic, but is never used in the upstream direction for client traffic, except for client registration. Similarly, the multicast MACs handle downstream multicast traffic, but are never used in the upstream direction for client traffic. Optional higher layers may be implemented to perform selective broadcast and multicast of frames. Such layers may require additional MACs (multicast MACs) to be instantiated in the OLT for some or all ONUs increasing the total number of MACs beyond the number of ONUs + 1.

When connecting the SCB MAC or a multicast MAC to an IEEE 802.1D bridge port it is possible that loops may be formed due to the broadcast or multicast nature of the associated LLIDs. Thus it is recommended that this MAC not be connected to an IEEE 802.1D bridge port.

Configuration of SCB channels as well as filtering and marking of frames for support of SCB is defined in 76.2.6.1.3.2 for 10G–EPON compliant Reconciliation Sublayers.

77.3.2.4 Delay requirements

The MPCP protocol relies on strict timing based on distribution of timestamps. A compliant implementation needs to guarantee a constant delay through the MAC and PHY in order to maintain the correctness of the timestamping mechanism. The actual delay is implementation dependent; however, a complying implementation shall maintain a delay variation of no more than 1 time_quantum through the MAC.

The OLT shall not grant less than 1024 time_quanta into the future, in order to allow the ONU processing time when it receives a gate message. The ONU shall process all messages in less than this period. The OLT shall not issue more than one message every 1024 time_quanta to a single ONU. The unit of time_quantum is defined in 77.2.2.1.

77.3.3 Discovery processing

Discovery is the process whereby newly connected or off-line ONUs are provided access to the PON. The process is driven by the OLT, which periodically makes available Discovery Windows during which off-line ONUs are given the opportunity to make themselves known to the OLT. The periodicity of these windows is unspecified and left up to the implementer. The OLT signifies that a discovery period is occurring by broadcasting a discovery GATE MPCPDU, which includes the starting time and length of the discovery window, along with the Discovery Information flag field, as defined in 77.3.6.1. With the appropriate settings of individual flags contained in this 16 bit wide field, the OLT notifies all the ONUs about its upstream and downstream channel transmission capabilities. Note that the OLT may simultaneously support more than one data rate in the given transmission direction.

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Off-line ONUs, upon receiving a Discovery GATE MPCPDU, wait for the period to begin and then transmit a REGISTER_REQ MPCPDU to the OLT. Discovery windows are unique in that they are the only times when multiple ONUs can access the PON simultaneously, and transmission overlap can occur. In order to reduce transmission overlaps, a contention algorithm is used by all ONUs. Measures are taken to reduce the probability for overlaps by artificially simulating a random distribution of distances from the OLT. Each ONU waits a random amount of time before transmitting the REGISTER_REQ MPCPDU that is shorter than the length of the discovery window. It should be noted that multiple valid REGISTER_REQ MPCPDUs can be received by the OLT during a single discovery window. Included in the REGISTER_REQ MPCPDU is the ONU's MAC address and number of maximum pending grants. Additionally, a registering ONU notifies the OLT of its transmission capabilities in the upstream and downstream channels by setting appropriately the flags in the Discovery Information field, as specified in 77.3.6.3.

Note that even though a compliant ONU is not prohibited from supporting more than one data rate in any transmission channel, it is expected that a single supported data rate for upstream and downstream channel is indicated in the Discovery Information field. Moreover, in order to assure maximum utilization of the upstream channel and to decrease the required size of the guard band between individual data bursts, the registering ONU notifies the OLT of the laser on/off times, by setting appropriate values in the Laser On Time and Laser Off Time fields, where both values are expressed in the units of time_quanta.

Upon receipt of a valid REGISTER_REQ MPCPDU, the OLT registers the ONU, allocating and assigning a new port identity (LLID), and bonding a corresponding MAC to the LLID.

The next step in the process is for the OLT to transmit a REGISTER MPCPDU to the newly discovered ONU, which contains the ONU's LLID, and the OLT's required synchronization time. Moreover, the OLT echoes the maximum number of pending grants. The OLT also sends the target value of laser on time and laser off time, which may be different than laser on time and laser off time delivered by the ONU in the REGISTER_REQ MPCPDU.

The OLT now has enough information to schedule the ONU for access to the PON and transmits a standard GATE message allowing the ONU to transmit a REGISTER_ACK. Upon receipt of the REGISTER_ACK, the discovery process for that ONU is complete, the ONU is registered and normal message traffic can begin. It is the responsibility of Layer Management to perform the MAC bonding, and start transmission from/to the newly registered ONU. The discovery message exchange is illustrated in Figure 77–15.

There may exist situations when the OLT requires that an ONU go through the discovery sequence again and reregister. Similarly, there may be situations where an ONU needs to inform the OLT of its desire to deregister. The ONU can then reregister by going through the discovery sequence. For the OLT, the REGISTER message may indicate a value, Reregister or Deregister, that if either is specified forces the receiving ONU into reregistering. For the ONU, the REGISTER_REQ message contains the Deregister bit that signifies to the OLT that this ONU should be deregistered.

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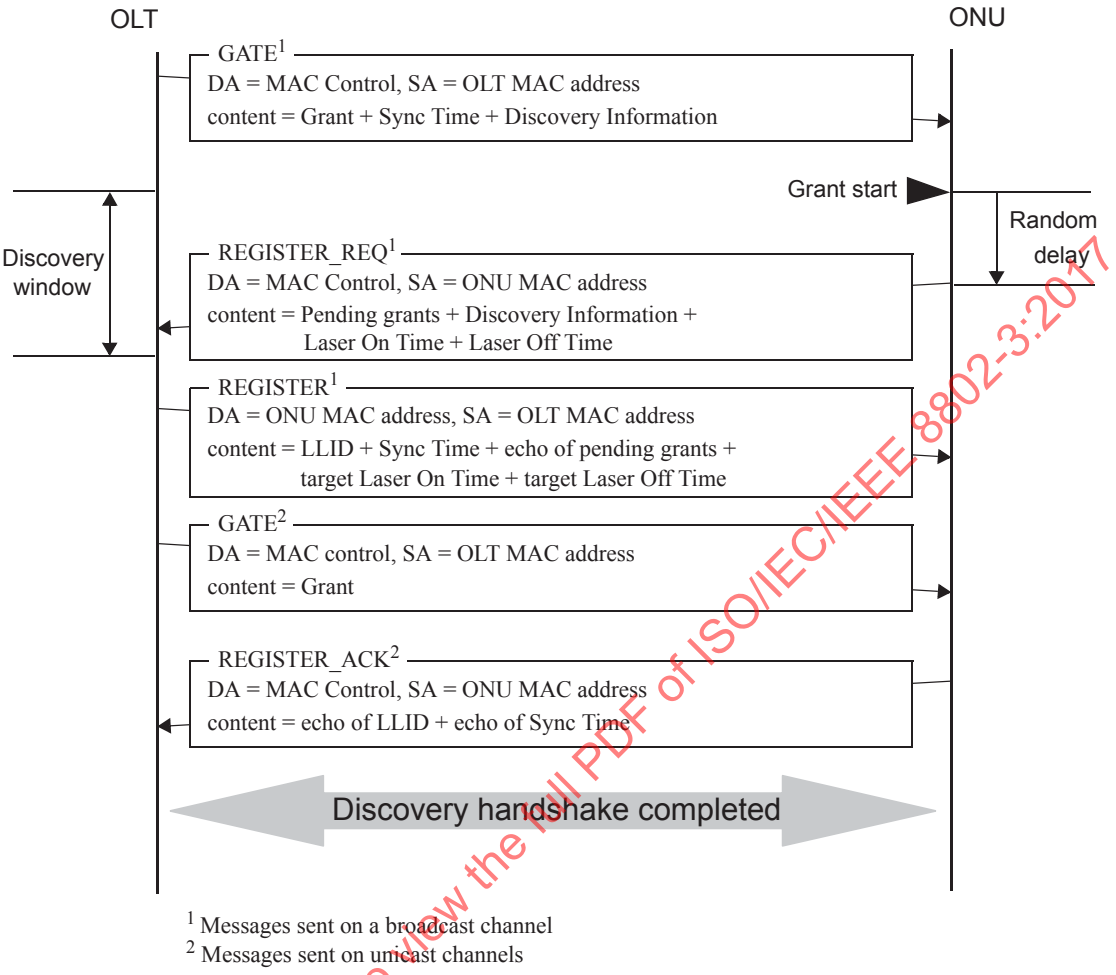

[1] Messages sent on a broadcast channel
[2] Messages sent on unicast channels

Figure 77–15—Discovery handshake message exchange

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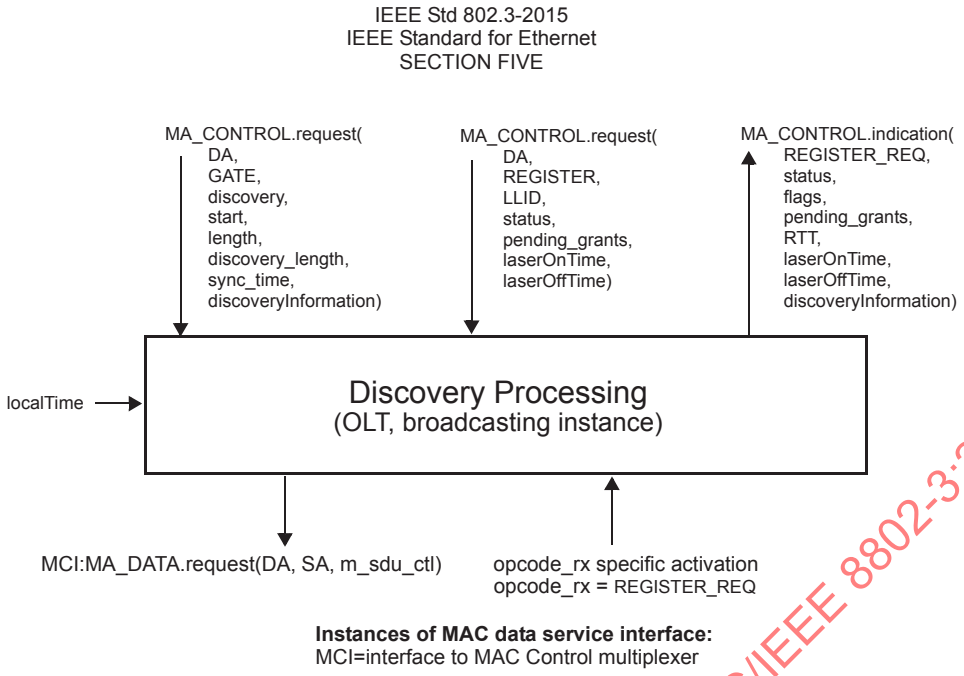

Figure 77–16—Discovery Processing service interfaces (OLT, broadcasting instance)

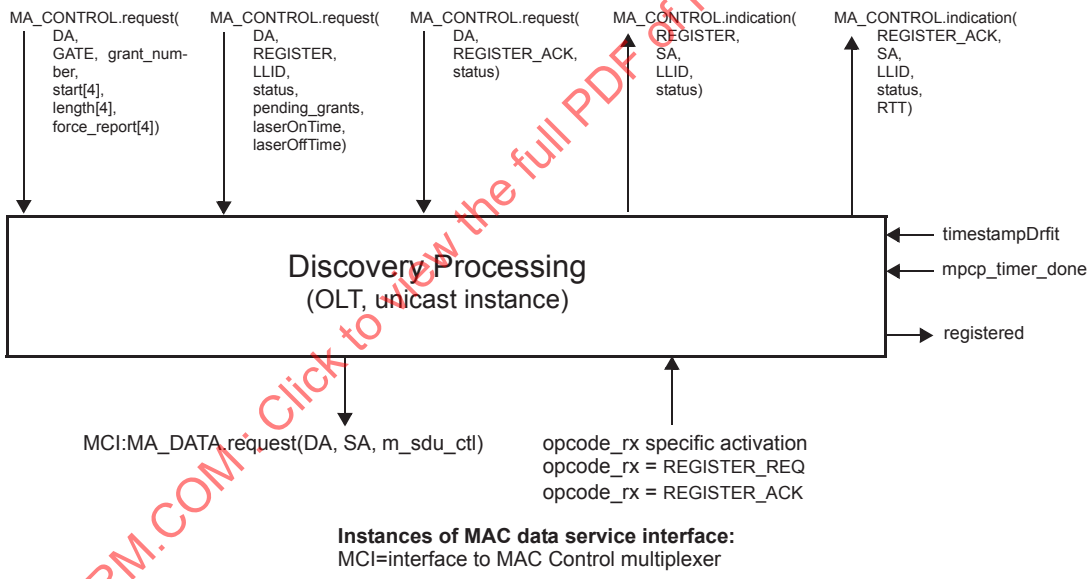

Figure 77–17—Discovery Processing service interfaces (OLT, unicasting instance)

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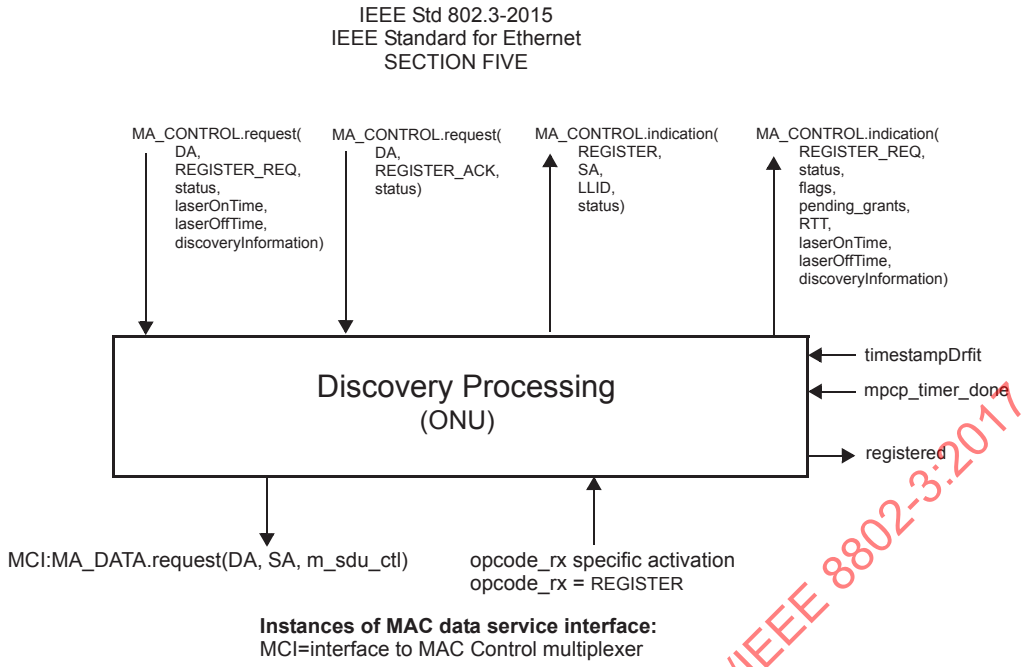

Figure 77–18—Discovery Processing service interfaces (ONU)

77.3.3.1 Constants

laserOffTimeCapability

TYPE: 8 bit unsigned

This constant represents the time required to terminate the laser, in units of time_quantum. While the default value corresponds to a maximum allowed T_{off} (as specified in Table 75–8 and Table 75–9), implementations may set it to the actual value time period required for turning off the PMD, as specified in 75.7.14.

VALUE: 0x20 (512 ns, default value)

laserOnTimeCapability

TYPE: 8 bit unsigned

This constant represents the time required to initialize the laser, in units of time_quantum. While the default value corresponds to a maximum allowed T_{on} (as specified in Table 75–8 and Table 75–9), implementations may set it to the actual value time period required for turning on the PMD, as specified in 75.7.14.

VALUE: 0x20 (512 ns, default value)

77.3.3.2 Variables

BEGIN

This variable is defined in 77.2.2.3.

data_rx

This variable is defined in 77.2.2.3.

data_tx

This variable is defined in 77.2.2.3.

grantEndTime

TYPE: 32 bit unsigned

This variable holds the time at which the OLT expects the ONU grant to complete. Failure of a

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REGISTER_ACK message from an ONU to arrive at the OLT before grantEndTime is a fatal error in the discovery process, and causes registration to fail for the specified ONU, who may then retry to register. The value of grantEndTime is measured in units of time_quantum.

insideDiscoveryWindow
TYPE: Boolean
This variable holds the current status of the discovery window. It is set to true when the discovery window opens, and is set to false when the discovery window closes.

laserOffTime
TYPE: 8 bit unsigned
This variable holds the time required to terminate the laser. It counts in time_quanta units the time period required for turning off the PMD, as specified by the value of T_{off} in 75.7.14.
VALUE: laserOffTimeCapability (default value)

laserOnTime
TYPE: 8 bit unsigned
This variable holds the time required to initiate the PMD. It counts in time_quanta units the time period required for turning on the PMD, as specified by the value of T_{on} in 75.7.14.
VALUE: laserOnTimeCapability (default value)

localTime
This variable is defined in 77.2.2.2.

m_sdu_ctl
This variable is defined in 77.2.2.3.

opcode_rx
This variable is defined in 77.2.2.3.

pendingGrants
TYPE: 16 bit unsigned
This variable holds the maximum number of pending grants that an ONU is able to queue.

registered
TYPE: Boolean
This variable holds the current result of the Discovery Process. It is set to true once the discovery process is complete and registration is acknowledged.

syncTime
TYPE: 16 bit unsigned
This variable holds the time required to stabilize the receiver at the OLT. It counts time_quanta units from the point where transmission output is stable to the point where synchronization has been achieved. The value of syncTime includes gain adjustment interval ($T_{receiver_settling}$), clock synchronization interval (T_{CDR}), and code–group alignment interval ($T_{code_group_align}$), as specified in 75.7.14. The OLT conveys the value of syncTime to ONUs in Discovery GATE and REGISTER messages. During the synchronization time a 10/1G–EPON ONU transmits only IDLE patterns, and a 10/10G–EPON ONU sends synchronization pattern (SP, see 76.3.2.5.2) followed by burst delimiter pattern (BURST_DELIMITER, see 76.3.2.5.2).

timestampDrift
This variable is defined in 77.2.2.3.

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77.3.3.3 Functions

None.

77.3.3.4 Timers

discovery_window_size_timer
: This timer is used to wait for the event signaling the end of the discovery window.
VALUE: The timer value is set dynamically based on the parameters received in a DISCOVERY GATE message.

mpcp_timer
: This timer is used to measure the arrival rate of MPCP frames in the link. Failure to receive frames is considered a fatal fault and leads to deregistration.

77.3.3.5 Messages

MA_DATA.indication(DA, SA, m_sdu, receiveStatus)
: The service primitive is defined in 2.3.2.

MA_DATA.request (DA, SA, m_sdu)
: The service primitive is defined in 2.3.2.

MA_CONTROL.request(DA, GATE, discovery, start, length, discovery_length, sync_time, discoveryInformation)
: The service primitive is used by the MAC Control client at the OLT to initiate the Discovery Process. This primitive takes the following parameters:

DA:	Multicast or unicast MAC address.
GATE:	Opcode for GATE MPCPDU as defined in Table 31A–1.
discovery:	Flag specifying that the given GATE message is to be used for discovery only.
start:	Start time of the discovery window.
length:	Length of the grant given for discovery.
discovery_length:	Length of the discovery window process.
sync_time:	The time interval required to stabilize the receiver at the OLT.
discoveryInformation:	This parameter represents the Discovery Information field in GATE MPCPDU as specified in 77.3.6.1, defining the speed(s) the OLT is capable of receiving and speed(s) at which the discovery window is opened for.

MA_CONTROL.request(DA, GATE, grant_number, start[4], length[4], force_report[4])
: This service primitive is used by the MAC Control client at the OLT to issue the GATE message to an ONU. This primitive takes the following parameters:

DA:	Multicast MAC Control address as defined in Annex 31B.
GATE:	Opcode for GATE MPCPDU as defined in Table 31A–1.
grant_number:	Number of grants issued with this GATE message. The number of grants ranges from 0 to 4.
start[4]:	Start times of the individual grants. Only the first grant_number elements of the array are used.
length[4]:	Lengths of the individual grants. Only the first grant_number elements of the array are used.

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force_report[4]: Flags indicating whether a REPORT message should be generated in the corresponding grant. Only the first grant_number elements of the array are used.

MA_CONTROL.request(DA, REGISTER_REQ, status, laserOnTime, laserOffTime, discoveryInformation)

The service primitive is used by a client at the ONU to request the Discovery Process to perform a registration. This primitive takes the following parameters:

DA: Multicast MAC Control address as defined in Annex 31B.

REGISTER_REQ: opcode for REGISTER_REQ MPCPDU as defined in Table 31A–1.

status: This parameter takes on the indication supplied by the flags field in the REGISTER_REQ MPCPDU as defined in Table 77–5.

laserOnTime: This parameter holds the laserOnTime value, expressed in units of time_quanta, as reported by MAC client and specified in 77.3.6.3.

laserOffTime: This parameter holds the laserOffTime value, expressed in units of time_quanta, as reported by MAC client and specified in 77.3.6.3.

discoveryInformation: This parameter represents the Discovery Information field, as specified in 77.3.6.3, defining the speed(s) the ONU is capable of transmitting and speed(s) at which the registration attempt is made.

MA_CONTROL.indication(REGISTER_REQ, status, flags, pending_grants, RTT, laserOnTime, laserOffTime, discoveryInformation)

The service primitive is issued by the Discovery Process to notify the client and Layer Management that the registration process is in progress. This primitive takes the following parameters:

REGISTER_REQ: Opcode for REGISTER_REQ MPCPDU as defined in Table 31A–1.

status: This parameter holds the values incoming or retry. Value incoming is used at the OLT to signal that a REGISTER_REQ message was received successfully. The value retry is used at the ONU to signal to the client that a registration attempt failed and needs to be repeated.

flags: This parameter holds the contents of the flags field in the REGISTER_REQ message. This parameter holds a valid value only when the primitive is generated by the Discovery Process in the OLT.

pending_grants: This parameter holds the contents of the pending_grants field in the REGISTER_REQ message. This parameter holds a valid value only when the primitive is generated by the Discovery Process in the OLT.

RTT: The measured round trip time to/from the ONU is returned in this parameter. RTT is stated in time_quanta units. This parameter holds a valid value only when the primitive is generated by the Discovery Process in the OLT.

laserOnTime: This parameter holds the contents of the laserOnTime field in the REGISTER_REQ message. This parameter holds a valid value only when the primitive is generated by the Discovery Process in the OLT.

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laserOffTime: This parameter holds the contents of the laserOffTime field in the REGISTER_REQ message. This parameter holds a valid value only when the primitive is generated by the Discovery Process in the OLT.

discoveryInformation: This parameter holds the contents of the Discovery Information field in the REGISTER_REQ MPCPDU. This parameter holds a valid value only when the primitive is generated by the Discovery process in the OLT.

MA_CONTROL.request(DA, REGISTER, LLID, status, pending_grants, laserOnTime, laserOffTime)

The service primitive is used by the MAC Control client at the OLT to initiate acceptance of an ONU. This primitive takes the following parameters:

DA: Unicast MAC address or multicast MAC Control address as defined in Annex 31B.

REGISTER: Opcode for REGISTER MPCPDU as defined in Table 31A–1.

LLID: This parameter holds the logical link identification number assigned by the MAC Control client.

status: This parameter takes on the indication supplied by the flags field in the REGISTER MPCPDU as defined in Table 77–7.

pending_grants: This parameters echoes back the pending_grants field that was previously received in the REGISTER_REQ message.

laserOnTime: This parameter carries the target value of Laser On Time for the given ONU transmitter. This value may be different than the laserOnTime value carried in the REGISTER_REQ MPCPDU received from the corresponding ONU MAC during Discovery stage.

laserOffTime: This parameter carries the target value of Laser Off Time for the given ONU transmitter. This value may be different than the laserOffTime value carried in the REGISTER_REQ MPCPDU received from the corresponding ONU MAC during Discovery stage.

MA_CONTROL.indication(REGISTER, SA, LLID, status)

This service primitive is issued by the Discovery Process at the OLT or an ONU to notify the MAC Control client and Layer Management of the result of the change in registration status. This primitive takes the following parameters:

REGISTER: Opcode for REGISTER MPCPDU as defined in Table 31A–1.

SA: This parameter represents the MAC address of the OLT.

LLID: This parameter holds the logical link identification number assigned by the MAC Control client.

status: This parameter holds the value of accepted / denied / deregistered / reregistered.

MA_CONTROL.request(DA, REGISTER_ACK, status)

This service primitive is issued by the MAC Control clients at the ONU and the OLT to acknowledge the registration. This primitive takes the following parameters:

DA: Multicast MAC Control address as defined in Annex 31B.

REGISTER_ACK: Opcode for REGISTER_ACK MPCPDU as defined in Table 31A–1.

status: This parameter takes on the indication supplied by the flags field in the REGISTER MPCPDU as defined in Table 77–8.

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MA_CONTROL.indication(REGISTER_ACK, SA, LLID, status, RTT)

This service primitive is issued by the Discovery Process at the OLT to notify the client and Layer Management that the registration process has completed. This primitive takes the following parameters:

REGISTER_ACK: Opcode for REGISTER_ACK MPCPDU as defined in Table 31A–1.

SA: This parameter represents the MAC address of the reciprocating device (ONU address at the OLT, and OLT address at the ONU).

LLID: This parameter holds the logical link identification number assigned by the MAC Control client.

status: This parameter holds the value of accepted/denied/reset/deregistered.

RTT: The measured round trip time to/from the ONU is returned in this parameter. RTT is stated in time_quanta units. This parameter holds a valid value only when the invoking Discovery Process in the OLT.

Opcode-specific function(opcode)

Functions exported from opcode specific blocks that are invoked on the arrival of a MAC Control message of the appropriate opcode.

77.3.3.6 State Diagrams

The Discovery Process in the OLT shall implement the discovery window setup state diagram shown in Figure 77–19, request processing state diagram as shown in Figure 77–20, register processing state diagram as shown in Figure 77–21, and final registration state diagram as shown in Figure 77–22. The discovery process in the ONU shall implement the registration state diagram as shown in Figure 77–23.

Instantiation of state diagrams as described in Figure 77–19, Figure 77–20, and Figure 77–21 is performed only at the Multipoint MAC Control instances attached to the broadcast LLID (0x7FFE). Instantiation of state diagrams as described in Figure 77–22 and Figure 77–23 is performed for every Multipoint MAC Control instance, except the instance attached to the broadcast channel.

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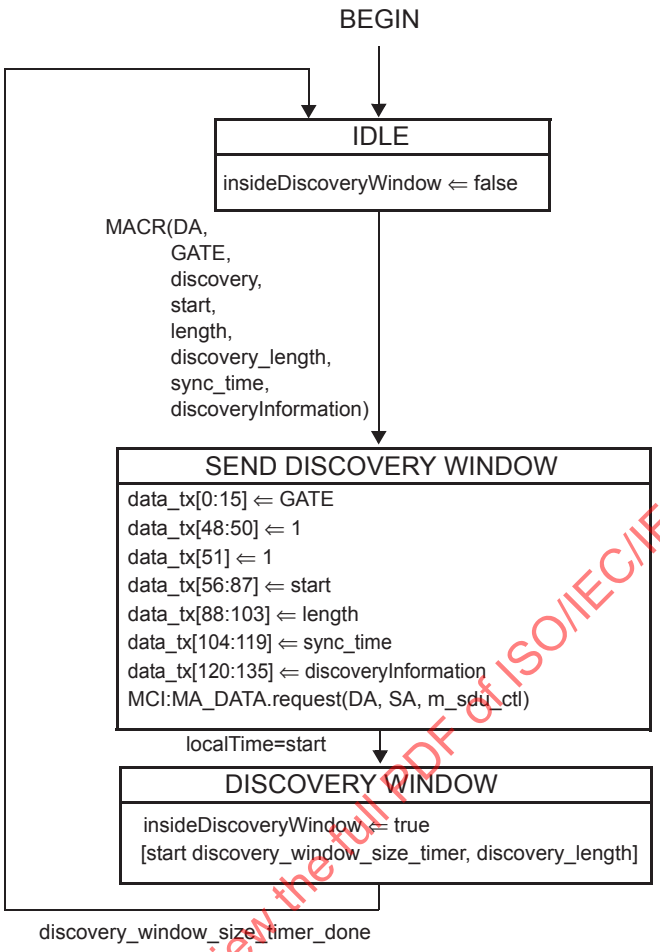

Instances of MAC data service interface:
MCI=interface to MAC Control multiplexer

Figure 77–19—Discovery Processing OLT Window Setup state diagram

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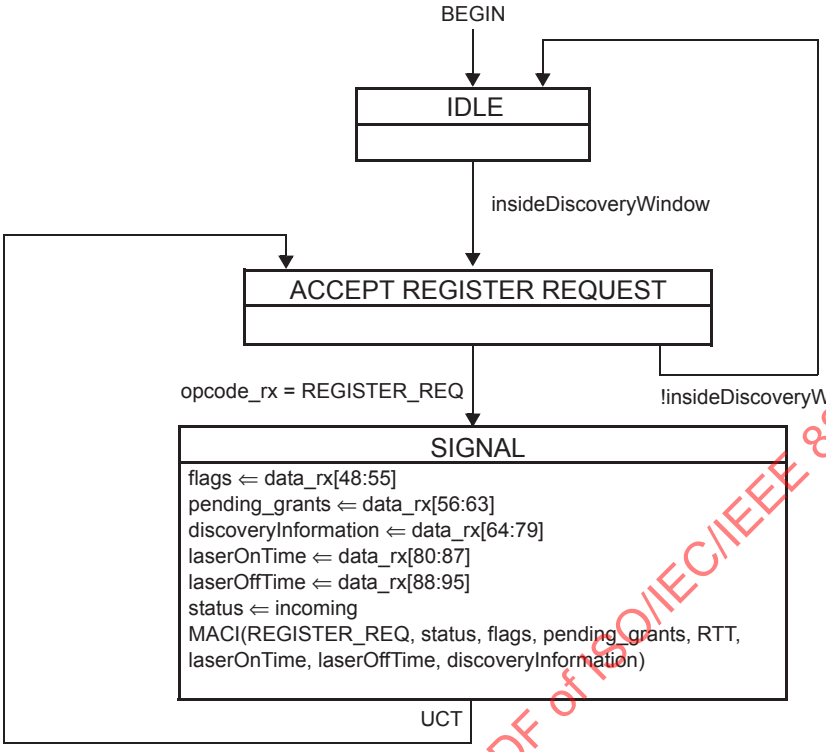
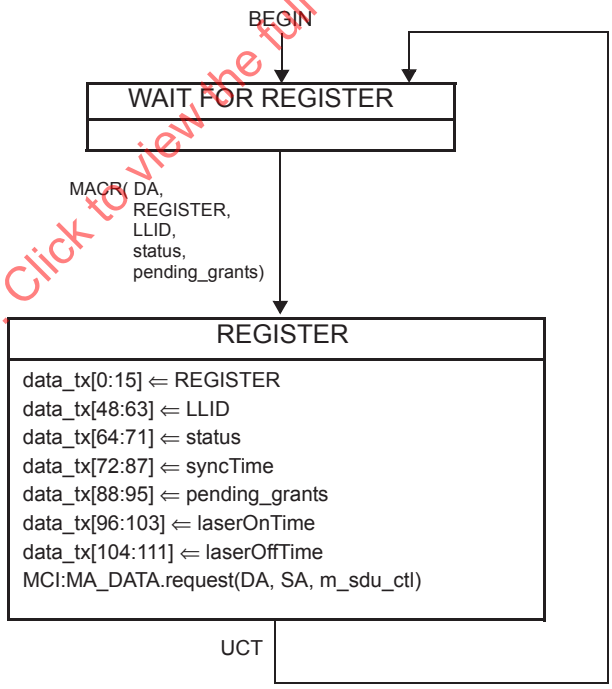


Figure 77–20—Discovery Processing OLT Process Requests state diagram



Instances of MAC data service interface:
MCI=interface to MAC Control multiplexer

Figure 77–21—Discovery Processing OLT Register state diagram

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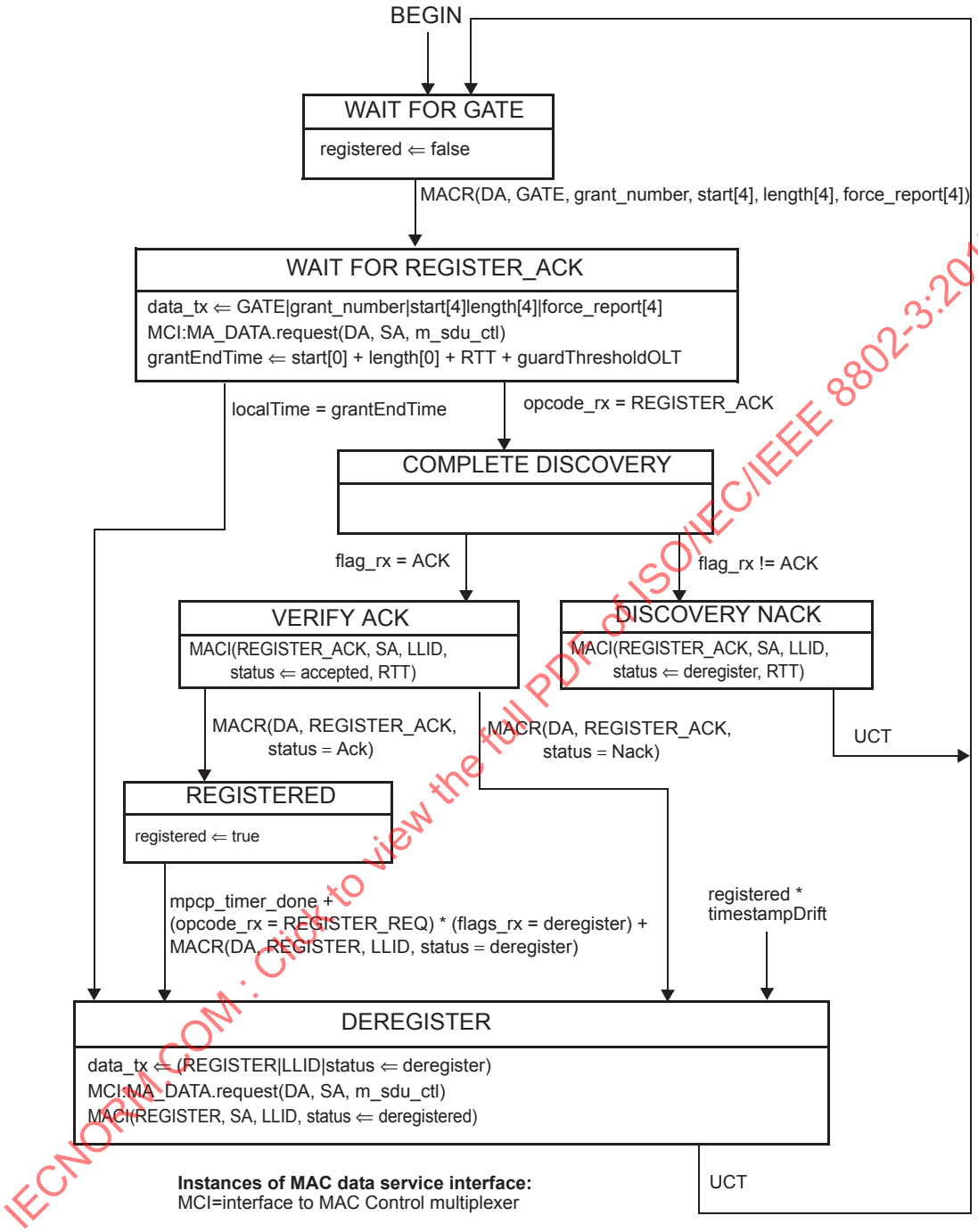

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NOTE—The MAC Control Client issues the grant following the REGISTER message, taking the ONU processing delay of REGISTER message into consideration.

Figure 77–22—Discovery Processing OLT Final Registration state diagram

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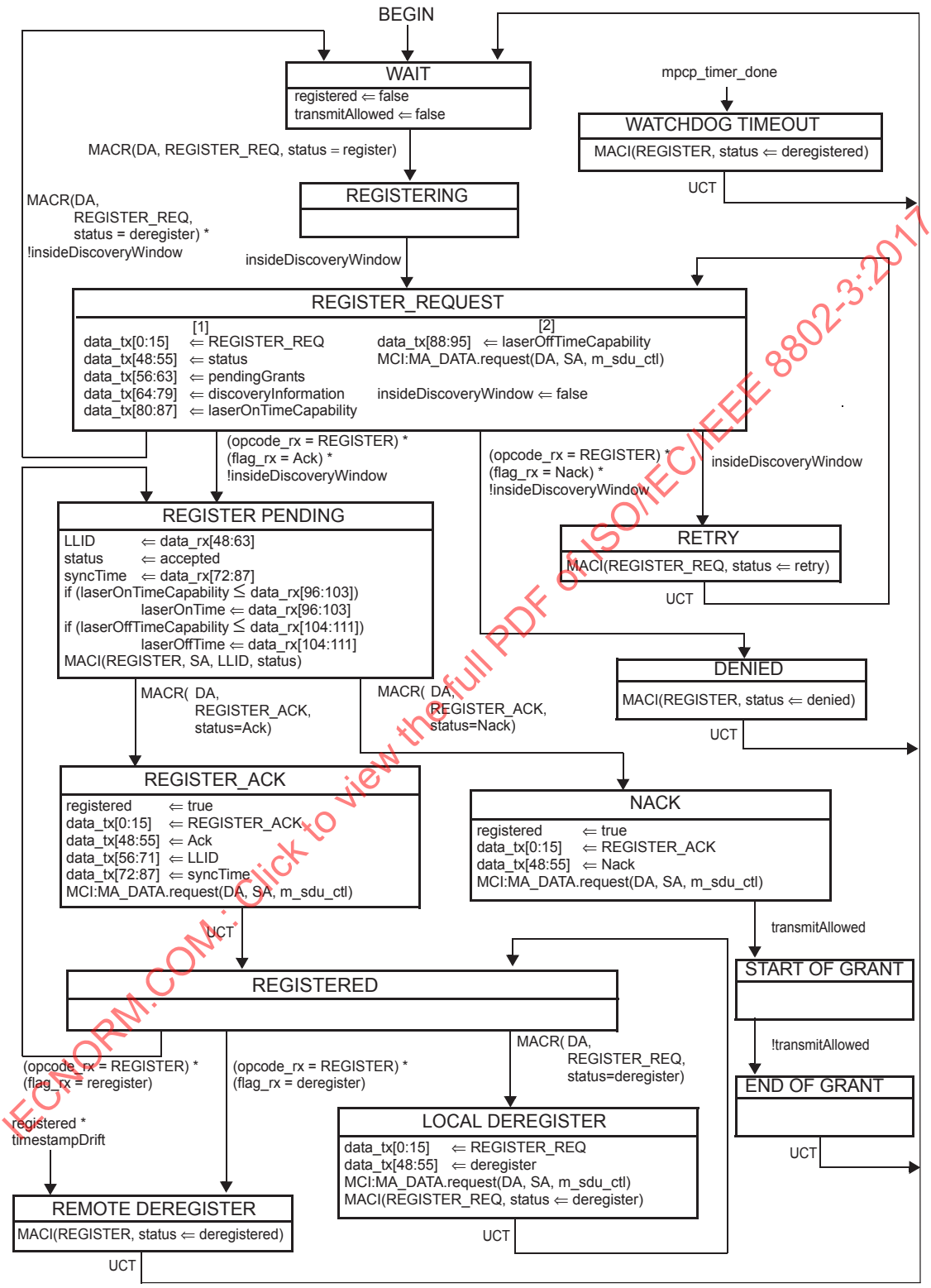

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Figure 77–23—Discovery Processing ONU Registration state diagram

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77.3.4 Report Processing

The Report Processing functional block has the responsibility of dealing with queue report generation and termination in the network. Reports are generated by higher layers and passed to the MAC Control sublayer by the MAC Control clients. Status reports are used to signal bandwidth needs as well as for arming the OLT watchdog timer.

Reports shall be generated periodically, even when no request for bandwidth is being made. This keeps a watchdog timer in the OLT from expiring and deregistering the ONU. For proper operation of this mechanism the OLT shall grant the ONU periodically.

The Report Processing functional block, and its MPCP protocol elements are designed for use in conjunction with an IEEE 802.1P capable bridge.

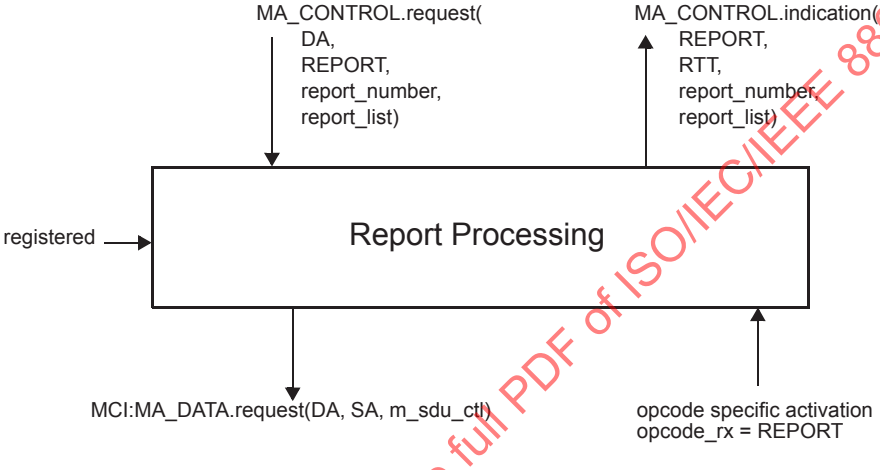

Figure 77–24—Report Processing service interfaces

77.3.4.1 Constants

None.

77.3.4.2 Variables

BEGIN
: TYPE: Boolean
This variable is used when initiating operation of the functional block state diagram. It is set to true following initialization and every reset.

data_rx
: This variable is defined in 77.2.2.3.

data_tx
: This variable is defined in 77.2.2.3.

m_sdu_ctl
: This variable is defined in 77.2.2.3.

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mpcp_timeout
TYPE: 32 bit unsigned
This variable represents the maximum allowed interval of time between two MPCPDU messages. Failure to receive at least one frame within this interval is considered a fatal fault and leads to deregistration. This variable is expressed in units of time_quanta.
VALUE: 0x03B9ACA0 (1 s, default value)

opcode_rx
This variable is defined in 77.2.2.3.

registered
This variable is defined in 77.3.3.2.

report_timeout
TYPE: 32 bit unsigned
This variable represents the maximum allowed interval of time between two REPORT messages generated by the ONU, expressed in units of time_quanta.
VALUE: 0x002FAF08 (50 ms, default value)

77.3.4.3 Functions

None.

77.3.4.4 Timers

report_periodic_timer
ONUs are required to generate REPORT MPCPDUs with a periodicity of less than report_timeout value. This timer counts down time remaining before a forced generation of a REPORT message in an ONU.

mpcp_timer
This timer is defined in 77.3.3.4.

77.3.4.5 Messages

MA_DATA.request (DA, SA, m_sdu)
The service primitive is defined in 2.3.2.

MA_CONTROL.request(DA, REPORT, report_number, report_list)
This service primitive is used by a MAC Control client to request the Report Process at the ONU to transmit a queue status report. This primitive may be called at variable intervals, independently of the granting process, in order to reflect the time varying aspect of the network. This primitive uses the following parameters:

DA:	Multicast MAC Control address as defined in Annex 31B.
REPORT:	Opcode for REPORT MPCPDU as defined in Table 31A–1.
report_number:	The number of queue status report sets located in report list. The report_number value ranges from 0 to a maximum of 13.
report_list:	The list of queue status reports. A queue status report consists of two fields: valid and status. The parameter valid is a Boolean array of length of 8. The index of an element of this array reflects the numbered priority queue in the IEEE 802.1P nomenclature. An element with the value of '0' or false indicates that the corresponding status field is not present (the

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length of status field is 0),while '1' or true indicates that the corresponding status field is present (the length of status field is 2 octets). The parameter status is an array of 16 bit unsigned integer values. This array consists only of entries whose corresponding bit in field valid is set to true.

MA_CONTROL.indication(REPORT, RTT, report_number, report_list)

The service primitive is issued by the Report Process at the OLT to notify the MAC Control client and higher layers the queue status of the MPCP link partner. This primitive may be called multiple times, in order to reflect the time–varying aspect of the network. This primitive uses the following parameters:

REPORT: Opcode for REPORT MPCPDU as defined in Table 31A–1.

RTT: This parameter holds an updated round trip time value that is recalculated following each REPORT message reception.

report_number: The number of queue status report sets located in report list. The report_number value ranges from 0 to a maximum of 13.

report_list: The list of queue status reports. A queue status report consists of two fields: valid and status. The parameter valid is a Boolean array of length of 8. The index of an element of this array reflects the numbered priority queue in the IEEE 802.1P nomenclature. An element with the value of '0' or false indicates that the corresponding status field is not present (the length of status field is 0),while '1' or true indicates that the corresponding status field is present (the length of status field is 2 octets). The parameter status is an array of 16 bit unsigned integer values. This array consists only of entries whose corresponding bit in field valid is set to true.

Opcode-specific function(opcode)

Functions exported from opcode specific blocks that are invoked on the arrival of a MAC Control message of the appropriate opcode.

77.3.4.6 State diagrams

The report process in the OLT shall implement the report processing state diagram as shown in Figure 77–25. The report process in the ONU shall implement the report processing state diagram as shown in Figure 77–26. Instantiation of state diagrams as described is performed for Multipoint MAC Control instances attached to unicast LLIDs only.

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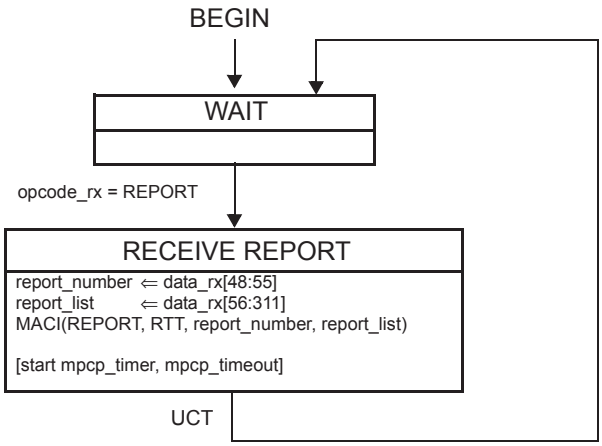
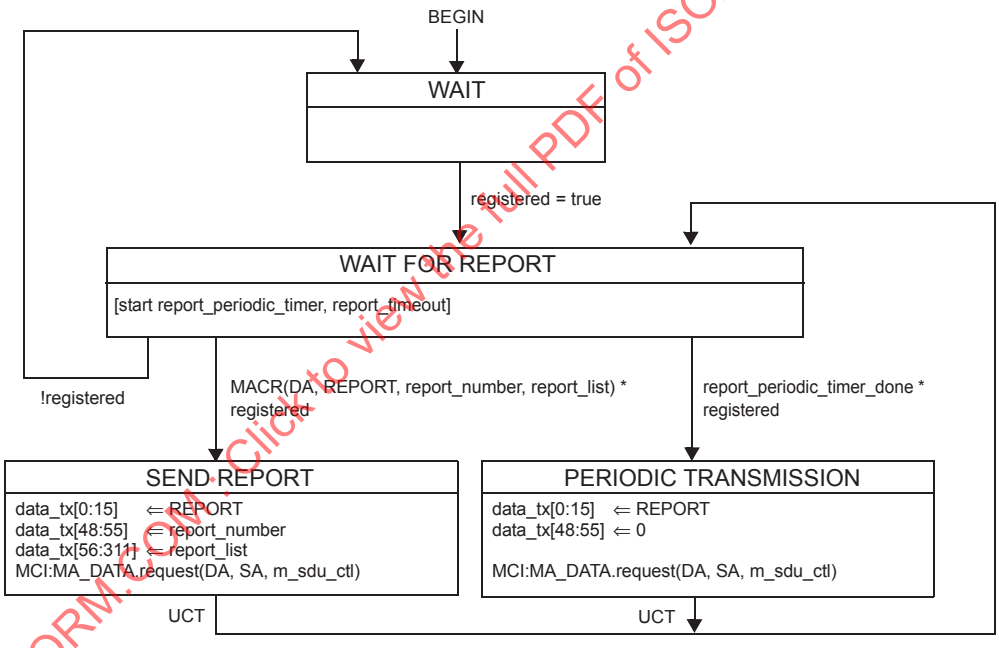


Figure 77–25—Report Processing state diagram at OLT



Instances of MAC data service interface:
MCI=interface to MAC Control multiplexer

Figure 77–26—Report Processing state diagram at ONU

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77.3.5 Gate Processing

A key concept pervasive in Multipoint MAC Control is the ability to arbitrate a single transmitter out of a plurality of ONUs. The OLT controls an ONU's transmission by the assigning of grants.

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The transmitting window of an ONU is indicated in the GATE message where start time and length are specified. An ONU begins transmission when its localTime counter matches the start_time value indicated in the GATE message. An ONU concludes its transmission with sufficient margin to ensure that the laser is turned off before the grant length interval has elapsed.

Multiple outstanding grants may be issued to each ONU. The OLT shall not issue more than the maximum supported maximum outstanding grants as advertised by the ONU during registration (see pending grants in 77.3.6.3).

In order to maintain the watchdog timer at the ONU, grants are periodically generated. For this purpose empty GATE messages may be issued periodically.

When registered, the ONU ignores all gate messages where the Discovery flag is set.

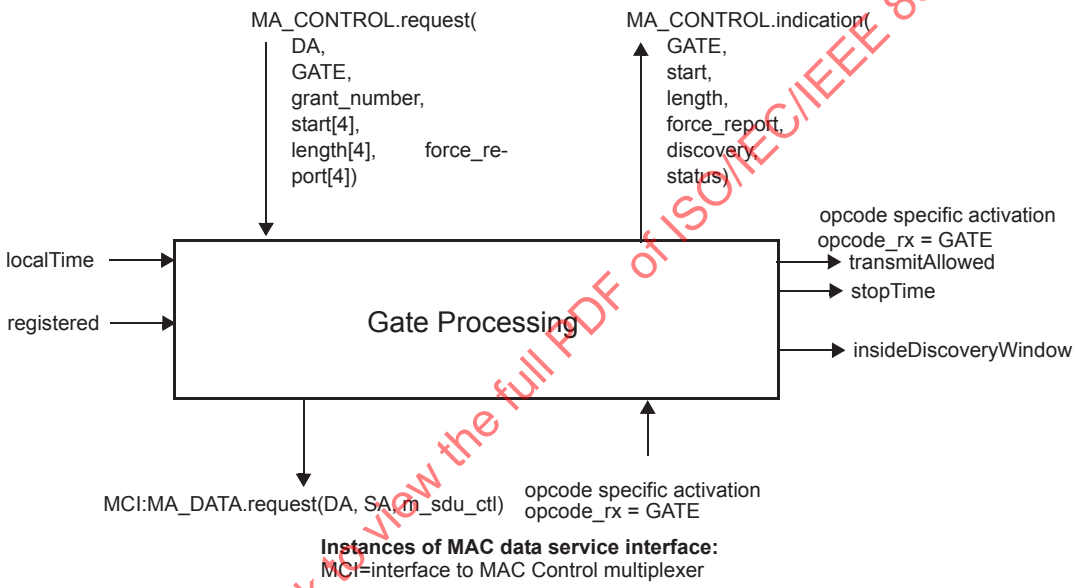

Figure 77–27—Gate Processing service interface

77.3.5.1 Constants

max_future_grant_time
TYPE: 32 bit unsigned
This constant holds the time limiting the future time horizon for a valid incoming grant.
VALUE: 0x03B9ACA0 (1 s)

min_processing_time
TYPE: 32 bit unsigned
This constant is the time required for the ONU processing time.
VALUE: 0x00000400 (16.384 µs)

minGrantLength
TYPE: 32 bit unsigned
This constant represents the minimum data portion of a grant. The minGrantLength is equal to one FEC codeword (see FEC_CODEWORD_SIZE in 77.2.2.1), less the initial 16 idle octets, expressed

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in units of time_quanta. The minimum grant length accepted by an ONU is equal to minGrantLength + BurstOverhead (see 77.3.5.2).
VALUE: 12

tqSize
This constant is defined in 77.2.2.1.

77.3.5.2 Variables

BEGIN
TYPE: Boolean
This variable is used when initiating operation of the functional block state diagram. It is set to true following initialization and every reset.

BurstOverhead
TYPE: integer
This variable represents the burst overhead and equals the sum of laserOnTime, laserOffTime, syncTime and an additional two time_quanta to account for END_BURST_DELIMITER and two leading IDLE vectors of the payload. This variable is expressed in units of time_quanta.

counter
TYPE: integer
This variable is used as a loop iterator counting the number of incoming grants in a GATE message.

currentGrant
TYPE:

```
structure
{
    DA:           48 bit unsigned, a.k.a MAC address type
    start         32 bit unsigned
    length        16 bit unsigned
    force_report  Boolean
    discovery     Boolean
}
```

This variable is used for local storage of a pending grant state during processing. It is dynamically set by the Gate Processing functional block and is not exposed.
The state is a structure field composed of multiple subfields.

data_rx
This variable is defined in 77.2.2.3.

data_tx
This variable is defined in 77.2.2.3.

effectiveLength
TYPE: 32 bit unsigned
This variable is used for temporary storage of a normalized net time value. It holds the net effective length of a grant normalized for elapsed time, and compensated for the periods required to turn the laser on and off, and waiting for receiver lock.

gate_timeout
TYPE: 32 bit unsigned
This variable represents the maximum allowed interval of time between two GATE messages gen-

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erated by the OLT to the same ONU, expressed in units of time_quanta.
VALUE: 0x002FAF08 (50 ms, default value)

grantList
TYPE: list of elements having the structure define in currentGrant
This variable is used for storage of the list of pending grants. It is dynamically set by the Gate Processing functional block and is not exposed. Each time a grant is received it is added to the list. The list elements are structure fields composed of multiple subfields. The list is indexed by the start subfield in each element for quick searches.

grantStart
This variable is defined in 77.2.2.3.

insideDiscoveryWindow
This variable is defined in 77.3.3.2.

maxDelay
TYPE: 16 bit unsigned
This variable holds the maximum delay that can be applied by an ONU before sending the REGISTER_REQ MPCPDU. This delay is calculated such that the ONU would have sufficient time to transmit the REGISTER_REQ message and its associated overhead (FEC parity data, end-of-frame sequence, etc.) and terminate the laser before the end of the discovery grant.

m_sdu_ctl
This variable is defined in 77.2.2.3.

nextGrant
TYPE: element having same structure as defined in currentGrant
This variable is used for local storage of a pending grant state during processing. It is dynamically set by the Gate Processing functional block and is not exposed. The content of the variable is the next grant to become active.

nextStopTime
TYPE: 32 bit unsigned
This variable holds the value of the localTime counter corresponding to the end of the next grant.

opcode_rx
This variable is defined in 77.2.2.3.

registered
This variable is defined in 77.3.3.2.

stopTime
This variable is defined in 77.2.2.3.

syncTime
This variable is defined in 77.3.3.2.

transmitAllowed
This variable is defined in 77.2.2.3.

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77.3.5.3 Functions

empty(list)

This function is use to check whether the list is empty. When there are no elements queued in the list, the function returns true. Otherwise, a value of false is returned.

confirmDiscovery(data)

This function is used to check whether the current Discovery Window is open for the given ONU (TRUE) or not (FALSE). This function returns values as shown in Table 77–1.

Table 77–1—Operation of the confirmDiscovery(data) function

OLT Discovery Information: Discovery Window		ONU Tx capability		confirmDiscovery(data) returns
1G	10G	1G	10G	
X	1	0	1	TRUE
1	X	1	0	TRUE
0	1	1	0	FALSE
1	0	0	1	FALSE
0	0	X	X	FALSE[a]

[a]These particular values for the Discovery Window fields should not be normally generated by the OLT.

InsertInOrder(sorted_list, inserted_element)

This function is used to queue an element inside a sorted list. The queuing order is sorted. In the condition that the list is full the element may be discarded. The length of the list is dynamic and it's maximum size equals the value advertised during registration as maximum number of pending grants.

IsBroadcast(grant)

This function is used to check whether its argument represents a broadcast grant, i.e., grant given to multiple ONUs. This is determined by the destination MAC address of the corresponding GATE message. The function returns the value true when MAC address is a global assigned MAC Control address as defined in Annex 31B, and false otherwise.

PeekHead(sorted_list)

This function is used to check the content of a sorted list. It returns the element at the head of the list without dequeuing the element.

Random(r)

This function is used to compute a random integer number uniformly distributed between 0 and r. The randomly generated number is then returned by the function.

RemoveHead(sorted_list)

This function is used to dequeue an element from the head of a sorted list. The return value of the function is the dequeued element.

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77.3.5.4 Timers

gntWinTmr
: This timer is used to wait for the event signaling the end of a grant window.
VALUE: The timer value is dynamically set according to the signaled grant length.

gate_periodic_timer
: The OLT is required to generate GATE MPCPDUs with a periodicity of less than gate_timeout value. This timer counts down time remaining before a forced generation of a GATE message in the OLT.

mpcp_timer
: This timer is defined in 77.3.3.4.

rndDlyTmr
: This timer is used to measure a random delay inside the discovery window. The purpose of the delay is to a priori reduce the probability of transmission overlap during the registration process, and thus lowering the expectancy of registration time in the PON.
VALUE: A random value less than the net discovery window size less the REGISTER_REQ MPCPDU frame size less the idle period and laser turn on and off delays less the preamble size less the IFG size. The timer value is set dynamically based on the parameters passed from the client.

77.3.5.5 Messages

MA_DATA.request (DA, SA, m_sdu)
: The service primitive is defined in 2.3.2.

MA_CONTROL.request(DA, GATE, grant_number, start[4], length[4], force_report[4])
: This service primitive is defined in 77.3.3.5.

MA_CONTROL.indication(GATE, start, length, force_report, discovery, status)
: This service primitive issued by the Gate Process at the ONU to notify the MAC Control client and higher layers that a grant is pending. This primitive is invoked multiple times when a single GATE message arrives with multiple grants. It is also generated at the start and end of each grant as it becomes active. This primitive uses the following parameters:

GATE:	Opcode for GATE MPCPDU as defined in Table 31A–1.
start:	start time of the grant. This parameter is not present when the parameter *status* value is equal to *deactive*.
length:	Length of the grant. This parameter is not present when the parameter *status* value is equal to *deactive*.
force_report:	Flags indicating whether a REPORT message should be transmitted in this grant. This parameter is not present when the parameter *status* value is equal to *deactive*.
discovery:	This parameter holds the value true when the grant is to be used for the discovery process, and false otherwise. This parameter is not present when the parameter *status* value is equal to *deactive*.
status:	This parameter takes the value *arrive* on grant reception, *active* when a grant becomes active, and *deactive* at the end of a grant.

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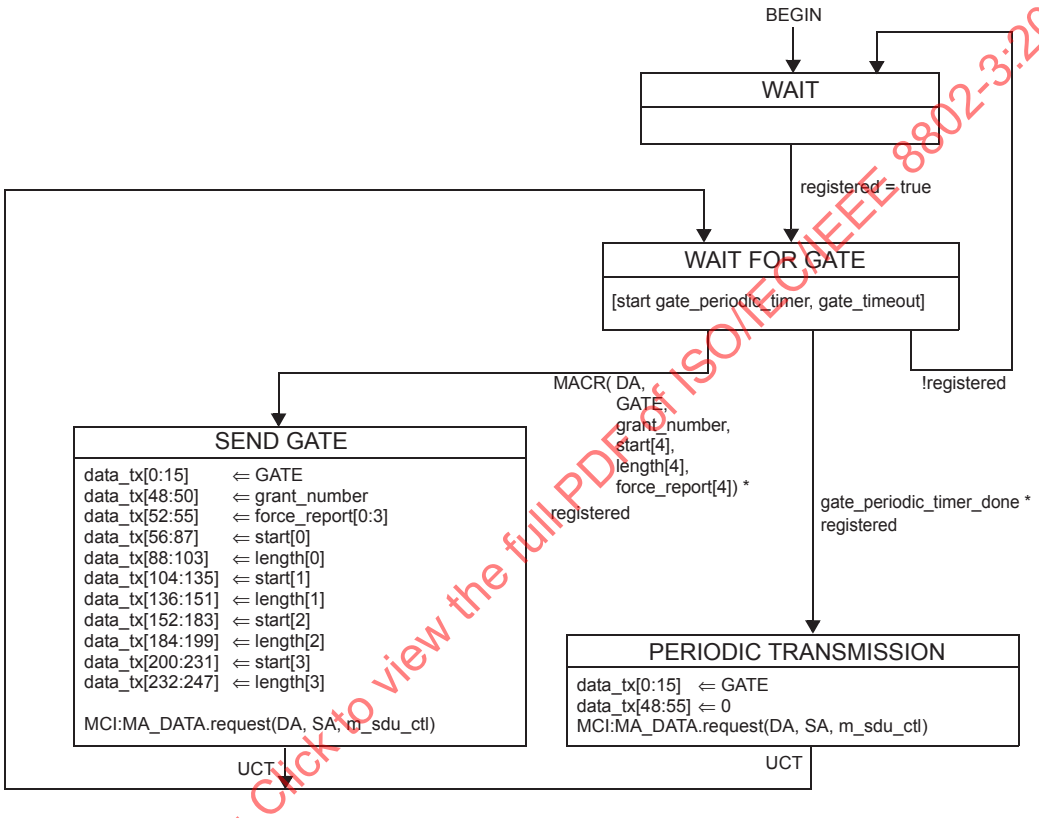
Opcode-specific function(opcode)

Functions exported from opcode specific blocks that are invoked on the arrival of a MAC Control message of the appropriate opcode.

77.3.5.6 State diagrams

The gating process in the OLT shall implement the Gate processing state diagram as shown in Figure 77–28. The gating process in the ONU shall implement the Gate processing state diagram as shown in Figure 77–29 and Figure 77–30. Instantiation of state diagrams as described is performed for all Multipoint MAC Control instances.



Instances of MAC data service interface:
MCI=interface to MAC Control multiplexer

Figure 77–28—Gate Processing state diagram at OLT

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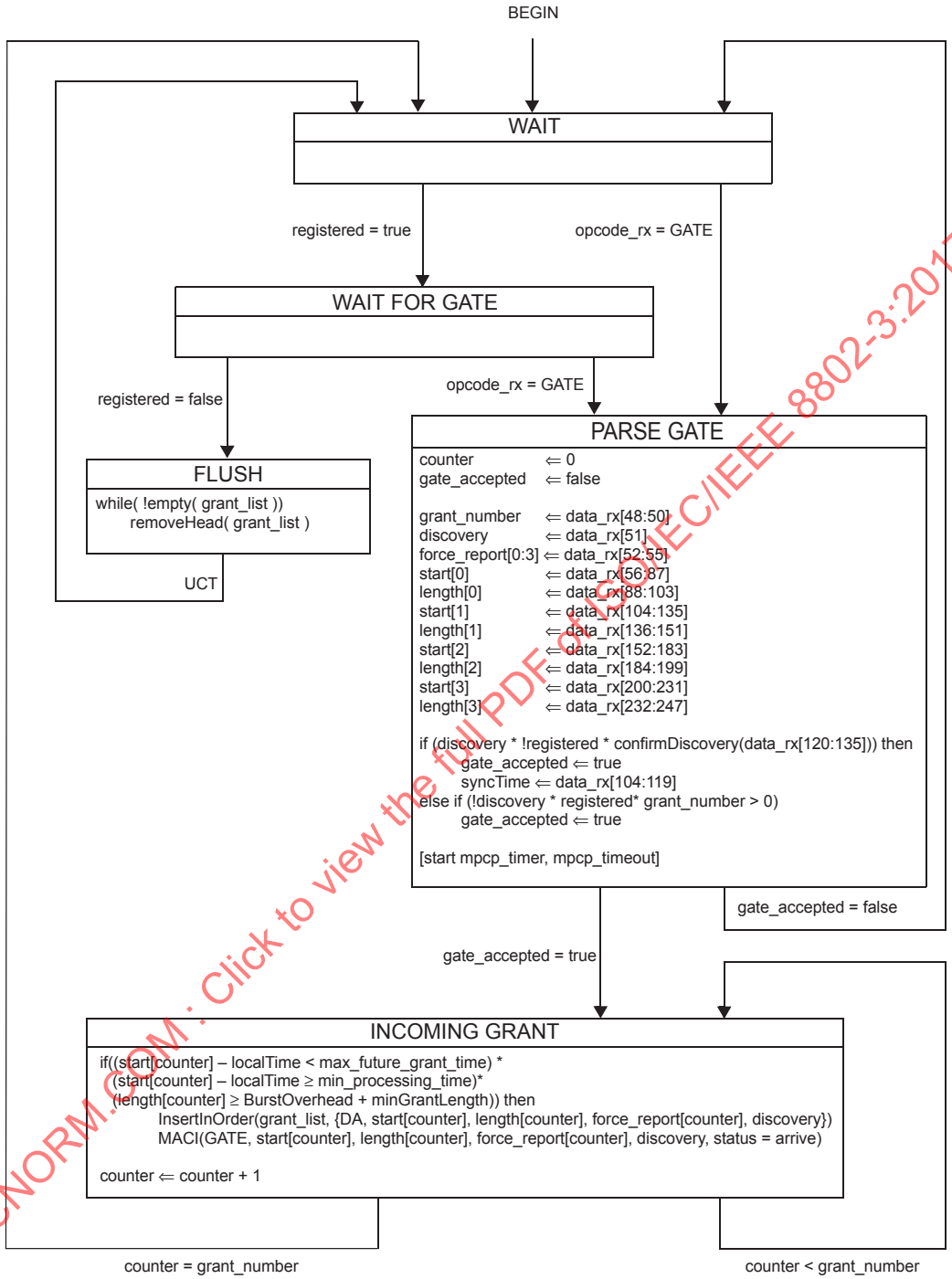

Figure 77–29—Gate Processing ONU Programing state diagram

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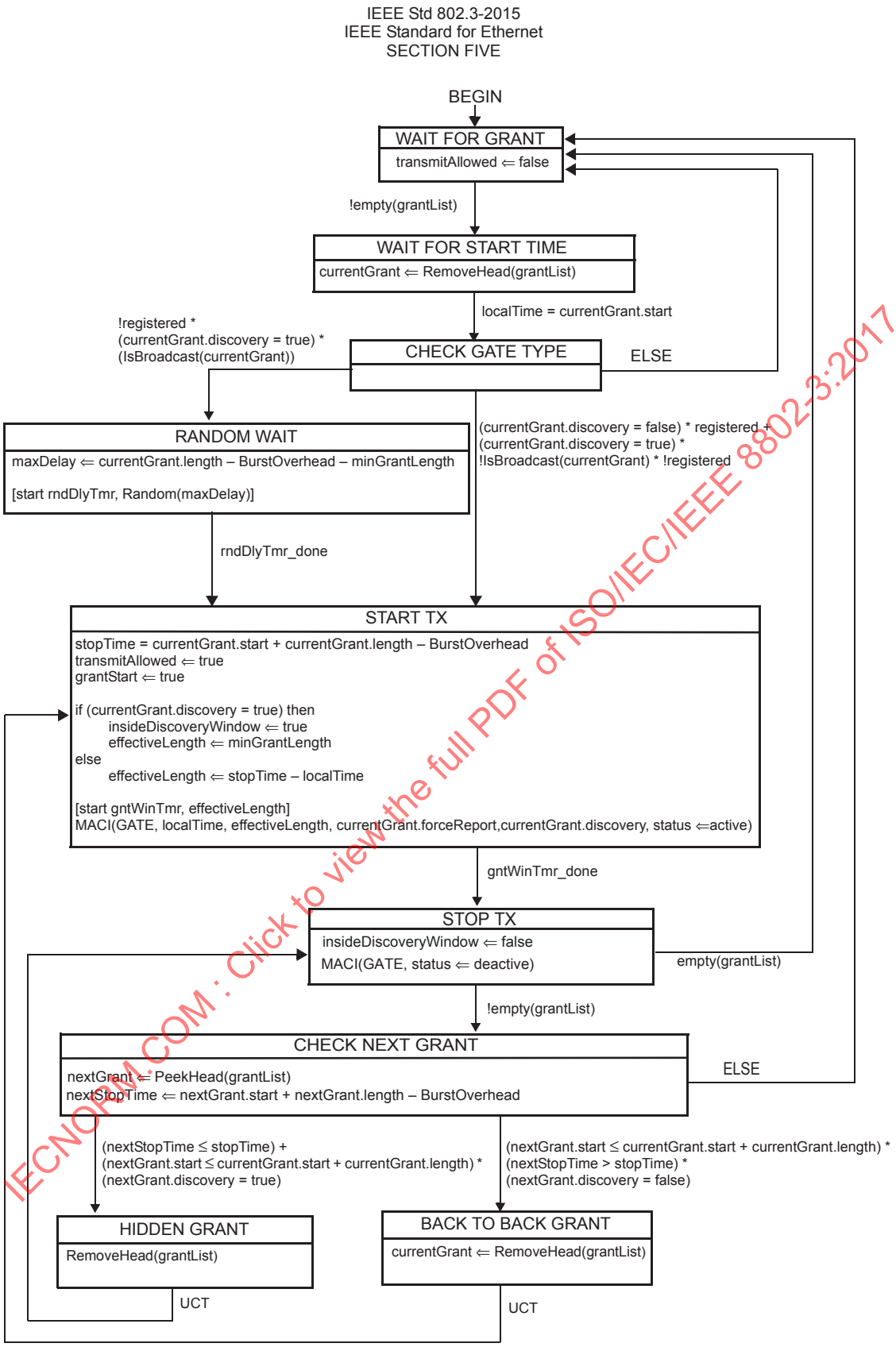

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Figure 77–30—Gate Processing ONU Activation state diagram

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77.3.6 MPCPDU structure and encoding

The MPCPDU structure shall be as shown in Figure 77–31, and is further defined in the following definitions:

a) Destination Address (DA). The DA in MPCPDU is the MAC Control Multicast address as specified in the annexes to Clause 31, or the individual MAC address associated with the port to which the MPCPDU is destined.

b) Source Address (SA). The SA in MPCPDU is the individual MAC address associated with the port through which the MPCPDU is transmitted. For MPCPDUs originating at the OLT end, this can be the address any of the individual MACs. These MACs may all share a single unicast address, as explained in 77.1.2.

c) Length/Type. The Length/Type in MPCPDUs carries the MAC_Control_Type field value as specified in 31.4.1.3.

d) Opcode. The opcode identifies the specific MPCPDU being encapsulated. Values are defined in Table 31A–1.

e) Timestamp. The timestamp field conveys the content of the localTime register at the time of transmission of the MPCPDUs. This field is 32 bits long and counts time in units of time_quanta.

f) Data/Reserved/PAD. These 40 octets are used for the payload of the MPCPDUs. When not used they would be filled with zeros on transmission, and be ignored on reception.

g) FCS. This field is the Frame Check Sequence, typically generated by the underlying MAC.
Based on the MAC instance used to generate the specific MPCPDU, the appropriate LLID shall be generated by the RS.

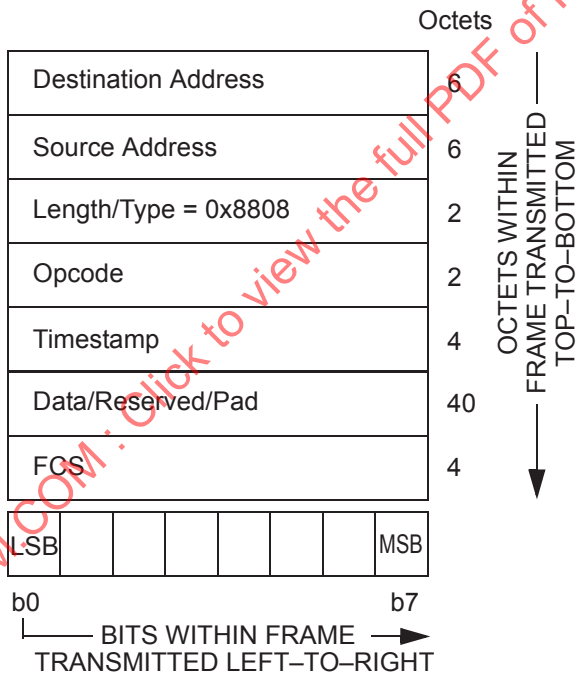

Figure 77–31—Generic MPCPDU

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77.3.6.1 GATE description

The purpose of GATE message is to grant transmission windows to ONUs for both discovery messages and normal transmission. Up to four grants can be included in a single GATE message. The number of grants can also be set to zero for using the GATE message as an MPCP keep alive from OLT to the ONU.

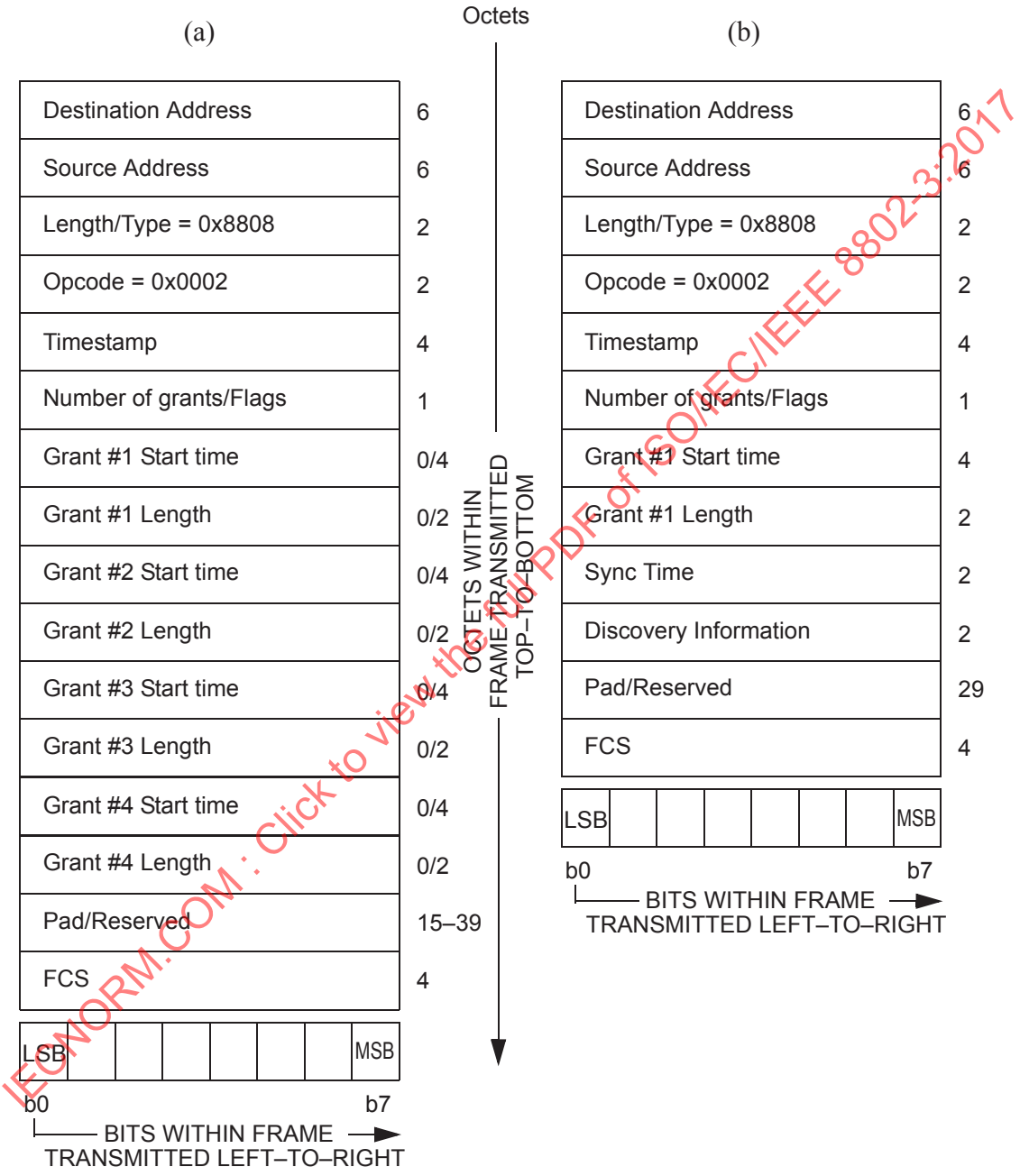

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Figure 77–32—GATE MPCPDU: (a) normal GATE MPCPDU, (b) discovery GATE MPCPDU

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The GATE MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) Opcode. The opcode for the GATE MPCPDU is 0x0002.

b) Flags. This is an 8 bit flag register that holds the following flags: As presented in Table 77–2, the Number of grants field contains the number of grants, composed of valid Length, Start Time pairs in this MPCPDU. This is a number between 0 and 4.

NOTE—When Number of grants is set to 0, sole purpose of message is conveying of timestamp to ONU.

The Discovery flag field indicates that the signaled grants would be used for the discovery process, in which case a single grant shall be issued in the GATE message.
The Force Report flag fields ask the ONU to issue a REPORT message related to the corresponding grant number at the corresponding transmission opportunity indicated in this GATE.

Table 77–2—GATE MPCPDU Number of grants/flags fields

Bit	Flag field	Values
0–2	Number of grants	0 – 4
3	Discovery	0 – Normal GATE 1 – Discovery GATE
4	Force Report Grant 1	0 – No action required 1 – A REPORT frame should be issued at the corresponding transmission opportunity indicated in Grant 1
5	Force Report Grant 2	0 – No action required 1 – A REPORT frame should be issued at the corresponding transmission opportunity indicated in Grant 2
6	Force Report Grant3	0 – No action required 1 – A REPORT frame should be issued at the corresponding transmission opportunity indicated in Grant 3
7	Force Report Grant 4	0 – No action required 1 – A REPORT frame should be issued at the corresponding transmission opportunity indicated in Grant 4

c) Grant #n Start Time. This 32 bit unsigned field represents the start time of the grant. The start time is compared to the local clock, to correlate the start of the grant. Transmitted values shall satisfy the condition Grant #n Start Time < Grant #n+1 Start Time for consecutive grants within the same GATE MPCPDU.

d) Grant #n Length. This 16 bit unsigned field represents the length of the grant. The length is counted in 1 time_quantum increments. There are 4 Grants that are possibly packed into the GATE MPCPDU. The laserOnTime, syncTime, laserOffTime, two initial Idle blocks, FEC parity overhead, and burst terminator sequence (composed of three END_BURST_DELIMITER blocks) are included in and thus consume part of the Grant #n length.

e) Sync Time. This is an unsigned 16 bit value signifying the required synchronization time of the OLT receiver. The ONU calculates the effective grant length by subtracting the syncTime, laserOnTime, laserOffTime and END_BURST_DELIMITER from the grant length it received from the OLT. The value is counted in 1 time_quantum increments. The advertised value includes synchronization requirement on all receiver elements including PMD, PMA and PCS. This field is present only when the GATE is a discovery GATE, as signaled by the Discovery flag and is not present otherwise.

f) Discovery Information. This is a 16 bit flag register. This field is present only when the GATE is a discovery GATE, as signaled by the Discovery flag and is not present otherwise. Table 77–3 presents the internal structure of the Discovery Information flag field.

g) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored on reception. The size of this field depends on the used Grant #n Length/Start Time entry-pairs as well as the presence of the Sync Time and Discovery Information fields, and varies in length from 15–39 accordingly.

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The GATE MPCPDU shall be generated by a MAC Control instance mapped to an active ONU, and as such shall be marked with a unicast type of LLID, except when the MPCPDU is a discovery GATE, as indicated by the Discovery flag being set to true. For the discovery procedure, a MAC Control instance is mapped to all ONUs, and therefore, the discovery GATE MPCPDU is marked with the appropriate broadcast LLID (see 77.3.2.3).

Table 77–3—GATE MPCPDU discovery information fields

Bit	Flag field	Values
0	OLT is 1G upstream capable	0 – OLT does not support 1 Gb/s reception 1 – OLT supports 1 Gb/s reception
1	OLT is 10G upstream capable	0 – OLT does not support 10 Gb/s reception 1 – OLT supports 10 Gb/s reception
2–3	Reserved	Ignored on reception
4	OLT is opening 1G discovery window	0 – OLT cannot receive 1 Gb/s data in this window 1 – OLT can receive 1 Gb/s data in this window
5	OLT is opening 10G discovery window	0 – OLT cannot receive 10 Gb/s data in this window 1 – OLT can receive 10 Gb/s data in this window
6–15	Reserved	Ignored on reception

77.3.6.2 REPORT description

REPORT messages have several functionalities. Time stamp in each REPORT message is used for round trip (RTT) calculation. In the REPORT messages ONUs indicate the upstream bandwidth needs they request per IEEE 802.1Q priority queue. REPORT messages are also used as keep–alives from ONU to OLT. ONUs issue REPORT messages periodically in order to maintain link health at the OLT as defined in 77.3.4. In addition, the OLT may specifically request a REPORT message.

The REPORT MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) Opcode. The opcode for the REPORT MPCPDU is 0x0003.
b) Number of Queue Sets. This field specifies the number of requests in the REPORT message. A REPORT frame may hold multiple sets of Report bitmap and Queue #n as specified in the Number of Queue Sets field.
c) Report bitmap. This is an 8 bit flag register that indicates which queues are represented in this REPORT MPCPDU—see Table 77–4.

Table 77–4—REPORT MPCPDU Report bitmap fields

Bit	Flag field	Values
0	Queue 0	0 – queue 0 report is not present; 1 – queue 0 report is present
1	Queue 1	0 – queue 1 report is not present; 1 – queue 1 report is present
2	Queue 2	0 – queue 2 report is not present; 1 – queue 2 report is present
3	Queue 3	0 – queue 3 report is not present; 1 – queue 3 report is present
4	Queue 4	0 – queue 4 report is not present; 1 – queue 4 report is present
5	Queue 5	0 – queue 5 report is not present; 1 – queue 5 report is present

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Table 77–4—REPORT MPCPDU Report bitmap fields *(continued)*

Bit	Flag field	Values
6	Queue 6	0 – queue 6 report is not present; 1 – queue 6 report is present
7	Queue 7	0 – queue 7 report is not present; 1 – queue 7 report is present

d) Queue #n Report. This value represents the length of queue #n at time of REPORT message generation. The reported length shall be adjusted and rounded up to the nearest time_quantum to account for the necessary inter–frame spacing and preamble. FEC parity overhead is not included in the reported length. The Queue #n Report field is an unsigned 16 bit integer representing the transmission request in units of time_quanta. This field is present only when the corresponding flag in the Report bitmap is set.

e) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored on reception. The size of this field depends on the used Queue Report entries, and accordingly varies in length from 0 to 39.

The REPORT MPCPDU shall be generated by a MAC Control instance mapped to an active ONU, and as such shall be marked with a unicast type of LLID.

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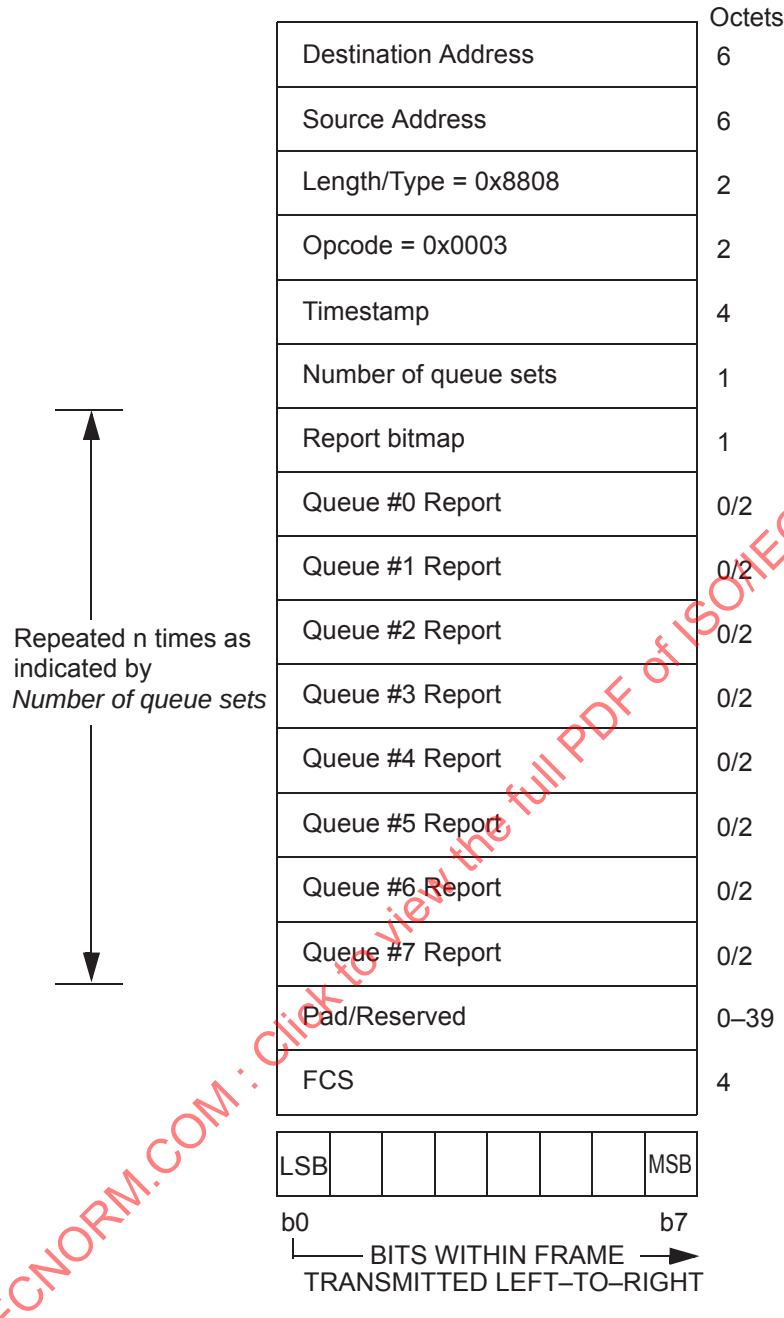

Figure 77–33—REPORT MPCPDU

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77.3.6.3 REGISTER_REQ description

The REGISTER_REQ MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) Opcode. The opcode for the REGISTER_REQ MPCPDU is 0x0004.
b) Flags. This is an 8 bit flag register that indicates special requirements for the registration, as presented in Table 77–5.

Table 77–5—REGISTER_REQ MPCPDU Flags fields

Value	Indication	Comment
0	Reserved	Ignored on reception.
1	Register	Registration attempt for ONU.
2	Reserved	Ignored on reception.
3	Deregister	This is a request to deregister the ONU. Subsequently, the MAC is deallocated and the LLID may be reused.
4–255	Reserved	Ignored on reception.

c) Pending grants. This is an unsigned 8 bit value signifying the maximum number of future grants the ONU is configured to buffer. The OLT should not grant the ONU more than this maximum number of Pending grants vectors comprised of {start, length, force_report, discovery} into the future.
d) Discovery Information. This is a 16 bit flag register. Table 77–6 presents the structure of the Discovery Information flag.

Table 77–6—REGISTER_REQ MPCPDU Discovery Information Fields

Bit	Flag field	Values
0	ONU is 1G upstream capable	0 – ONU transmitter is not capable of 1 Gb/s 1 – ONU transmitter is capable of 1 Gb/s
1	ONU is 10G upstream capable	0 – ONU transmitter is not capable of 10 Gb/s 1 – ONU transmitter is capable of 10 Gb/s
2–3	Reserved	Ignored on reception
4	1G registration attempt	0 – 1 Gb/s registration is not attempted 1 – 1 Gb/s registration is attempted
5	10G registration attempt	0 – 10 Gb/s registration is not attempted 1 – 10 Gb/s registration is attempted
6–15	Reserved	Ignored on reception

e) Laser On Time. This field is 1 octet long and carries the Laser On Time characteristic for the given ONU transmitter. The value is expressed in the units of time_quanta.
f) Laser Off Time. This field is 1 octet long and carries the Laser Off Time characteristic for the given ONU transmitter. The value is expressed in the units of time_quanta.
g) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored on reception.

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The REGISTER_REQ MPCPDU shall be generated by a MAC Control instance mapped to an undiscovered ONU, and as such shall be marked with a broadcast type of LLID (77.3.2.3).

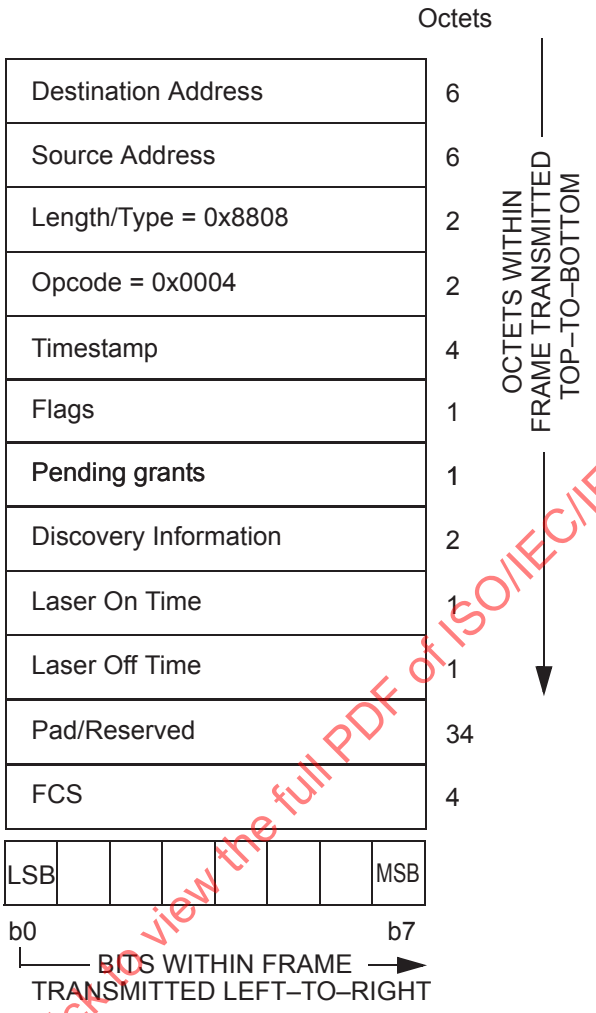

Figure 77–34—REGISTER_REQ MPCPDU

77.3.6.4 REGISTER description

The REGISTER MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) DA. The destination address used shall be an individual MAC address.
b) Opcode. The opcode for the REGISTER MPCPDU is 0x0005.
c) Assigned Port. This field holds a 16 bit unsigned value reflecting the LLID of the port assigned following registration.
d) Flags. this is an 8 bit flag register that indicates special requirements for the registration, as presented in Table 77–7.
e) Sync Time. This is an unsigned 16 bit value signifying the required synchronization time of the OLT receiver. The ONU calculates the effective grant length by subtracting the syncTime, laserOnTime, laserOffTime, and END_BURST_DELIMITER from the grant length it received from the OLT. The value is counted in 1 time_quantum increments. The advertised value includes synchronization requirement on all receiver elements including PMD, PMA, and PCS.

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Table 77–7—REGISTER MPCPDU Flags field

Value	Indication	Comment
0	Reserved	Ignored on reception.
1	Reregister	The ONU is explicitly asked to re-register.
2	Deregister	This is a request to deallocate the port and free the LLID. Subsequently, the MAC is deallocated.
3	Ack	The requested registration is successful.
4	Nack	The requested registration attempt is denied by the MAC Control Client.
5–255	Reserved	Ignored on reception.

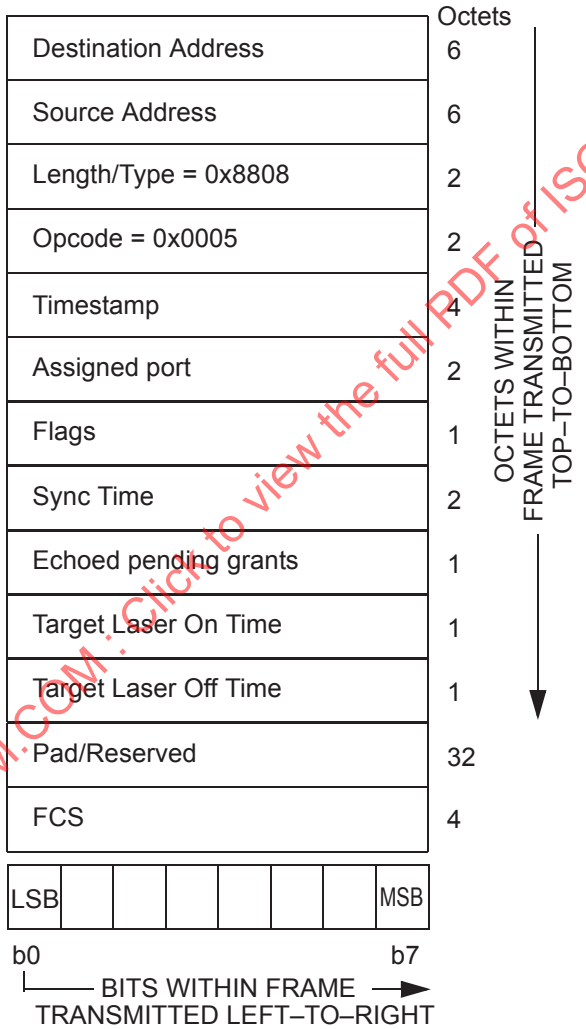

Figure 77–35—REGISTER MPCPDU

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f) Echoed pending grants. This is an unsigned 8 bit value signifying the number of future grants the ONU may buffer before activating. The OLT should not grant the ONU more than this number of grants into the future.
g) Target Laser On Time. This is an unsigned 8 bit value, expressed in the units of time_quanta, signifying the Laser On Time for the given ONU transmitter. This value may be different from Laser On Time delivered by the ONU in the REGISTER_REQ MPCPDU during the Discovery process. The ONU updates the local laserOnTime variable per state diagram in Figure 77–23.
h) Target Laser Off Time. This is an unsigned 8 bit value, expressed in the units of time_quanta, signifying the Laser Off Time for the given ONU transmitter. This value may be different from Laser Off Time delivered by the ONU in the REGISTER_REQ MPCPDU during the Discovery process. The ONU updates the local laserOffTime variable per state diagram in Figure 77–23.
i) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored on reception.

The REGISTER MPCPDU shall be generated by a MAC Control instance mapped to all ONUs and such frame is marked by the broadcast LLID (77.3.2.3).

77.3.6.5 REGISTER_ACK description

The REGISTER_ACK MPCPDU is an instantiation of the Generic MPCPDU, and is further defined using the following definitions:

a) Opcode. The opcode for the REGISTER_ACK MPCPDU is 0x0006.
b) Flags. This is an 8 bit flag register that indicates special requirements for the registration, as presented in Table 77–8.
c) Echoed assigned port. This field holds a 16 bit unsigned value reflecting the LLID for the port assigned following registration.
d) Echoed Sync Time. This is an unsigned 16 bit value echoing the required synchronization time of the OLT receiver as previously advertised (77.3.6.4).
e) Pad/Reserved. This is an empty field that is transmitted as zeros, and ignored at reception.

Table 77–8—REGISTER_ACK MPCPDU Flags fields

Value	Indication	Comment
0	Nack	The requested registration attempt is denied by the MAC Control Client.
1	Ack	The registration process is successfully acknowledged.
2–255	Reserved	Ignored on reception.

The REGISTER_ACK MPCPDU shall be generated by a MAC Control instance mapped to an active ONU, and as such shall be marked with a unicast type of LLID.

77.4 Discovery Process in dual-rate systems

The enhancements introduced to the Clause 77 discovery process for EPONs facilitate the coexistence of 10G–EPON with 1G–EPON.

77.4.1 OLT speed-specific discovery

The discovery GATE MPCPDU is defined in Clause 64 for 1 Gb/s operation and in Clause 77 for 10 Gb/s operation. An additional field (Discovery Information field) was added to the 10 Gb/s discovery GATE MPCPDU. This field allows the OLT to relay speed-specific information regarding the discovery window to the different ONUs that may coexist in the same PON. The OLT has the ability to transmit common discovery GATE MPCPDUs on both the 1 Gb/s transmit path and 10 Gb/s transmit path, or it can send

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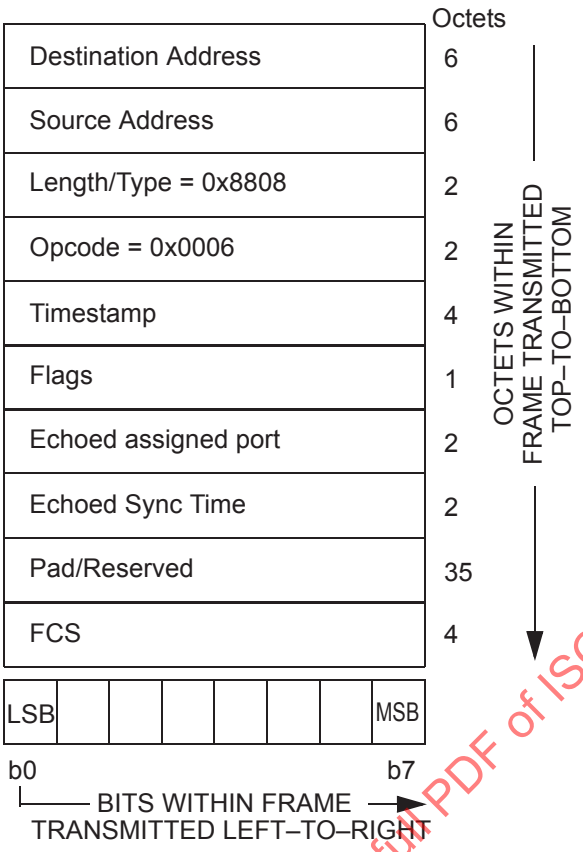

Figure 77–36—REGISTER_ACK MPCPDU

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completely separate and independent GATE messages on these different paths. For each discovery window, the OLT is capable of opening windows for individual speeds or multiple speeds.

These different combinations allow the OLT MAC Control Client to open a number of discovery windows for all of the different ONU types. Table 77–9 shows the different types of windows that are possible, along with the necessary LLID and discovery information that also needs to be present in the discovery GATE MPCPDUs. For some combinations, it may be desirable for the OLT MAC Control Client to open overlapping discovery windows. It may do so by sending one discovery GATE MPCPDU on the 1 Gb/s downstream channel and a similar discovery GATE MPCPDU on the 10 Gb/s downstream channel; both discovery GATE MPCPDUs having the same Start Time value.

Figure 77–37 shows the three primary combinations of discovery windows and the different types of REGISTER_REQ MPCPDUs that may be received during the window. Figure 77–37(a) shows reception of messages from 1 Gb/s and 10/1 Gb/s ONUs. Figure 77–37(b) shows reception of messages from 10 Gb/s ONUs. Figure 77–37(c) shows reception of messages from all types of ONUs.

77.4.2 ONU speed-specific registration

A 1G–EPON ONU receives only discovery GATE messages transmitted by the OLT in the 1 Gb/s broadcast channel. Operation and registration of these ONUs is specified in Clause 64.

A 10/1G–EPON ONU is only capable of receiving discovery GATE MPCPDU transmitted by the OLT in the 10 Gb/s broadcast channel. These messages are parsed, and if a 1 Gb/s discovery window is opened, the ONU may attempt to register in the EPON.

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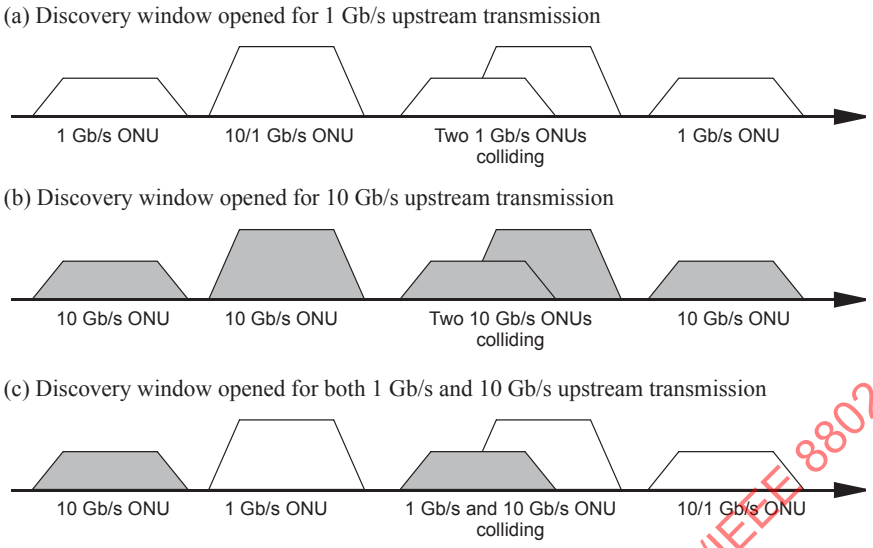

Figure 77–37—Combinations of REGISTER_REQ MPCPDUs during discovery window for 10G–EPON and 1G–EPON coexisting in the same PON

Table 77–9—Discovery GATE MPCPDUs for all ONU types

ONU types targeted by discovery GATE MPCPDU	LLID of discovery GATE(s)	Discovery information			
		Upstream capable		Discovery window	
		1G	10G	1G	10G
1G–EPON	0x7FFF	No Discovery Information field present			
10/1G–EPON	0x7FFE	1	0	1	0
1G–EPON and 10/1G–EPON	0x7FFF[a]	No Discovery Information field present			
	0x7FFE[a]	1	0	1	0
10/10G–EPON	0x7FFE	0	1	0	1
10/1G–EPON and 10/10G–EPON	0x7FFE	1	1	1	1
1G–EPON, 10/1G–EPON, and 10/10G–EPON	0x7FFF[a]	No Discovery Information field present			
	0x7FFE[a]	1	1	1	1

[a]Two discovery GATE MPCPDUs are transmitted in two separate downstream broadcast channels: one with the LLID of 0x7FFF transmitted in the 1 Gb/s downstream broadcast channel and another one the LLID of 0x7FFE transmitted in the 10 Gb/s downstream broadcast channel.

A 10/10G–EPON ONU is only capable of receiving discovery GATE MPCPDU transmitted by the OLT in the 10 Gb/s broadcast channel. These messages are parsed, and if a 10 Gb/s discovery window is opened, the ONU may attempt to register in the EPON.

A dual speed ONU capable of 10/1G–EPON operation or 10/10G–EPON operation is also only capable of receiving discovery GATE MPCPDU transmitted by the OLT in the 10 Gb/s broadcast channel. These messages need to be parsed, and the ONU makes the registration decision based on the available information. The ONU should attempt to register during the discovery window announced as supporting the

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highest speed common to both the OLT and ONU. Table 77–10 shows the action the ONU should take based on the ONU transmit capabilities and the received discovery information.

Table 77–10—ONU action during discovery window

OLT Discovery information				ONU Tx capability		ONU action
Upstream capable		Discovery window				
1G	10G	1G	10G	1G	10G	
1	0	1	0	1	X	Attempt 1G registration
1	X	1	X	1	0	Attempt 1G registration
X	1	X	1	X	1	Attempt 10G registration
1	1	0	1	1	0	Wait for 1G discovery window
1	1	1	0	X	1	Wait for 10G discovery window

The ONU generates the REGISTER_REQ MPCPDU with the same LLID as the discovery GATE MPCPDU it responds to, i.e., 1G–EPON ONU (per Clause 64) use LLID 0x7FFF, while the 10G–EPON ONUs use LLID 0x7FFE.

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77.5 Protocol implementation conformance statement (PICS) proforma for Clause 77, Multipoint MAC Control[34]

77.5.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 77 Multipoint MAC Control, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

77.5.2 Identification

77.5.2.1 Implementation identification

Supplier	
Contact point for inquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	
NOTE 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. NOTE 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

77.5.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Clause 77, Multipoint MAC Control
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	
Date of Statement	

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[34] *Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

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77.5.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
*OLT	OLT functionality	77.1	Device supports functionality required for OLT	O/1	Yes [ ] No [ ]
*ONU	ONU functionality	77.1	Device supports functionality required for ONU	O/1	Yes [ ] No [ ]

77.5.4 PICS proforma tables for Multipoint MAC Control

77.5.4.1 Compatibility considerations

Item	Feature	Subclause	Value/Comment	Status	Support
CC1	Delay through MAC	77.3.2.4	Maximum delay variation of 1 time_quantum	M	Yes [ ]
CC2	OLT grant time delays	77.3.2.4	Not grant nearer than 1024 time_quanta into the future	OLT:M	Yes [ ]
CC3	ONU processing delays	77.3.2.4	Process all messages in less than 1024 time_quanta	ONU:M	Yes [ ]
CC4	OLT grant issuance	77.3.2.4	Not grant more than one message every 1024 time_quanta to a single ONU	OLT:M	Yes [ ]

77.5.4.2 Multipoint MAC Control

Item	Feature	Subclause	Value/Comment	Status	Support
OM1	OLT localTime	77.2.2.2	Track transmit clock	OLT:M	Yes [ ]
OM2	ONU localTime	77.2.2.2	Track receive clock	ONU:M	Yes [ ]
OM3	Random wait for transmitting REGISTER_REQ messages	77.3.3	Shorter than length of discovery window	ONU:M	Yes [ ]
OM4	Periodic report generation	77.3.4	Reports are generated periodically	ONU:M	Yes [ ]
OM5	Periodic granting	77.3.4	Grants are issued periodically	OLT:M	Yes [ ]
OM6	Issuing of grants	77.3.5	Not issue more than maximum supported grants	OLT:M	Yes [ ]

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77.5.4.3 State diagrams

Item	Feature	Subclause	Value/Comment	Status	Support
SM1	Multipoint Transmission Control	77.2.2.7	Meets the requirements of Figure 77–10	M	Yes [ ]
SM2	OLT Control Parser	77.2.2.7	Meets the requirements of Figure 77–11	M	Yes [ ]
SM3	ONU Control Parser	77.2.2.7	Meets the requirements of Figure 77–12	M	Yes [ ]
SM4	OLT Control Multiplexer	77.2.2.7	Meets the requirements of Figure 77–13	OLT:M	Yes [ ]
SM5	ONU Control Multiplexer	77.2.2.7	Meets the requirements of Figure 77–14	OLT:M	Yes [ ]
SM6	Discovery Processing OLT Window Setup	77.3.3.6	Meets the requirements of Figure 77–19	OLT:M	Yes [ ]
SM7	Discovery Processing OLT Process Requests	77.3.3.6	Meets the requirements of Figure 77–20	OLT:M	Yes [ ]
SM8	Discovery Processing OLT Register	77.3.3.6	Meets the requirements of Figure 77–21	ONU:M	Yes [ ]
SM9	Discovery Processing OLT Final Registration	77.3.3.6	Meets the requirements of Figure 77–22	OLT:M	Yes [ ]
SM10	Discovery Processing ONU Registration	77.3.3.6	Meets the requirements of Figure 77–23	ONU:M	Yes [ ]
SM11	Report Processing at OLT	77.3.4.6	Meets the requirements of Figure 77–25	OLT:M	Yes [ ]
SM12	Report Processing at ONU	77.3.4.6	Meets the requirements of Figure 77–26	ONU:M	Yes [ ]
SM13	Gate Processing at OLT	77.3.5.6	Meets the requirements of Figure 77–28	OLT:M	Yes [ ]
SM14	Gate Processing at ONU	77.3.5.6	Meets the requirements of Figure 77–29	ONU:M	Yes [ ]
SM15	Gate Processing ONU Activation	77.3.5.6	Meets the requirements of Figure 77–30	ONU:M	Yes [ ]

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77.5.4.4 MPCP

Item	Feature	Subclause	Value/Comment	Status	Support
MP1	MPCPDU structure	77.3.6	As in Figure 77–31	M	Yes [ ]
MP2	LLID for MPCPDU	77.3.6	RS generates LLID for MPCPDU	M	Yes [ ]
MP3	Grants during discovery	77.3.6.1	Single grant in GATE message during discovery	OLT:M	Yes [ ]
MP4	Grant start time	77.3.6.1	Grants within one GATE MPCPDU are sorted by their Start time values	OLT:M	Yes [ ]
MP5	GATE generation	77.3.6.1	GATE generated for active ONU except during discovery	OLT:M	Yes [ ]
MP6	GATE LLID	77.3.6.1	Unicast LLID except for discovery	OLT:M	Yes [ ]
MP7	REPORT issuing	77.3.6.2	Issues REPORT periodically	ONU:M	Yes [ ]
MP8	REPORT generation	77.3.6.2	Generated by active ONU	ONU:M	Yes [ ]
MP9	REPORT generation	77.3.6.2	REPORT Queue #n length rounding	ONU:M	Yes [ ]
MP10	REPORT LLID	77.3.6.2	REPORT has unicast LLID	ONU:M	Yes [ ]
MP11	REGISTER_REQ generation	77.3.6.3	Generated by undiscovered ONU	ONU:M	Yes [ ]
MP12	REGISTER_REQ LLID	77.3.6.3	Use broadcast LLID	ONU:M	Yes [ ]
MP13	REGISTER DA address	77.3.6.4	Use individual MAC address	OLT:M	Yes [ ]
MP14	REGISTER generation	77.3.6.4	Generated for all ONUs	OLT:M	Yes [ ]
MP15	REGISTER_ACK generation	77.3.6.5	Generated by active ONU	ONU:M	Yes [ ]
MP16	REGISTER_ACK LLID	77.3.6.5	Use unicast LLID	ONU:M	Yes [ ]

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Annex 57A

(normative)

Requirements for support of Slow Protocols

57A.1 Introduction and rationale

There are two distinct classes of protocols used to control various aspects of the operation of IEEE 802.3 devices. They are as follows:

a) Protocols such as the MAC Control PAUSE operation (Annex 31B) that need to process and respond to PDUs rapidly in order to avoid performance degradation. These are likely to be implemented as embedded hardware functions, making it relatively unlikely that existing equipment could be easily upgraded to support additional such protocols.

   NOTE—This consideration was one of the contributing factors in the decision to use a separate group MAC address to support LACP and the Marker protocol, rather than re-using the group MAC address currently used for PAUSE frames.

b) Protocols such as LACP, with less stringent frequency and latency requirements. These may be implemented in software, with a reasonable expectation that existing equipment be upgradeable to support additional such protocols, depending upon the approach taken in the original implementation.

In order to place some realistic bounds upon the demands that might be placed upon such a protocol implementation, this annex defines the characteristics of this class of protocols and identifies some of the behaviors that an extensible implementation needs to exhibit.

57A.2 Slow Protocol transmission characteristics

Protocols that make use of the addressing and protocol identification mechanisms identified in this annex are subject to the following constraints:

a) The number of frames transmitted in any one-second period per Slow Protocol subtype shall not exceed aSlowProtocolFrameLimit (see 30.3.1.1.38).
b) The maximum number of Slow Protocols subtypes is 10.
c) The MAC Client data generated by any of these protocols shall be no larger than maxBasicDataSize (see 4.2.7.1). It is recommended that the maximum length for a Slow Protocol frame be limited to 128 octets.

The effect of these restrictions is to restrict the bandwidth consumed and performance demanded by this set of protocols; by default the maximum traffic loading that would result is 100 maximum length frames per second per point-to-point link and 100 maximum length frames per ONU for point-to-multipoint topologies.

57A.3 Addressing

The Slow_Protocols_Multicast address has been allocated exclusively for use by Slow Protocols PDUs; its value is identified in Table 57A–1.

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Table 57A–1—Slow_Protocols_Multicast address

Name	Value
Slow_Protocols_Multicast address	01-80-C2-00-00-02

NOTE 1—This address is within the range reserved by IEEE Std 802.1D for link-constrained protocols. As such, frames sent to this address will not be forwarded by conformant MAC Bridges; its use is restricted to a single link.

NOTE 2—Although the two currently existing Slow Protocols (i.e., LACP and the Marker protocol) always use this MAC address as the destination address in transmitted PDUs, this may not be true for all Slow Protocols. In some yet-to-be-defined protocol, unicast addressing may be appropriate and necessary. Rather, the requirement is that this address not be used by any protocols that are not Slow Protocols.

57A.4 Protocol identification

All Slow Protocols use type interpretation of the Length/Type field, and use the Slow_Protocols_Type value as the primary means of protocol identification; its value is shown in Table 57A–2.

Table 57A–2—Slow_Protocols_Type value

Name	Value
Slow_Protocols_Type	88-09

The first octet of the MAC Client data following the Length/Type field is a protocol subtype identifier that distinguishes between different Slow Protocols. Table 57A–3 identifies the semantics of this subtype.

Table 57A–3—Slow Protocols subtypes

Protocol Subtype value	Protocol name
0	Unused—Illegal value
1	Link Aggregation Control Protocol (LACP)
2	Link Aggregation—Marker Protocol
3	Operations, Administration, and Maintenance (OAM)
4	Reserved for future use
5	Reserved for future use
6	Reserved for future use
7	Reserved for future use
8	Reserved for future use
9	Reserved for future use
10	Organization Specific Slow Protcol (OSSP)
11–255	Unused—Illegal values

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NOTE—Although this mechanism is defined as part of an IEEE 802.3 standard, it is the intent that the reserved code points in this table will be made available to protocols defined by other working groups within IEEE 802, should this mechanism be appropriate for their use.

57A.5 Handling of Slow Protocol frames

Any received MAC frame that carries the Slow_Protocols_Type field value is assumed to be a Slow Protocol frame. An implementation that claims conformance to this standard shall handle all Slow Protocol frames as follows:

a) Discard any Slow Protocol frame that carries an illegal value of Protocol Subtype (see Table 57A–3). Such frames shall not be passed to the MAC Client.

b) Pass any Slow Protocol frames that carry Protocol Subtype values that identify supported Slow Protocols to the protocol entity for the identified Slow Protocol.

c) Pass any Slow Protocol frames that carry Protocol Subtype values that identify unsupported Slow Protocols to the MAC Client.

NOTE—The intent of these rules is twofold. First, they rigidly enforce the maximum number of Slow Protocols, ensuring that early implementations of this mechanism do not become invalidated as a result of "scope creep." Second, they make it clear that the appropriate thing to do in any embedded frame parsing mechanism is to pass frames destined for unsupported protocols up to the MAC Client rather than discarding them, thus allowing for the possibility that, in soft configurable systems, the MAC Client might be enhanced in the future in order to support protocols that were not implemented in the hardware.

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57A.6 Protocol implementation conformance statement (PICS) proforma for Annex 57A, Requirements for support of Slow Protocols[35]

57A.6.1 Introduction

The supplier of an implementation that is claimed to conform to Annex 57A shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

57A.6.2 Identification

57A.6.2.1 Implementation identification

Supplier (Note 1)	
Contact point for inquiries about the PICS (Note 1)	
Implementation Name(s) and Version(s) (Notes 1 and 3)	
Other information necessary for full identification—e.g., name(s) and version(s) of machines and/or operating system names (Note 2)	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

57A.6.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Annex 57A, Requirements for support of Slow Protocols.
Identification of amendments and corrigenda to the PICS proforma that have been completed as part of the PICS	
Have any Exception items been required? (See Clause 21: the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	No [ ] Yes [ ]

Date of Statement	

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57A.6.2.3 Transmission characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
SP1	Transmission rate	57A.2	Max 10 frames in any one-second period	M	Yes [ ]
SP2	Data field	57A.2	No larger than maxBasicDataSize (see 4.2.7.1)	M	Yes [ ]

57A.6.2.4 Frame handling

Item	Feature	Subclause	Value/Comment	Status	Support
FH1	Handling of Slow Protocol frames	57A.5	As specified in 57A.5	M	Yes [ ]

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Annex 57B

(normative)

Organization specific slow protocol (OSSP)

The organization specific slow protocol (OSSP) provides a standardized means for organizations to define their own slow protocols outside the scope of this standard. The requirements defined in Annex 57A apply to these slow protocols.

57B.1 Transmission and representation of octets

An organization specific slow protocol data unit (OSSPDU) comprises an integral number of octets. The bits in each octet are numbered from 0 to 7, where 0 is the least significant bit. When consecutive octets are used to represent a numerical value, the most significant octet is transmitted first, followed by successively less significant octets.

57B.1.1 OSSPDU frame structure

The OSSPDU frame structure shall be as depicted in Figure 57B–1. In this figure:

a) Octets are transmitted from top to bottom.
b) Within an octet, bits are shown with bit 0 to the left and bit 7 to the right, and are transmitted from left to right.
c) When consecutive octets are used to represent a binary number, the octet transmitted first has the more significant value.
d) When consecutive octets are used to represent a MAC address, the least significant bit of the first octet is assigned the value of the first bit of the MAC address, the next most significant bit the value of the second bit of the MAC address, and so on through the eighth bit. Similarly the least significant through most significant bits of the second octet are assigned the value of the ninth through seventeenth bits of the MAC address, and so on for all the octets of the MAC address.
e) OSSPDUs are at least minFrameSize in length.

A OSSPDU shall have the following fields:

f) *Destination Address (DA).* The DA in OSSPDUs is the Slow_Protocols_Multicast address. Its use and encoding are specified in Annex 57A.
g) *Source Address (SA).* The SA in OSSPDUs is the individual MAC address associated with the port through which the OSSPDU is transmitted.
h) *Length/Type.* The Length/Type in OSSPDUs carries the Slow_Protocols_Type field value specified in 57A.4.
i) *Subtype.* The Subtype field identifies the specific Slow Protocol being encapsulated. OSSPDUs carry the Subtype value 0x0A as specified in Annex 57A.
j) *Organizationally Unique Identifier (OUI) or Company ID (CID).* The OUI/CID field contains the OUI or CID to identify the Organization Specific Data. The bit/octet ordering of the OUI/CID field within an OSSPDU is identical to the bit/octet ordering of the OUI portion of the DA/SA.
k) *Organization Specific Data*. The format and function of the Organization Specific Data field is dependent on the value of the OUI/CID field and is beyond the scope of this standard.
l) *FCS.* This field is the Frame Check Sequence, typically generated by the underlying MAC.

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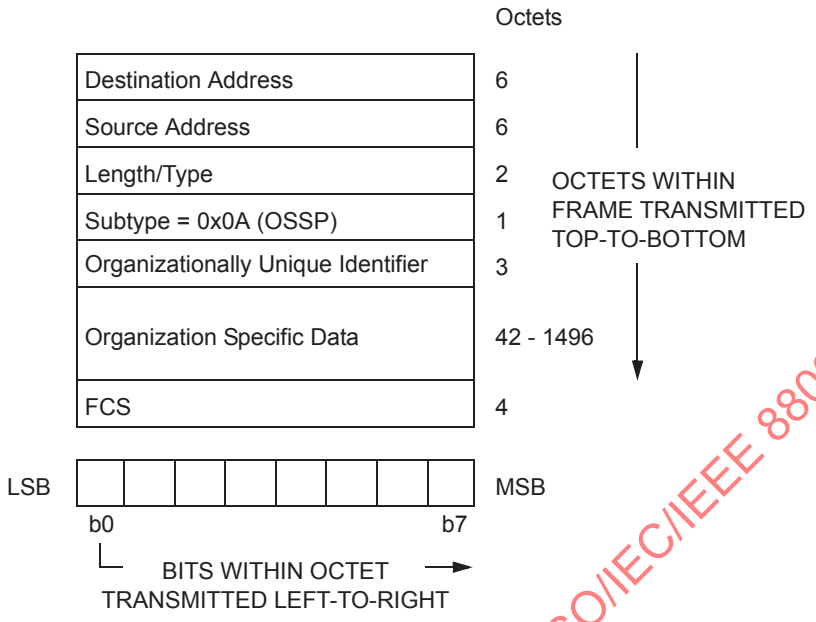

Figure 57B–1—OSSPDU structure

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57B.2 Protocol implementation conformance statement (PICS) proforma for Annex 57B, Organization specific slow protocol (OSSP)[36]

57B.2.1 Introduction

The supplier of an implementation that is claimed to conform to Annex 57B shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

57B.2.2 Identification

57B.2.2.1 Implementation identification

Supplier (Note 1)	
Contact point for inquiries about the PICS (Note 1)	
Implementation Name(s) and Version(s) (Notes 1 and 3)	
Other information necessary for full identification—e.g., name(s) and version(s) of machines and/or operating system names (Note 2)	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

57B.2.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3-2015, Annex 57B, Organization specific slow protocol (OSSP).
Identification of amendments and corrigenda to the PICS proforma that have been completed as part of the PICS	
Have any Exception items been required? (See Clause 21: the answer Yes means that the implementation does not conform to IEEE Std 802.3-2015.)	No [ ] Yes [ ]

Date of Statement	

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57B.2.2.3 OSSPDU structure

Item	Feature	Subclause	Value/Comment	Status	Support
OS1	Organization Specific Protocol Data Unit (OSSPDU) frame structure	57B.1.1	As shown in Figure 57B–1 and as described	M	Yes [ ]

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Annex 58A

(informative)

Frame-based testing

The use of the frame-based test patterns described in Clause 58, Clause 59, and Clause 60 provides for the most general testing of the external interfaces. They combine patterns appropriate for testing the desired parameters with a flexible frame structure that allows the test pattern to be passed through a compliant system. However, the frame-based nature of the patterns may cause difficulties with some bit oriented test systems if care is not taken.

The concern is that streams of data that are passed through a system under test may have their inter-frame gap altered by rate control mechanisms. This changes the bit sequence, even in the presence of no errors, and causes difficulties with bit sequence oriented test systems. There are several methods of addressing this issue. The solutions fall roughly into the following three categories:

a) Error detection internal to the equipment under test
b) Use of frame-based test equipment
c) Synchronized systems

An example of the first type of test where the internal error detection would be used is a receiver sensitivity test. The input pattern may be generated by any method, including a bit oriented serial pattern generator or a frame-based pattern generator. Errored frames would be rejected internal to the system under test based on FCS errors. This type of test has the advantage of testing all of the components of an input interface. The error count may be made by accessing the error counters internal to the system under test.

The number of bit errors may be assumed to be the same as the number of frame errors to a 90% confidence level as long as frame error ratio is less than 0.2. The bit error ratio may be determined by dividing the frame error ratio by the number of bits in the test frame that are used in the computation of the FCS.

If the internal error counters are not accessible, the test frames may be passed to an output port and the number of received frames may the counted. Any missing frames may be assumed to have had errors. The frame count may be made by conventional frame-based test equipment. The missing frames render the use of bit stream oriented test equipment inappropriate.

When testing transmitter outputs, frames may be passed to the port under test from another port in the system under test. In this case, loss of frames within the system is not expected and testing may be done using a bit oriented test system by making the system synchronous. This may be done by recovering the clock from the output under test and using this as a clock source for the input. If there are no variable delays in the system under test, such as variable queuing delays, the input data stream will be reproduced in the output and conventional Bit Error Ratio Testing (BERT) systems may be used. In the case of 100BASE-X, the output bit stream may be inverted.

Two frame-based alternatives avoid the need for synchronization. The first is to use a frame-based tester for both the pattern generation and the error detection. The optical signal will need to be received by an optical receiver with the proper characteristics for the specific test. The processed data stream would then be sent to the frame-based receiver to determine possible frame errors.

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Another method would be to use a bit oriented test system suitable for burst mode operation. This type of tester will examine only the frame contents for errors. Two methods are used for determining the frame contents. An external gating signal may be used. This must be triggered by the data source and include any latency associated with the system under test. Alternately, the test set may recognize the frame boundaries in the incoming data stream.

As the behavior above the MAC is not specified by this standard, the system under test might not be able to forward, return or respond to incoming frames at line rate. Diluting the frame rate is thought to be acceptable for 1000BASE-X but for 100BASE-X testing, groups of 12 frames should be kept together. A system might emit additional frames from a port and may need to be configured so that it does not.

NOTE—Users are advised to take care that the system under test is not connected to a network in service.

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Annex 61A

(informative)

EFM Copper examples

61A.1 Purpose and scope

The purpose of this informative annex is to provide practical examples of the use of

a) Aggregation Discovery, for aggregated operation of 10PASS-TS PHYs (Clause 62) or 2BASE-TL PHYs (Clause 63); see 61A.2.
b) 64/65-octet encapsulation, as specified in 61.3.3; see 61A.3.

61A.2 Aggregation Discovery example

An example procedure for PME aggregation discovery is described for system components as shown in Figure 61A–1, connected as in Figure 61A–2. Additional information on example discovery transactions are shown in Figure 61A–3. An example procedure for discovering this connectivity follows:

a) -O system writes remote_discovery_register to value *alpha* (*alpha* may be any 48-bit value, but would benefit from being locally unique e.g. MAC address) using PME-1.
b) -O system reads remote_discovery_register for all other PMEs.
c) -O system discovers that PME-2, PME-6 and PME-7 are associated with the same remote MAC device as PME-1.
d) -O system writes remote_discovery_register to value *alpha* using PME-3— the next non-associated PME.
e) -O system reads remote_discovery_register for all other PMEs.
f) -O system expects that PME-1, PME-2, PME-3, PME-6 and PME-7 will already be written to value *alpha*.
g) -O system discovers that no other PME is associated with the same remote MAC device as PME-3.
h) -O system writes remote_discovery_register to value *alpha* using PME-4—the next non-associated PME.
i) -O system reads remote_discovery_register for all other PMEs.
j) -O system expects that PME-1, PME-2, PME-3, PME-4, PME-6 and PME-7 will already be written to value *alpha*.
k) -O system discovers that PME-5, PME-9 and PME-11 are associated with the same remote MAC device as PME-4.
l) This procedure repeats for all of the PMEs connected to -O system.

An alternate example procedure for discovering this connectivity uses two different 48-bit values:

m) -O system writes remote_discovery_register to value *alpha* (*alpha* may be any 48-bit value, but would benefit from being locally unique e.g. MAC address) using PME-1.
n) -O system reads remote_discovery_register for all other PMEs.
o) -O system discovers that PME-2, PME-6 and PME-7 are associated with the same remote MAC device as PME-1.
p) -O system rewrites remote_discovery_register to value *beta* (*beta* may be any 48-bit value, different to *alpha*) using PME-1.
q) -O system writes remote_discovery_register to value *alpha* using PME-3— the next non-associated PME.

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r) -O system reads remote_discovery_register for all other PMEs.
s) -O system discovers that no other PME is associated with the same remote MAC device as PME-3.
t) -O system rewrites remote_discovery_register to value *beta* using PME-3.
u) -O system writes remote_discovery_register to value *alpha* using PME-4—the next non-associated PME.
v) -O system reads remote_discovery_register for all other PMEs.
w) -O system discovers that PME-5, PME-9 and PME-11 are associated with the same remote MAC device as PME-4.
x) -O system rewrites remote_discovery_register to value *beta* using PME-4.
y) This procedure repeats for all of the PMEs connected to -O system.

NOTE— This procedure can be expanded at the -O end to provide up to 32 unique alpha values. The -O end would then write a different alpha value on each port and then read all remote_discovery_register. Since the write operation is an atomic write, only one alpha value for each remote PCS will be written. All other subsequent write operations on that PCS will fail.

Observe also that a large and complex -O system may perform multiple discovery operations in parallel by using multiple unique 48-bit values for writing the remote_discovery_register.

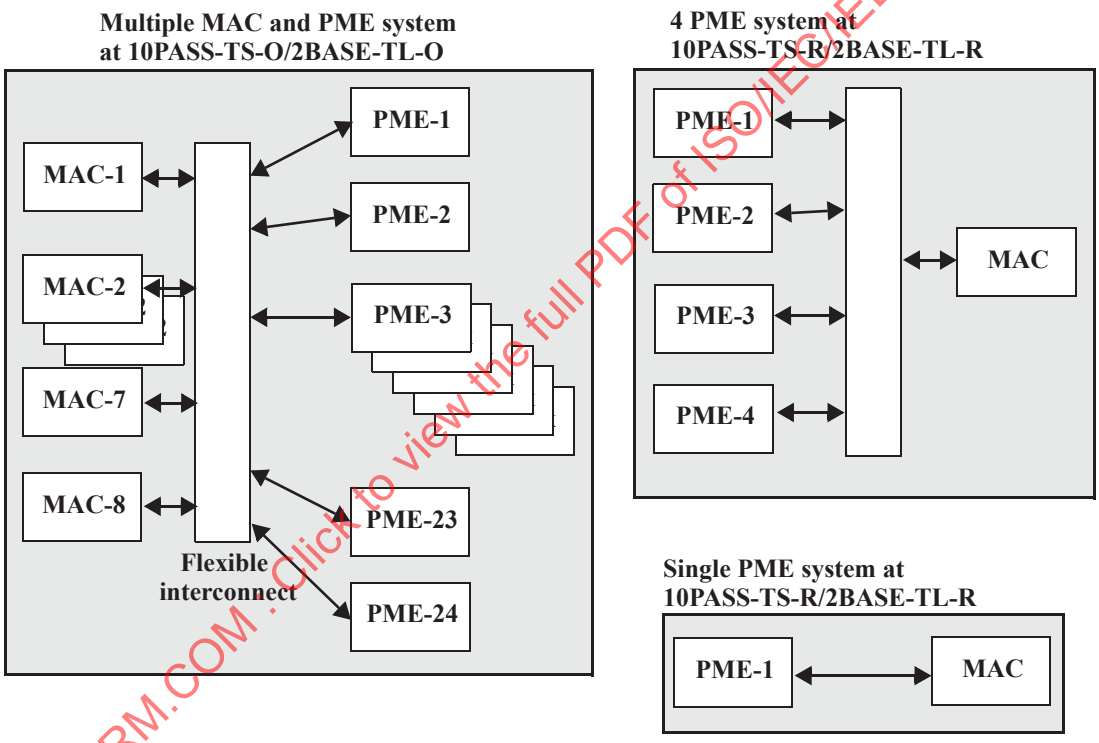

Figure 61A–1—Example systems for discovery

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