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

Part 3: Standard for Ethernet

AMENDMENT 6: Physical layer specifications and management parameters for ethernet passive optical networks protocol over coax

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

Partie 3: Norme pour Ethernet

AMENDEMENT 6

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IEEE Std 802.3bn™-2016
(Amendment to
IEEE Std 802.3™-2015
as amended by
IEEE Std 802.3bw™-2015,
IEEE Std 802.3by™-2016,
IEEE Std 802.3bq™-2016,
IEEE Std 802.3bp™-2016, and
IEEE Std 802.3br™-2016)

IEEE Standard for Ethernet

Amendment 6: Physical Layer Specifications and Management Parameters for Ethernet Passive Optical Networks Protocol over Coax

LAN/MAN Standards Committee
of the
IEEE Computer Society

Approved 22 September 2016

IEEE-SA Standards Board

Abstract: Physical Layer specifications and management parameters for the operation of Ethernet Passive Optical Networks (EPON) Protocol over coaxial media is defined by this amendment to IEEE Std 802.3-2015.

Keywords: amendment, EPoC, EPON, EPON Protocol over Coax, Ethernet; Ethernet Passive Optical Networks, IEEE 802.3™, IEEE 802.3bn™, Multi-Point MAC Control (MPMC), orthogonal frequency division multiplexing (OFDM), Physical Coding Sublayer (PCS), Physical Media Attachment (PMA), Physical Medium Dependent (PMD), PON, point to multipoint (P2MP)

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Introduction

This introduction is not part of IEEE Std 802.3bn-2016, IEEE Standard for Ethernet—Amendment 6: Physical Layer Specifications and Management Parameters for Ethernet Passive Optical Networks Protocol over Coax.

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

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

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

At the date of IEEE Std 802.3bn-2016 publication, IEEE Std 802.3 is composed of the following documents:

IEEE Std 802.3-2015

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

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

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

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

Section Five—Includes Clause 56 through Clause 77 and Annex 57A through Annex 76A. Clause 56 through Clause 67 and Clause 75 through Clause 77, as well as associated annexes, specify subscriber access and other Physical Layers and sublayers for operation from 512 kb/s to 10 Gb/s, and defines services and protocol elements that enable the exchange of IEEE Std 802.3 format frames between stations in a subscriber access network. Clause 68 specifies a 10 Gb/s Physical Layer specification. Clause 69 through Clause 74 and associated annexes specify Ethernet operation over electrical backplanes at speeds of 1000 Mb/s and 10 Gb/s.

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

IEEE Std 802.3bw-2015

Amendment 1—This amendment includes changes to IEEE Std 802.3-2015 and adds Clause 96. This amendment adds 100 Mb/s Physical Layer (PHY) specifications and management parameters for operation on a single balanced twisted-pair copper cable.

IEEE Std 802.3by-2016

Amendment 2—This amendment includes changes to IEEE Std 802.3-2015 and adds Clause 105 through Clause 112, Annex 109A, Annex 109B, Annex 110A, Annex 110B, and Annex 110C. This amendment adds MAC parameters, Physical Layers, and management parameters for the transfer of IEEE 802.3 format frames at 25 Gb/s.

IEEE Std 802.3bq-2016

Amendment 3—This amendment includes changes to IEEE Std 802.3-2015 and adds Clause 113 and Annex 113A. This amendment adds new Physical Layers for 25 Gb/s and 40 Gb/s operation over balanced twisted-pair structured cabling systems.

IEEE Std 802.3bp-2016

Amendment 4—This amendment includes changes to IEEE Std 802.3-2015 and adds Clause 97 and Clause 98. This amendment adds point-to-point 1 Gb/s Physical Layer (PHY) specifications and management parameters for operation on a single balanced twisted-pair copper cable in automotive and other applications not utilizing the structured wiring plant.

IEEE Std 802.3br-2016

Amendment 5—This amendment includes changes to IEEE Std 802.3-2015 and adds Clause 99. This amendment adds a MAC Merge sublayer and a MAC Merge Service Interface to support for Interspersing Express Traffic over a single link.

IEEE Std 802.3bn-2016

Amendment 6—This amendment adds the Physical Layer specifications and management parameters for symmetric and/or asymmetric operation of up to 10 Gb/s on point-to-multipoint Radio Frequency (RF) distribution plants comprising either amplified or passive coaxial media. It also extends the operation of Ethernet Passive Optical Networks (EPON) protocols, such as Multipoint Control Protocol (MPCP) and Operation Administration and Management (OAM).

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

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

Acknowledgments

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The editing instructions are shown in ***bold italic***. Four editing instructions are used: change, delete, insert, and replace. ***Change*** is used to make corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~strikethrough~~ (to remove old material) and <u>underscore</u> (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Deletions and insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make changes in figures or equations by removing the existing figure or equation and replacing it with a new one. Editing instructions, change markings, and this NOTE will not be carried over into future editions because the changes will be incorporated into the base standard.

Cross references that refer to clauses, tables, equations, or figures not covered by this amendment are highlighted in green.

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

1. Introduction

1.2 Notation

Insert a new 1.2.7 after 1.2.6 "Accuracy and resolution of numerical quantities" as follows:

1.2.7 Qm.n number format

The Qm.n number format is a fixed-point number format where the number of fractional bits is specified by n and optionally the number of integer bits is specified by m. For example, a Q14 number has 14 fractional bits; a Q2.14 number has 2 integer bits and 14 fractional bits. Preceding the "Q" with a "U" indicates an unsigned number.

1.3 Normative references

Insert the following references in alphanumeric order:

CFR 76, Code of Federal Regulations, Title 47, Part 76, October 2005.

IEC 61169-24:2009, Radio-frequency connectors—Part 24: Sectional specification—Radio frequency coaxial connectors with screw coupling, typically for use in 75 Ω cable networks (type F).

IEEE Std 802.1AS™-2011, IEEE Standard for Local and metropolitan area networks—Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks.

SCTE 02 2006, Specification for "F" Port, Female, Indoor.

1.4 Definitions

Insert the following definition after 1.4.49 "10GBASE-X" as follows:

1.4.49a 10GPASS-XR: A collection of IEEE 802.3 EPON Protocol over Coax (EPoC) Physical Layer specifications for up to 10 Gb/s downstream and up to 1.6 Gb/s upstream point-to-multipoint link over a coax cable distribution network. (See IEEE Std 802.3, Table 56–1, Clause 100, Clause 101, Clause 102, and Clause 103.)

Change the definition of 1.4.134 as modified by IEEE Std 802.3by-2016 as follows:

1.4.134 channel: In 10BROAD36 and 10GPASS-XR, a band of frequencies dedicated to a certain service transmitted on the broadband medium. Otherwise, a defined path along which data in the form of an electrical or optical signal passes. (For 10BROAD36, see IEEE Std 802.3, Clause 11, for 10GPASS-XR see Clause 100, Clause 101, and Clause 102.)

Insert the following definitions after 1.4.144 "Clocked Violation LO (CVL)" as follows:

1.4.144a coax cable distribution network (CCDN): A radio frequency (RF) distribution plant composed of either amplified or passive coaxial media.

1.4.144b coax line terminal (CLT): The network-end DTE for a coaxial access network. The CLT is the master entity in a P2MP EPoC network with regard to the MPCP protocol.

1.4.144c coax network unit (CNU): The subscriber-end DTE to a coaxial access network. A CNU is a slave entity in a P2MP EPoC network with regard to the MPCP protocol.

Insert the following definition after 1.4.170 "cross connect" as follows:

1.4.170a cyclic prefix (CP): A redundant set of samples prepended to an OFDM symbol.

Insert the following definition after 1.4.277 "mixing segment" and before 1.4.277a (as inserted by IEEE Std 802.3bq-2016)as follows:

1.4.277aa modulation error ratio (MER): The ratio of average signal constellation power to average constellation error power—that is, digital complex baseband signal-to-noise ratio—expressed in decibels.

Insert the following definition after 1.4.294 "OAM Discovery" as follows:

1.4.294a OFDM channel: See orthogonal frequency division multiplexing (OFDM) channel.

Insert the following definition after 1.4.296 "Operations, Administration, and Maintenance (OAM)" as follows:

1.4.296a optical distribution network (ODN): An optical distribution plant composed of fiber optic cabling and a passive optical splitter or cascade of splitters .

Insert the following definition after 1.4.306 "Organizationally Unique Identifier (OUI)" as follows:

1.4.306a orthogonal frequency division multiplexing (OFDM) channel: A data transmission channel in which the transmitted data is carried over a number of orthogonal subcarriers.

Change the definition of 1.4.331 "Point-to-Multipoint network (P2MP)" as follows:

1.4.331 Point-to-Multipoint network (P2MP): ~~A passive optical network providing transport of Ethernet frames~~ A network topology based on a centralized station connected to a number of end stations. Frames transit the network between the central station and the end stations and do not transit directly from end station to end station. (See IEEE Std 802.3, Clause 64, ~~and~~ Clause 65, Clause 76, Clause 77, Clause 101, and Clause 103).

Insert the following definition after 1.4.348 "quad" as follows:

1.4.348a quadrature amplitude modulation (QAM) symbol: The amplitude-phase representation of the bits of data that modulate a carrier signal or that modulate each of the subcarriers in OFDM.

Change the note in 1.4.400 as follows:

NOTE—See Clause 64, ~~and~~ Clause 77, and Clause 103. The value of time_quantum is defined in 64.2.2.1.

1.5 Abbreviations

Insert the following new abbreviations into the list, in alphabetical order:

CCDN	coax cable distribution network
CLT	coax line terminal
CNU	coax network unit
CP	cyclic prefix

EPoC	EPON protocol over coax
HFC	hybrid fiber coax
MER	modulation error ratio
OFDM	orthogonal frequency division multiplexing
OFDMA	orthogonal frequency division multiple access
QAM	quadrature amplitude modulation
RF	radio frequency
RTT	round trip time

30. Management

30.3 Layer management for DTEs

30.3.2 PHY device managed object class

30.3.2.1 PHY device attributes

30.3.2.1.2 aPhyType

Insert after 10/1GBASE-PRX a single line for "10GPASS-XR" type into the APPROPRIATE SYNTAX list of 30.3.2.1.2 aPhyType (as modified by IEEE Std 802.3bw-2015, IEEE Std 802.3by-2016, IEEE Std 802.3bq-2016, and IEEE Std 802.3bp-2016) as follows:

...

10GPASS-XR — Clause 101 PCS up to 10 Gb/s 64B/66B OFDM downstream and up to 1.6 Gb/s 64B/66B OFDMA upstream

...

30.3.2.1.3 aPhyTypeList

Insert after 10/1GBASE-PRX a single line for "10GPASS-XR" type into the APPROPRIATE SYNTAX list of 30.3.2.1.3 aPhyTypeList (as modified by IEEE Std 802.3bw-2015, IEEE Std 802.3by-2016, IEEE Std 802.3bq-2016, and IEEE Std 802.3bp-2016) as follows:

...

10GPASS-XR — Clause 101 PCS up to 10 Gb/s 64B/66B OFDM downstream and up to 1.6 Gb/s 64B/66B OFDMA upstream

...

30.3.5 MPCP managed object class

Change the capitalization of the title for 30.3.5.1 as follows:

30.3.5.1 MPCP ~~A~~attributes

30.3.5.1.2 aMPCPAdminState

Change the description for "BEHAVIOUR DEFINED AS" section of 30.3.5.1.2 aMPCPAdminState to add Clause 103 to the list of cross references as follows:

....

BEHAVIOUR DEFINED AS:

A read-only value that identifies the operational state of the Multipoint MAC Control sublayer. An interface that can provide the Multipoint MAC Control sublayer functions specified in Clause 64, ~~or~~ Clause 77, or Clause 103 is enabled to do so when this attribute has the enumeration "enabled". When this attribute has the enumeration "disabled", the interface acts as it would if it had no Multipoint MAC Control sublayer. The operational state of the Multipoint MAC Control sublayer can be changed using the acMPCPAdminControl action.;

30.3.5.1.3 aMPCPMode

Change the description for "APPROPRIATE SYNTAX" and "BEHAVIOUR DEFINED AS" section of 30.3.5.1.3 aMPCPMode as follows:

...

APPROPRIATE SYNTAX:

An ENUMERATED VALUE that has the following entries:
OLT
ONU
<u>CLT</u>
<u>CNU</u>

BEHAVIOUR DEFINED AS:

A read-only value that identifies the operational mode of the Multipoint MAC Control sublayer. An interface that can provide the Multipoint MAC Control sublayer functions specified in Clause 64, ~~or~~ Clause 77<u>, or Clause 103. When</u> ~~operates as an OLT when~~ this attribute has the enumeration "OLT"<u>, the interface acts as an OLT</u>. When this attribute has the enumeration "ONU", the interface acts as an ONU. <u>When this attribute has the enumeration "CLT", the interface acts as a CLT. When this attribute has the enumeration "CNU", the interface acts as a CNU.</u>;

30.5 Layer management for medium attachment units (MAUs)

30.5.1 MAU managed object class

30.5.1.1 MAU attributes

30.5.1.1.2 aMAUType

Insert after 10GBASE-T a single line for "10GPASS-XR" type into the APPROPRIATE SYNTAX list of 30.5.1.1.2 aMAUType (as modified by IEEE Std 802.3bw-2015, IEEE Std 802.3by-2016, IEEE Std 802.3bq-2016, and IEEE Std 802.3bp-2016) as follows:

...

10GBASE-XR	Coax cable distribution network PHY continuous downstream/burst mode upstream PHY as specified in Clause 100 and Clause 101

...

45. Management Data Input/Output (MDIO) Interface

45.2 MDIO Interface Registers

Change reserved row 12 through 28 of Table 45–1 and insert a new row 12 as follows (unchanged rows are not shown):

Table 45–1—MDIO Manageable Device addresses

Device address	MMD name
12	OFDM PMA/PMD
~~12~~13 through 28	Reserved

Change the identified reserved row in Table 45–2 and insert a new row for OFDM devices immediately below the changed row as follows (unchanged rows and footnotes not shown):

Table 45–2—Devices in package registers bit definitions

Bit(s)	Name	Description	R/W
m.5.15:~~12~~13	Reserved	Value always 0	RO
m.5.12	OFDM	1 = OFDM present in package 0 = OFDM not present in package	RO

45.2.1 PMA/PMD registers

Change the reserved row for 1.17 in Table 45–3 (as inserted by IEEE Std 802.3bw-2015) as follows (unchanged rows not shown):

Table 45–3—PMA/PMD registers

Register address	Register name	Subclause
1.17	~~Reserved~~EPoC PMA/PMD ability	45.2.1.14aa

Change Table 45–3 (as inserted by IEEE Std 802.3bw-2015) as follows (unchanged rows not shown):

Table 45–3—PMA/PMD registers

Register address	Register name	Subclause
1.1809 through 1.1899~~2099~~	Reserved	
1.1900	10GPASS-XR control and status	45.2.1.130a
1.1901	DS OFDM control	45.2.1.130b
1.1902 through 1.1906	DS OFDM channel frequency control	45.2.1.130c
1.1907	US OFDM control	45.2.1.130d
1.1908	US OFDM channel frequency control	45.2.1.130e
1.1909	US OFDMA pilot pattern	45.2.1.130f
1.1910	Profile control	45.2.1.130g
1.1911	DS PHY Link control	45.2.1.130h
1.1912	US PHY Link control	45.2.1.130i
1.1913 and 1.1914	PHY Discovery control	45.2.1.130j
1.1915	New CNU control	45.2.1.130k
1.1916 through 1.1920	New CNU info	45.2.1.130l
1.1921	DS PHY Link frame counter	45.2.1.130m
1.1922 and 1.1923	PMA/PMD timing offset	45.2.1.130n
1.1924	PMA/PMD power offset	45.2.1.130o
1.1925 and 1.1926	PMA/PMD ranging offset	45.2.1.130p
1.1927 through 1.1929	DS PMA/PMD data rate	45.2.1.130q
1.1930 through 1.1932	US PMA/PMD data rate	45.2.1.130r
1.1933 and 1.1934	10GPASS-XR FEC codeword counter	45.2.1.130s
1.1935 and 1.1936	10GPASS-XR FEC codeword success counter	45.2.1.130t
1.1937 and 1.1938	10GPASS-XR FEC codeword fail counter	45.2.1.130u
1.1939	PHY Link EPFH counter	45.2.1.130v
1.1940	PHY Link EPFH error counter	45.2.1.130w
1.1941	PHY Link EPCH counter	45.2.1.130x

Table 45–3—PMA/PMD registers *(continued)*

Register address	Register name	Subclause
1.1942	PHY Link EPCH error counter	45.2.1.130y
1.1943	PHY Link EMB counter	45.2.1.130z
1.1944	PHY Link EMB error counter	45.2.1.130z1
1.1945	PHY Link FPMB counter	45.2.1.130z2
1.1946	PHY Link FPMB error counter	45.2.1.130z3
1.1947	US PHY Link response time	45.2.1.130z4
1.1948	10GPASS-XR modulation ability	45.2.1.130z5
1.1949	PHY Discovery Response power control	45.2.1.130z6
1.1950	US target receive power	45.2.1.130z7
1.1951 through 1.1955	DS transmit power	45.2.1.130z8
1.1956 and 1.1957	US receive power measurement	45.2.1.130z9
1.1958	Reported power	45.2.1.130z10
1.1959 through 1.2099	Reserved	

45.2.1.4 PMA/PMD speed ability (Register 1.4)

Change the reserved row for 1.4.10 in Table 45–6 as inserted by IEEE Std 802.3by-2016 as follows (unchanged rows not shown):

Table 45–6—PMA/PMD speed ability register bit definitions

Bit(s)	Name	Description	R/W[a]
1.4.10	~~Reserved~~ 10GPASS-XR capable	~~Value always 0~~ 1 = PMA/PMD is capable of operating as 10GPASS-XR 0 = PMA/PMD is not capable of operating as 10GPASS-XR	RO

[a]RO = Read only

Insert 45.2.1.4.b after 45.2.1.4.a (as inserted by IEEE Std 802.3by-2016) as follows:

45.2.1.4.b 10GPASS-XR capable (1.4.10)

When read as one, bit 1.4.10 indicates that the PMA/PMD is able to operate as 10GPASS-XR. When read as zero, bit 1.4.10 indicates that the PMA/PMD is not able to operate as 10GPASS-XR.

45.2.1.6 PMA/PMD control 2 register (Register 1.7)

Change the PMA/PMD type selection row in Table 45–7 to add 10GPASS-XR PMDs as follows (only Bits, Name, added Description text, and R/W is shown). Change "reserved" line(s) as appropriate for values defined by this and other approved amendments.

Table 45–7—PMA/PMD control 2 register bit definitions

Bit(s)	Name	Description	R/W[a]
1.7.5:0	PMA/PMD type selection	1 1 0 0 1 1 = 10GPASS-XR-U PMA/PMD 1 1 0 0 1 0 = 10GPASS-XR-D PMA/PMD	R/W

[a]R/W = Read/Write, RO = Read only

Insert 45.2.1.14aa and Table 45–17aa before 45.2.1.14a as inserted by IEEE Std 802.3bw-2015 as follows:

45.2.1.14aa EPoC PMA/PMD ability register (Register 1.17)

The assignment of bits in the EPoC PMA/PMD ability register is shown in Table 45–17aa. All of the bits in the EPoC PMA/PMD ability register are read only; a write to the EPoC PMA/PMD ability register shall have no effect.

Table 45–17aa—EPoC PMA/PMD ability register bit definitions

Bit(s)	Name	Description	R/W[a]
1.17.15:2	Reserved	Value always 0	RO
1.17.1	10GPASS-XR-D ability	1 = PMA/PMD is able to perform 10GPASS-XR-D 0 = PMA/PMD is not able to perform 10GPASS-XR-D	RO
1.17.0	10GPASS-XR-U ability	1 = PMA/PMD is able to perform 10GPASS-XR-U 0 = PMA/PMD is not able to perform 10GPASS-XR-U	RO

[a]RO = Read only

45.2.1.14aa.1 10GPASS-XR-D ability (1.17.1)

When read as one, bit 1.17.1 indicates that the PMA/PMD is able to operate as a 10GPASS-XR-D PMA/PMD type. When read as zero, bit 1.17.1 indicates that the PMA/PMD is not able to operate as a 10GPASS-XR-D PMA/PMD type.

45.2.1.14aa.2 10GPASS-XR-U ability (1.17.0)

When read as one, bit 1.17.0 indicates that the PMA/PMD is able to operate as a 10GPASS-XR-U PMA/PMD type. When read as zero, bit 1.17.0 indicates that the PMA/PMD is not able to operate as a 10GPASS-XR-U PMA/PMD type.

Insert 45.2.1.130a through 45.2.1.130z10 after 45.2.1.130 as follows:

45.2.1.130a 10GPASS-XR control and status register (Register 1.1900)

The assignment of bits in the 10GPASS-XR control and status register is shown in Table 45–98aa.

Table 45–98aa—10GPASS-XR control and status register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1900.15:14	Reserved	Value always 0	RO
1.1900.13	Time synch capable	1 = The CNU supports time synchronization variables 0 = The CNU does not support time synchronization variables	RO
1.1900.12	US rate mismatch	1 = the upstream rate calculated at the CNU and the CLT matches within 10 b/s 0 = the upstream rate calculated at the CNU and the CLT is mismatched by greater than 10 b/s	RO
1.1900.11	DS rate mismatch	1 = the downstream rate calculated at the CNU and the CLT matches within 10 b/s 0 = the downstream rate calculated at the CNU and the CLT is mismatched by greater than 10 b/s	RO
1.1900.10	Link up ready	1 = the CNU is ready to enter the Link-Up state 0 = the CNU is not ready to enter the Link-Up state	R/W
1.1900.9:3	Continuous pilot scaling factor	Number of continuous pilots in the downstream OFDM channels	R/W
1.1900.2	CRC40 errored blocks	1 = 65-bit blocks with detected CRC40 errors are labeled as errored 0 = 65-bit blocks with detected CRC40 errors are not labeled as errored	R/W
1.1900.1	PHY Discovery complete	1 = The PMA/PMD has completed PHY Discovery on the coaxial cable distribution network 0 = The PMA/PMD has not completed PHY Discovery on the coaxial cable distribution network	R/W
1.1900.0	PHY Discovery enable	1 = PMA/PMD is permitted to transmit on the media 0 = PMA/PMD is not permitted to transmit on the media	R/W

[a]RO = Read only, R/W = Read/Write

45.2.1.130a.1 Time sync capable (1.1900:13)

When read as one, bit 1.1900:13 indicates that the 10G-PASS-XR PMA/PMD is capable of supporting the time synchronization variables PHY differential delay and PHY differential delay tolerance reflected in registers 1.1949 and 1.1950. This bit is a reflection of the *TimeSyncCapable* variable defined in 101.6.

45.2.1.130a.2 US rate mismatch (1.1900:12)

When read as one, bit 1.1900.12 indicates that the upstream rate calculated at the CNU and the CLT is mismatched by greater than 10 b/s. This bit is defined in 10GPASS-XR-U PMA/PMD only, in 10GPASS-XR-D always read as zero. This bit is a reflection of the *US_RateMatchFail* variable defined in 100.3.2.3.

45.2.1.130a.3 DS rate mismatch (1.1900:11)

When read as one, bit 1.1900.11 indicates that the downstream rate calculated at the CNU and the CLT is mismatched by greater than 10 b/s. This bit is defined in 10GPASS-XR-U PMA/PMD only, in 10GPASS-XR-D always read as zero. This bit is a reflection of the *DS_RateMatchFail* variable defined in 100.3.2.3.

45.2.1.130a.4 Link up ready (1.1900:10)

Bit 1.1900.10 indicates that the CNU is ready for the link-up state. This bit is a reflection of the *LinkUpRdy* variable defined in 102.4.1.9.2.

45.2.1.130a.5 Continuous pilot scaling factor (1.1900.9:3)

Bits 1.1900.9:3 form an unsigned integer that is used to determine the number of continuous pilots in the downstream OFDM channels. These bits are a reflection of the variable *CntPltSF* defined in 101.4.3.6.5.

45.2.1.130a.6 CRC40 errored blocks (1.1900.2)

Bit 1.1900.2 is used to control whether 65-bit blocks with detected CRC40 errors are labeled as errored before being passed higher layers as described in 101.3.3.1.4. This bit is a reflection of the variable *CRC40ErrCtrl* defined in 101.3.3.1.6.

45.2.1.130a.7 PHY Discovery complete (1.1900.1)

When read as one, bit 1.1900.1 indicates that the 10GPASS-XR PMA/PMD has completed PHY Discovery (see 102.4.1) on the coaxial cable distribution network. When read as zero, bit 1.1900.1 indicates that the PMA/PMD has not completed PHY Discovery on the coaxial cable distribution network. This bit is defined in 10GPASS-XR-U PMA/PMD only, in 10GPASS-XR-D always read as one. This bit is a reflection of the variable *PhyDiscCmplt* defined in 102.4.1.9.2.

The default value for bit 1.1900.1 is zero.

45.2.1.130a.8 PHY Discovery enable (1.1900.0)

When read as one, bit 1.1900.0 indicates that the 10GPASS-XR PMA/PMD is permitted to transmit on the media. When read as zero, bit 1.1900.0 indicates that the PMA/PMD is not permitted to transmit on the media. This bit is a reflection of the variable *PD_Enable* defined in 102.2.7.3.

The default value for bit 1.1900.0 is zero.

45.2.1.130b DS OFDM control register (Register 1.1901)

The assignment of bits in the DS OFDM control register is shown in Table 45–98ab.

Table 45–98ab—DS OFDM control register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1901.15	CLT tx mute	1 = CLT PHY muted state for test purposes 0 = CLT PHY not muted (normal operation)	R/W

Table 45–98ab—DS OFDM control register bit definitions *(continued)*

Bit(s)	Name	Description	R/W[a]
1.1901.14:12	DS OFDM channels	Indicates the number of OFDM channels the PMA/PMD is operating in the downstream direction	R/W
1.1901.11:7	DS time interleaving	Indicates the number of OFDM symbols the PMA/PMD is time interleaving in the downstream direction	R/W
1.1901.6:4	DS windowing	Indicates the size of the windowing control for the PMA/PMD in the downstream direction	R/W
1.1901.3:0	DS cyclic prefix	Indicates the size of the cyclic prefix for the PMA/PMD in the downstream direction	R/W

[a]R/W = Read/Write

45.2.1.130b.1 CLT tx mute (1.1901.15)

When bit 1.1901.15 is set to one, the CLT PMD transmitter enters the test mode and it is muted. When bit 1.1901.15 is set to a zero, the CLT PMD enters the normal operating state. This bit has no effect in the CNU. This bit is a reflection of the variable *CLT_TxMute* defined in 100.4.1.

45.2.1.130b.2 DS OFDM channels (1.1901.14:12)

Bits 1.1901.14:12 indicate the integer number of downstream OFDM channels in use. The number is between 1 and 5; where bit 1.1901.12 is the LSB and bit 1.1901.14 is the MSB. These bits are a reflection of the counter *DS_ChCnt* defined in 100.3.2.3.

45.2.1.130b.3 DS time interleaving (1.1901.11:7)

Bits 1.1901.11:7 indicate the integer number of time interleaved OFDM symbols in the downstream direction. The number is between 1 and 32; where bit 1.1901.7 is the LSB and bit 1.1901.11 is the MSB. These bits are a reflection of the variable *DS_TmIntrlv* defined in 101.4.3.9.5.

45.2.1.130b.4 DS windowing (1.1901.6:4)

Bits 1.1901.6:4 indicate the size, in OFDM Clock periods (1/204.8 MHz), of the windowing control for the 10GPASS-XR PMA/PMD in the downstream direction. These bits are a reflection of the variable *DSNrp* defined in 101.4.3.12.1 with bits 1.1901.6:4 mapping to bits 2:0 of *DSNrp*, respectively.

45.2.1.130b.5 DS cyclic prefix (1.1901.3:0)

Bits 1.1901.3:0 indicate the size, in OFDM Clock periods (1/204.8 MHz), of the cyclic prefix control for the 10GPASS-XR PMA/PMD in the downstream direction. These bits are a reflection of the variable *DSNcp* defined in 101.4.3.12.1 with bits 1.1901.3:0 mapping to bits 3:0 of *DSNcp*, respectively.

45.2.1.130c DS OFDM channel frequency control register 1 through 5 (Register 1.1902 through 1.1906)

The assignment of bits in the DS OFDM channel frequency control register 1 through 5 is shown in Table 45–98ac.

Table 45–98ac—DS OFDM channel frequency control register 1 through 5 bit definitions

Bit(s)	Name	Description	R/W[a]
1.1902.15:0	DS OFDM freq ch 1	This register specifies the center frequency of subcarrier 0 of downstream OFDM channel number 1.	R/W
1.1903.15:0	DS OFDM freq ch 2	This register specifies the center frequency of subcarrier 0 of downstream OFDM channel number 2.	R/W
1.1904.15:0	DS OFDM freq ch 3	This register specifies the center frequency of subcarrier 0 of downstream OFDM channel number 3.	R/W
1.1905.15:0	DS OFDM freq ch 4	This register specifies the center frequency of subcarrier 0 of downstream OFDM channel number 4.	R/W
1.1906.15:0	DS OFDM freq ch 5	This register specifies the center frequency of subcarrier 0 of downstream OFDM channel number 5.	R/W

[a]R/W = Read/Write

45.2.1.130c.1 DS OFDM freq ch 1 (1.1902.15:0)

Register 1.1902 specifies the center frequency for OFDM channel number 1 in units of 50 kHz. This register is a reflection of the variable *DS_FreqCh(1)* defined in 100.3.2.3.

45.2.1.130c.2 DS OFDM freq ch 2 (1.1903.15:0)

Register 1.1903 specifies the center frequency of OFDM channel number 2 in units of 50 kHz. This register is a reflection of the variable *DS_FreqCh(2)* defined in 100.3.2.3.

45.2.1.130c.3 DS OFDM freq ch 3 (1.1904.15:0)

Register 1.1904 specifies the center frequency of OFDM channel number 3 in units of 50 kHz. This register is a reflection of the variable *DS_FreqCh(3)* defined in 100.3.2.3.

45.2.1.130c.4 DS OFDM freq ch 4 (1.1905.15:0)

Register 1.1905 specifies the center frequency of OFDM channel number 4 in units of 50 kHz. This register is a reflection of the variable *DS_FreqCh(4)* defined in 100.3.2.3.

45.2.1.130c.5 DS OFDM freq ch 5 (1.1906.15:0)

Register 1.1906 specifies the center frequency of OFDM channel number 5 in units of 50 kHz. This register is a reflection of the variable *DS_FreqCh(5)* defined in 100.3.2.3.

45.2.1.130d US OFDM control register (Register 1.1907)

The assignment of bits in the US OFDM control register is shown in Table 45–98ad.

Table 45–98ad—US OFDM control register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1907.15:8	Random seed	Random back-off seed for PHY Discovery	R/W
1.1907.7	Resource Block size	1 = 16 OFDMA symbols in the upstream OFDMA Resource Block 0 = 8 OFDMA symbols in the upstream OFDMA Resource Block	R/W
1.1907.6:4	US windowing	Indicates the size of the windowing control for the PMA/PMD in the upstream direction	R/W
1.1907.3:0	US cyclic prefix	Indicates the size of the cyclic prefix for the PMA/PMD in the upstream direction	R/W

[a]R/W = Read/Write

45.2.1.130d.1 Random seed (1.1907.15:8)

Bits 1.1907.15:8 form an 8-bit integer that is used by the CNU for the seed of the PHY Discovery back-off algorithm. These bits are a reflection of the *Rnd* variable defined in 102.4.1.9.2.

45.2.1.130d.2 Resource Block size (1.1907.7)

Bit 1.1907.7 indicates the number of OFDM symbols in a Resource Block in the upstream direction. This bit is a reflection of the variable *RBsize* defined in 101.4.4.3.5.

45.2.1.130d.3 US windowing (1.1907.6:4)

Bits 1.1907.6:4 indicate the size, in units of OFDM Clock periods (1/204.8 MHz), of the windowing control for the 10GPASS-XR PMA/PMD in the upstream direction. These bits are a reflection of the variable *USNrp* defined in 101.4.4.10.1 with bits 1.1907.6:4 mapping to bits 2:0 of *USNrp*, respectively.

45.2.1.130d.4 US cyclic prefix (1.1907.3:0)

Bits 1.1907.3:0 indicate the size, in units of OFDM Clock periods (1/204.8 MHz), of the cyclic prefix control for the 10GPASS-XR PMA/PMD in the upstream direction. These bits are a reflection of the variable *USNcp* defined in 101.4.4.10.1 with bits 1.1907.3:0 mapping to bits 3:0 of *USNcp*, respectively.

45.2.1.130e US OFDM channel frequency control register (Register 1.1908)

The assignment of bits in the US OFDM channel frequency control register is shown in Table 45–98ae.

Register 1.1908 indicates the center frequency, in units of 50 kHz, of subcarrier 0 for the upstream OFDM channel. This register is a reflection of the variable *US_FreqCh1* defined in 100.3.2.3.

Table 45–98ae—US OFDM channel frequency control register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1908.15:0	US OFDM freq	This specifies the center frequency of subcarrier 0 of the upstream OFDM channel.	R/W

[a]R/W = Read/Write

45.2.1.130f US OFDMA pilot pattern register (Register 1.1909)

The assignment of bits in the US OFDMA pilot pattern register is shown in Table 45–98af. For additional information on the use of the parameters in this register see 101.4.4.6.

Table 45–98af—US OFDMA pilot pattern register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1909.15	Reserved	Value always 0	RO
1.1909.14:12	Type 2 repeat	Indicates the number of subcarriers between Type 2 Pilots	R/W
1.1909.11:8	Type 2 start	Indicates the number of the subcarrier on which the Type 2 Pilot pattern starts	R/W
1.1909.7	Reserved	Value always 0	RO
1.1909.6:4	Type 1 repeat	Indicates the number of subcarriers between Type 1 Pilots	R/W
1.1909.3:0	Type 1 start	Indicates the number of the subcarrier on which the Type 1 Pilot pattern starts	R/W

[a]RO = Read only, R/W = Read/Write

45.2.1.130f.1 Type 2 repeat (1.1909.14:12)

Bits 1.1909.14:12 indicate the number of subcarriers between repeating Type 2 Pilots. Additional information on pilot patterns and encoding for these bits is located in 101.4.4.6 and Table 101–14. These bits are a reflection of the variable *Type2_Repeat* defined in 101.4.4.6.1.

45.2.1.130f.2 Type 2 start (1.1909.11:8)

Bits 1.1909.11:8 indicate the number of the first subcarrier designated as a Type 2 Pilot. These bits are a reflection of the variable *Type2_Start* defined in 101.4.4.6.1.

45.2.1.130f.3 Type 1 repeat (1.1909.6:4)

Bits 1.1909.6:4 indicate the number of subcarriers between repeating Type 1 Pilots. Additional information on pilot patterns and encoding for these bits is located in 101.4.4.6 and Table 101–14. These bits are a reflection of the variable *Type1_Repeat* defined in 101.4.4.6.1.

45.2.1.130f.4 Type 1 start (1.1909.3:0)

Bits 1.1909.3:0 indicate the number of the first subcarrier designated as a Type 1 Pilot. These bits are a reflection of the variable *Type1_Start* defined in 101.4.4.6.1.

45.2.1.130g Profile control register (Register 1.1910)

The assignment of bits in the Profile control register is shown in Table 45–98ag. See 102.4.5 for additional information on the profile copy functionality.

Table 45–98ag—Profile control register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1910.15:12	Reserved	Value always 0	RO
1.1910.11	US copy in process	1 = the active upstream profile is being copied to the off-line profile 0 = the upstream off-line profile is not being modified by a profile copy	RO
1.1910.10	US profile copy	1 = initiates a copy of the active upstream profile to the off-line profile 0 = no copy initiated	R/W, SC
1.1910.9:8	US configuration ID	Controls switching the active upstream profile	RO
1.1910.7	Reserved	Value always 0	RO
1.1910.6:4	DS copy channel ID	Indicates which of the 5 downstream OFDM channel profiles is to be copied	
1.1910.3	DS copy in process	1 = the active downstream profile is being copied to the off-line profile 0 = the downstream off-line profile is not being modified by a profile copy	RO
1.1910.2	DS profile copy	1 = initiates a copy of the active downstream profile to the off-line profile 0 = normal	R/W, SC
1.1910.1:0	DS configuration ID	Controls switching the active downstream profile	RO

[a]R/W = Read/Write, RO = Read only, SC = Self-clearing

45.2.1.130g.1 US copy in process (1.1910.11)

When read as one, bit 1.1910.11 indicates that a copy of the currently active upstream profile to the inactive profile is in process, writes to all upstream profile descriptors and their reflective registers (see 45.2.7a.3 and 102.4.5) are ignored, and switching between profiles (see 102.2.3.1.1) is prohibited. This bit is a reflection of the variable *US_CpyInP* defined in 102.4.5.1.

45.2.1.130g.2 US profile copy (1.1910.10)

When bit 1.1910.10 is set to one, a copy of the currently active upstream profile to the inactive profile is initiated and will continue to completion. This bit is set to zero by the PMA/PMD on or before completion of the profile copy. This bit is a reflection of the variable *US_PrflCpy* defined in 102.4.5.1.

45.2.1.130g.3 US configuration ID (1.1910.9:8)

Bits 1.1910.9:8 indicate the value of the most recently received upstream Configuration ID bits (see 102.2.3.1). These bits are a reflection of the variable *US_CID* defined in 102.2.3.1.1.

45.2.1.130g.4 DS copy channel ID (1.1910.6:4)

Bits 1.1910.6:4 indicate which one of the five downstream ODFM channel profiles is to be copied. These bits are a reflection of the *DS_CpyCh* variable defined in 102.4.5.1.

45.2.1.130g.5 DS copy in process (1.1910.3)

When read as one, bit 1.1910.3 indicates that a copy of the currently active downstream profile to the inactive profile is in process, writes to all downstream profile descriptors and their reflective registers (see 45.2.7a.2 and 102.4.5) are ignored, and switching between profiles (see 102.2.3.1) is prohibited. This bit is a reflection of the variable *DS_CpyInP* defined in 102.4.5.1.

45.2.1.130g.6 DS profile copy (1.1910.2)

When bit 1.1910.2 is set to one, a copy of the currently active downstream profile to the inactive profile is initiated and will continue to completion. This bit is set to zero by the PMA/PMD on or before completion of the profile copy. This bit is a reflection of the variable *UDS_PrflCpy* defined in 102.4.5.1.

45.2.1.130g.7 DS configuration ID (1.1910.1:0)

Bits 1.1910.1:0 indicate the value of the most recently received downstream Configuration ID bits (see 102.2.3.1). These bits are a reflection of the variable *DS_CID* defined in 102.2.7.3.

45.2.1.130h DS PHY Link control register (Register 1.1911)

The assignment of bits in the DS PHY Link control register is shown in Table 45–98ah.

Table 45–98ah—DS PHY Link control register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1911.15:12	Reserved	Value always 0	RO
1.1911.11:0	DS PHY Link start	DS PHY Link starting subcarrier	R/W

[a]RO = Read only, R/W = Read/Write

45.2.1.130h.1 DS PHY Link start (1.1911.11:0)

Bits 1.1911.11:0 set the starting subcarrier number of the downstream 10GPASS-XR PHY Link. They indicate the lowest frequency subcarrier of the downstream PHY Link used to carry PHY Link information bits. See 102.2 for additional details on the downstream PHY Link. These bits are a reflection of the variable *DS_PhyLinkStrt* defined in 102.2.7.3.

45.2.1.130i US PHY Link control register (Register 1.1912)

The assignment of bits in the US PHY Link control register is shown in Table 45–98ai.

45.2.1.130i.1 US PHY Link modulation (1.1912.15:12)

Bits 1.1912.15:12 are used to set the modulation type of the upstream PHY Link. These bits are a reflection of the *US_PhyLinkMod* variable defined in 102.3.5.3 with bits 1.1912.15:12 mapping to bits 3:0 of *US_PhyLinkMod*, respectively.

Table 45–98ai—US PHY Link control register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1912.15:12	US PHY Link modulation	US PHY Link modulation type	R/W
1.1912.11:0	US PHY Link start	US PHY Link starting subcarrier	R/W

[a]R/W = Read/Write

45.2.1.130i.2 US PHY Link start (1.1912.11:0)

Bits 1.1912.11:0 set the starting subcarrier number of the upstream 10GPASS-XR PHY Link. They indicate the lowest frequency subcarrier of the upstream PHY Link used to carry PHY Link information bits. See 102.3 for additional details on the upstream PHY Link. These bits are a reflection of the variable *US_PhyLinkStrt* defined in 102.3.5.3.

45.2.1.130j PHY Discovery control registers (Registers 1.1913 and 1.1914)

The PHY Discovery process is used to bring up new CNUs on the EPoC coax cable distribution network. Registers 1.1913 and 1.1914 indicate when the next PHY Discovery window is opened relative to the downstream Timestamp with bit 1.1913.0 being the LSB and bit 1.1914.15 being the MSB. Setting the PHY Discovery start parameter to zero disables the PHY Discovery window. The PHY Discovery control registers direct this process, which is described in 102.4.1. The assignment of bits in the PHY Discovery control registers is shown in Table 45–98aj. These registers are a reflection of the *DiscStrt* variable defined in 102.2.3.2.4

Table 45–98aj—PHY Discovery control register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1913.15:0	PHY Discovery start lower	Time of next open PHY Discovery window bits [15:0]	R/W, MW
1.1914.15:0	PHY Discovery start upper	Time of next open PHY Discovery window bits [31:16]	R/W, MW

[a] R/W = Read/Write, MW = Multi-word

45.2.1.130k New CNU control register (Register 1.1915)

The assignment of bits in the New CNU control register is shown in Table 45–98ak. Additional information on the use of the New CNU control register can be found in 102.4.1.6 and 102.4.3.

Table 45–98ak—New CNU control register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1915.15	CNU_ID assigned flag	1 = the allowed CNU_ID value has been assigned to a CNU 0 = the allowed CNU_ID value has not been assigned to a CNU	R/W
1.1915.14:0	Allowed CNU_ID	A new CNU may be assigned this value for CNU_ID if the CNU_ID assigned flag is FALSE	R/W

[a]R/W = Read/Write

45.2.1.130k.1 CNU_ID assigned flag 1 (1.1915.15)

Bit 1.1915.15 indicates if the associated CNU_ID value has been assigned to a CNU by the PHY. When this bit is set to one, the associated CNU_ID has been assigned to a CNU. When this bit is set to zero the associated CNU_ID has not been assigned. See 102.4.1.6 and 102.4.3 for additional details on the use of this flag. This bit is a reflection of the variable *AssgndCNU_ID* defined in 102.4.1.9.2.

45.2.1.130k.2 Allowed CNU_ID (1.1915.14:0)

Bits 1.1915.14:0 indicate to the 10GPASS-XR PHY a valid CNU_ID value. The value may be assigned to a new CNU when the CNU_ID assigned flag (bit 1.1915.15) is set to zero, when the flag is set to one it is an indication that this value has already been assigned to a CNU and it should not be use for another CNU. These bits are a reflection of the *AllwdCNU_ID* variable defined in 102.4.1.9.2.

45.2.1.130l New CNU info registers 1 through 5 (Registers 1.1916 through 1.1920)

The assignment of bits in the New CNU info registers 1 through 5 is shown in Table 45–98al. Additional information on the use of the New CNU info registers see 102.4.3.

Table 45–98al—New CNU info registers 1 through 5 bit definitions

Bit(s)	Name	Description	R/W[a]
1.1916.15:0	New CNU range	The range of the CNU corresponding to Allowed CNU_ID	RO
1.1917.15:0	New CNU MAC 0	MAC address bits [15:0] of the CNU corresponding to Allowed CNU_ID	RO, MW
1.1918.15:0	New CNU MAC 1	MAC address bits [31:16] of the CNU corresponding to Allowed CNU_ID	RO, MW
1.1919.15:0	New CNU MAC 2	MAC address bits [47:32] of the CNU corresponding to Allowed CNU_ID	RO, MW
1.1920.15:0	Reserved	Value always 0	RO

[a]RO = Read only, MW = Multi-word

45.2.1.130l.1 New CNU range (1.1916.15:0)

Register 1.1916 forms an integer that indicates the range of the CNU corresponding to Allowed CNU_ID (see 102.4.1.6) in units of OFDM Clock periods (1/204.8 MHz). This register is a reflection of the variable *NewCNU_Rng* defined in 102.4.1.9.2.

45.2.1.130l.2 New CNU MAC 0 through 2 (1.1917.15:0 through 1.1919.15:0)

Registers 1.1917 through 1.1919 hold the MAC address of the CNU, as determined by the PHY Discovery process, corresponding to Allowed CNU_ID (see 45.2.1.130k) with bit 1.1917.0 being the LSB and 1.1919.15 being the MSB. These registers are a reflection of the variable *New_MAC* defined in 102.4.1.9.2.

45.2.1.130m DS PHY Link frame counter (Register 1.1921)

Register 1.1921 represents the DS PHY Link frame count. This counter is incremented at the beginning of the PHY Link frame and, on terminal count, rolls over to zero. The assignment of bits in the DS PHY Link frame counter is shown in Table 45–98am.

Table 45–98am—DS PHY Link frame counter bit definitions

Bit(s)	Name	Description	R/W[a]
1.1921.15:0	PHY Link frame counter	Counter that indicates the PHY Link frame currently being processed by the PHY. This counter rolls over to zero and is incremented at the beginning of each PHY Link frame	RO

[a]RO = Read only

45.2.1.130n PMA/PMD timing offset register (Registers 1.1922 and 1.1923)

The assignment of bits in the PMA/PMD timing offset registers is shown in Table 45–98an. Registers 1.1923 and 1.1922 form an offset, in units of OFDM Clock periods (1/204.8 MHz), used to align the CNU to the upstream OFDM timing. For more information on the use of this register see 102.4.1.6. These registers are a reflection of the variable *PhyTimingOffset* defined in 102.4.1.9.2.

Table 45–98an—PMA/PMD timing offset register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1922.15:0	PMA/PMD timing offset lower	Transmit timing offset [15:0]	R/W, MW
1.1923.15:0	PMA/PMD timing offset upper	Transmit timing offset [31:16]	R/W, MW

[a]R/W = Read/Write, MW = Multi-word

45.2.1.130o PMA/PMD power offset register (Register 1.1924)

The assignment of bits in the PMA/PMD power offset register is shown in Table 45–98ao.

Table 45–98ao—PMA/PMD power offset register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1924.15:8	Reserved	Value always 0	RO
1.1924.7:0	PMA/PMD power offset	TX Power offset	R/W

[a] RO = Read Only, R/W = Read/Write

45.2.1.130o.1 PMA/PMD power offset (1.1924.7:0)

Bits 1.1924.7:0 represent a power offset, in units of 0.25 dB, the CNU is to make in order that transmissions arrive at the CLT at the desired power level. For more information on the use of these bits see 102.4.1.6. These bits are a reflection of the variable *PhyPowerOffset* defined in 102.4.1.9.2.

45.2.1.130p PMA/PMD ranging offset registers (Registers 1.1925 and 1.1926)

Registers 1.1925 and 1.1926 represent the PMA/PMD ranging offset parameter, in units of OFDM Clock periods (1/204.8 MHz). The assignment of bits in the PMA/PMD ranging offset register is shown in Table 45–98ap. These registers are a reflection of the variable *PhyRngOffset* defined in 102.4.1.9.2.

Table 45–98ap—PMA/PMD ranging offset registers bit definitions

Bit(s)	Name	Description	R/W[a]
1.1925.15:0	PMA/PMD ranging offset lower	PMA/PMD ranging offset register bits [15:0]	R/W, MW
1.1926.15:0	PMA/PMD ranging offset upper	PMA/PMD ranging offset register bits [31:16]	R/W, MW

[a]R/W = Read/Write, MW = Multi-word

45.2.1.130q DS PMA/PMD data rate registers (Registers 1.1927, 1.1928 and 1.1929)

Registers 1.1927, 1.1928, and 1.1929 represent the downstream data rate, in units of b/s. Bit 1.1929.4 is the MSB and bit 1.1927.0 is the LSB of the value. The bit assignments for the DS Data Rate registers is illustrated in Table 45–98aq. These registers are a reflection of the variable *DS_DataRate* defined in 100.3.2.3.

45.2.1.130r US PMA/PMD data rate registers (Registers 1.1930, 1.1931 and 1.1932)

Registers 1.1930, 1.1931, and 1.1932 represent the upstream data rate in units of b/s. Bit 1.1932.4 is the MSB and bit 1.1930.0 is the LSB of the value. The bit assignments for the US Data Rate registers is illustrated in Table 45–98ar. These registers are a reflection of the variable *US_DataRate* defined in 100.3.2.3.

Table 45–98aq—DS PMA/PMD data rate register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1927.15:3	DS PMA/PMD data rate lower	The downstream PMA/PMD data rate bits [15:3] of a UQ34.3 formatted number	RO, MW
1.1927.2:0	DS PMA/PMD data rate fractional	The downstream PMA/PMD data rate bits [2:0] of a UQ34.3 formatted number	RO, MW
1.1928.15:0	DS PMA/PMD data rate mid	The downstream PMA/PMD data rate bits [31:16] of a UQ34.3 formatted number	RO, MW
1.1929.15:5	Reserved	Value always 0	RO
1.1929.4:0	DS PMA/PMD data rate upper	The downstream PMA/PMD data rate bits [36:32] of a UQ34.3 formatted number	RO, MW

[a]RO = read only, MW = Multi-word

Table 45–98ar—US PMA/PMD data rate register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1930.15:3	US PMA/PMD data rate lower	The upstream PMA/PMD data rate bits [15:3] of a UQ34.3 formatted number	RO, MW
1.1930.2:0	US PMA/PMD data rate fractional	The upstream PMA/PMD data rate bits [2:0] of a UQ34.3 formatted number	RO, MW
1.1931.15:0	US PMA/PMD data rate mid	The upstream PMA/PMD data rate bits [31:16] of a UQ34.3 formatted number	RO, MW
1.1932.15:5	Reserved	Value always 0	RO
1.1932.4:0	US PMA/PMD data rate upper	The upstream PMA/PMD data rate bits [36:32] of a UQ34.3 formatted number	RO, MW

[a]RO = read only, MW = Multi-word

45.2.1.130s 10GPASS-XR FEC codeword counter (Registers 1.1933, 1.1934)

The assignment of bits in the 10GPASS-XR FEC codeword counter is shown in Table 45–98as. Registers 1.1933 and 1.1934 are used to read the value of a 32-bit counter. When registers 1.1933 and 1.1934 are used to read the 32-bit counter value, the register 1.1933 is read first, the value of the register 1.1934 is latched when (and only when) register 1.1933 is read and reads of register 1.1934 return the latched value rather than the current value of the counter. These registers are a reflection of the variable *FecCodeWordCount* defined in 101.3.3.1.6.

Table 45–98as—10GPASS-XR FEC codeword counter bit definitions

Bit(s)	Name	Description	R/W[a]
1.1933.15:0	FEC codeword counter lower	Total FEC codewords counter [15:0]	RO, MW
1.1934.15:0	FEC codeword counter upper	Total FEC codewords counter [31:0]	RO, MW

[a]RO = Read only, MW = Multi-word

45.2.1.130t 10GPASS-XR FEC codeword success counter (Registers 1.1935 and 1.1936)

The assignment of bits in the 10GPASS-XR FEC codeword success counter is shown in Table 45–98at. Registers 1.1935 and 1.1936 are used to read the value of a 32-bit counter. When registers 1.1935 and 1.1936 are used to read the 32-bit counter value, the register 1.1935 is read first, the value of the register 1.1936 is latched when (and only when) register 1.1935 is read and reads of register 1.1936 return the latched value rather than the current value of the counter. These registers are a reflection of the variable *FecCodeWordSuccess* defined in 101.3.3.1.6.

Table 45–98at—10GPASS-XR FEC codeword success counter bit definitions

Bit(s)	Name	Description	R/W[a]
1.1935.15:0	FEC codeword success counter lower	Total FEC codewords successfully decoded counter bits [15:0]	RO, MW
1.1936.15:0	FEC codeword success counter upper	Total FEC codewords successfully decoded counter bits [31:0]	RO, MW

[a]RO = Read only, MW = Multi-word

45.2.1.130u 10GPASS-XR FEC codeword fail counter (Registers 1.1937 and 1.1938)

The assignment of bits in the 10GPASS-XR FEC codeword fail counter is shown in Table 45–98au. Registers 1.1937 and 1.1938 are used to read the value of a 32-bit counter. When registers 1.1937 and 1.1938 are used to read the 32-bit counter value, the register 1.1937 is read first, the value of the register 1.1938 is latched when (and only when) register 1.1937 is read and reads of register 1.1938 return the latched value rather than the current value of the counter. These registers are a reflection of the variable *FecCodeWordFail* defined in 101.3.3.1.6.

Table 45–98au—10GPASS-XR FEC codeword fail counter bit definitions

Bit(s)	Name	Description	R/W[a]
1.1937.15:0	FEC codeword fail counter lower	Total FEC codewords unsuccessfully decoded counter bits [15:0]	RO, MW
1.1938.15:0	FEC codeword fail counter upper	Total FEC codewords unsuccessfully decoded counter bits [31:0]	RO, MW

[a]RO = Read only, MW = Multi-word

45.2.1.130v PHY Link EPFH counter (Register 1.1939)

The assignment of bits in the PHY Link EPFH counter is shown in Table 45–98av. This register is reset to all zeros when read by the management function or upon PMA/PMD reset. These bits are held at all ones in the case of overflow. This register is a reflection of the counter *EPFHcnt* defined in 102.2.7.2.

Table 45–98av—PHY Link EPFH counter bit definitions

Bit(s)	Name	Description	R/W[a]
1.1939.15:0	PHY Link EPFH counter	Total PHY Link EPFH message blocks received [15:0]	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.1.130w PHY Link EPFH error counter (Register 1.1940)

The assignment of bits in the PHY Link EPFH error counter is shown in Table 45–98aw. This register is reset to all zeros when read by the management function or upon PMA/PMD reset. These bits are held at all ones in the case of overflow. This register is a reflection of the counter *EPFHerr* defined in 102.2.7.2.

Table 45–98aw—PHY Link EPFH error counter bit definitions

Bit(s)	Name	Description	R/W[a]
1.1940.15:0	PHY Link EPFH error counter	Total PHY Link EPFH message blocks received with CRC32 errors [15:0]	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.1.130x PHY Link EPCH counter (Register 1.1941)

The assignment of bits in the PHY Link EPCH counter is shown in Table 45–98ax. This register is reset to all zeros when read by the management function or upon PMA/PMD reset. These bits are held at all ones in the case of overflow. This register is a reflection of the counter *EPCHcnt* defined in 102.2.7.2.

Table 45–98ax—PHY Link EPCH counter bit definitions

Bit(s)	Name	Description	R/W[a]
1.1941.15:0	PHY Link EPCH counter	Total PHY Link EPCH message blocks received [15:0]	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.1.130y PHY Link EPCH error counter (Register 1.1942)

The assignment of bits in the PHY Link EPCH error counter is shown in Table 45–98ay. This register is reset to all zeros when read by the management function or upon PMA/PMD reset. These bits are held at all ones in the case of overflow. This register is a reflection of the counter *EPCHerr* defined in 102.2.7.2.

45.2.1.130z PHY Link EMB counter (Register 1.1943)

The assignment of bits in the PHY Link EMB counter is shown in Table 45–98az. This register is reset to all zeros when read by the management function or upon PMA/PMD reset. These bits are held at all ones in the case of overflow. This register is a reflection of the counter *EMBcnt* defined in 102.2.7.2.

Table 45–98ay—PHY Link EPCH error counter bit definitions

Bit(s)	Name	Description	R/W[a]
1.1942.15:0	PHY Link EPCH error counter	Total PHY Link EPCH message blocks received with CRC32 errors [15:0]	RO, NR

[a]RO = Read only, NR = Non Roll-over

Table 45–98az—PHY Link EMB counter bit definitions

Bit(s)	Name	Description	R/W[a]
1.1943.15:0	PHY Link EMB counter	Total PHY Link EMB message blocks received [15:0]	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.1.130z1 PHY Link EMB error counter (Register 1.1944)

The assignment of bits in the PHY Link EMB error counter is shown in Table 45–98az1. This register is reset to all zeros when read by the management function or upon PMA/PMD reset. These bits are held at all ones in the case of overflow. This register is a reflection of the counter *EMBerr* defined in 102.2.7.2.

Table 45–98az1—PHY Link EMB error counter bit definitions

Bit(s)	Name	Description	R/W[a]
1.1944.15:0	PHY Link EMB error counter	Total PHY Link EMB message blocks received with CRC32 errors [15:0]	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.1.130z2 PHY Link FPMB counter (Register 1.1945)

The assignment of bits in the PHY Link FPMB counter is shown in Table 45–98az2. This register is reset to all zeros when read by the management function or upon PMA/PMD reset. These bits are held at all ones in the case of overflow. This register is a reflection of the counter *FPMBcnt* defined in 102.2.7.2.

Table 45–98az2—PHY Link FPMB counter bit definitions

Bit(s)	Name	Description	R/W[a]
1.1945.15:0	PHY Link FPMB counter	Total PHY Link FPMB message blocks received [15:0]	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.1.130z3 PHY Link FPMB error counter (Register 1.1946)

The assignment of bits in the PHY Link FPMB error counter is shown in Table 45–98az3. This register is reset to all zeros when read by the management function or upon PMA/PMD reset. These bits are held at all ones in the case of overflow. This register is a reflection of the counter *FPMBerr* defined in 102.2.7.2.

Table 45–98az3—PHY Link FPMB error counter bit definitions

Bit(s)	Name	Description	R/W[a]
1.1946.15:0	PHY Link FPMB error counter	Total PHY Link FPMB message blocks received with CRC32 errors [15:0]	RO, NR

[a]RO = Read only, NR = Non Roll-over

45.2.1.130z4 US PHY Link response time register (Register 1.1947)

The assignment of bits in the US PHY Link response time register is shown in Table 45–98az4. These bits indicate the time, in units of OFDM Clock periods (1/204.8 MHz), required by a CNU to respond to an EPoC message block received on the PHY Link and are a reflection of the variable *PhyLinkRspTm* defined in 102.2.7.3.

Table 45–98az4—US PHY Link response time register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1947.15:0	US PHY Link response time	Time required by a CNU to respond to an EPoC message block	RO

[a]RO = Read only

45.2.1.130z5 10GPASS-XR modulation ability register (Register 1.1948)

The assignment of bits in the 10GPASS-XR modulation ability register is shown in Table 45–98az5.

Table 45–98az5—10GPASS-XR modulation ability register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1948.15:10	Reserved	Value always 0	RO
1.1948.9:8	US modulation ability	Indicates the PHYs ability to support optional upstream modulation types	RO
1.1948.7:5	DS OFDM channel ability	Indicates the number of downstream ODFM channels supported	RO
1.1948.4:0	DS modulation ability	Indicates the PHYs ability to support optional downstream modulation types	RO

[a]RO = Read only

45.2.1.130z5.1 US modulation ability (1.1948.9:8)

Bits 1.1948.9:8 indicate the ability of the PHY to support optional upstream modulation formats 4096-QAM and 2048-QAM. These bits are a reflection of the variable *US_ModAbility* defined in 101.4.4.4.4.

45.2.1.130z5.2 DS OFDM channel ability (1.1948.7:5)

Bits 1.19487:5 indicate the number of OFDM channels the PMA/PMD is able to support in the downstream direction. The value of these bits is between 1 and 5 inclusive. These bits are a reflection of the variable *DS_OFDM_ChAbility* defined in 101.4.3.4.5.

45.2.1.130z5.3 DS modulation ability (1.1948.4:0)

Bits 1.1948.4:0 indicate the ability of the PHY to support optional downstream modulation formats 16384-QAM, 8192-QAM, 32-QAM, 16-QAM, and 8-QAM. These bits are a reflection of variable *DS_ModAbility* defined in 101.4.3.4.5.

45.2.1.130z6 PHY Discovery Response power control register (Register 1.1949)

The assignment of bits in the PHY Discovery Response power control register is shown in Table 45–98az6.

Table 45–98az6—PHY Discovery Response power control register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1949.15:8	PHY Discovery Response power step	Indicate the power increase of the PHY Discovery Response if there is no acknowledgment	R/W
1.1949.7:0	PHY Discover Response initial power	Initial power for CNU PHY Discovery Response	R/W

[a]R/W = Read/Write

45.2.1.130z6.1 PHY Discovery Response power step (1.1949.15:8)

Bits 1.1949.15:8 indicate to the CNU the amount of power to increase, in units of 0.25 dB, the PHY Discovery Response by if there is no acknowledgment from the CLT to a PHY Discovery Response from the CNU. These bits are a reflection of the *PdRespPwrStep* variable defined in 102.4.1.8.

45.2.1.130z6.2 PHY Discover Response initial power (1.1949.7:0)

Bits 1.1949.7:0 indicate to the CNU the initial power to be used when transmitting the PHY Discovery Response in units of 0.25 dBmV/1.6 MHz. These bits are a reflection of the *PdRespInitPwr* variable defined in 102.4.1.8.

45.2.1.130z7 US target receive power register (Register 1.1950)

The assignment of bits in the US target receive power register is shown in Table 45–98az7. Bits 1.1950.9:0 are used to set the target upstream receive power, in units of 0.1 dBmV/6.4 MHz, and are a reflection of the *CLT_TargetReceivePower* variable defined in 100.3.5.1. These bits are valid only for 10GBASS-XR-D PMA/PMD and are reserved for 10GBASS-XR-U PMA/PMD and always read as zero.

Table 45–98az7—US target receive power register bit definitions

Bit(s)	Name	Description	R/W[a]
1.1950.15:10	Reserved	Value always 0	RO
1.1950.9:0	US target receive power	Sets the target upstream receive power	R/W

[a]R/W = Read/Write, RO = Read only

45.2.1.130z8 DS transmit power registers (Registers 1.1951 through 1.1955)

The assignment of bits in the DS transmit power registers is shown in Table 45–98az8.

Table 45–98az8—DS transmit power registers bit definitions

Bit(s)	Name	Description	R/W[a]
1.1951.15:9	Reserved	Value always 0	RO
1.1951.8:0	DS transmit power Ch 1	Sets the transmit power for OFDM channel 1	R/W
1.1952.15:9	Reserved	Value always 0	RO
1.1952.8:0	DS transmit power Ch 2	Sets the transmit power for OFDM channel 2	R/W
1.1953.15:9	Reserved	Value always 0	RO
1.1953.8:0	DS transmit power Ch 3	Sets the transmit power for OFDM channel 3	R/W
1.1954.15:9	Reserved	Value always 0	RO
1.1954.8:0	DS transmit power Ch 4	Sets the transmit power for OFDM channel 4	R/W
1.1955.15:9	Reserved	Value always 0	RO
1.1955.8:0	DS transmit power Ch 5	Sets the transmit power for OFDM channel 5	R/W

[a]R/W = Read/Write, RO = Read only

45.2.1.130z8.1 DS transmit power Ch1 (1.1951.8:0)

Bits 1.1951.8:0 are used to set the transmit level of the downstream OFDM channel 1, in units of 0.2 dBmV/6 MHz. These bits are a reflection of the *DS_PowerCh(1)* variable defined in 100.3.3.2.1. These bits are valid only for 10GBASS-XR-D PMA/PMD and are reserved for 10GBASS-XR-U PMA/PMD and always read as zero.

45.2.1.130z8.2 DS transmit power Ch2 (1.1952.8:0)

Bits 1.1952.8:0 are used to set the transmit level of the downstream OFDM channel 2, in units of 0.2 dBmV/6 MHz. These bits are a reflection of the *DS_PowerCh(2)* variable defined in 100.3.3.2.1. These bits are valid only for 10GBASS-XR-D PMA/PMD and are reserved for 10GBASS-XR-U PMA/PMD and always read as zero.

45.2.1.130z8.3 DS transmit power Ch3 (1.1953.8:0)

Bits 1.1953.8:0 are used to set the transmit level of the downstream OFDM channel 3, in units of 0.2 dBmV/6 MHz. These bits are a reflection of the *DS_PowerCh(3)* variable defined in 100.3.3.2.1. These bits are valid only for 10GBASS-XR-D PMA/PMD and are reserved for 10GBASS-XR-U PMA/PMD and always read as zero.

45.2.1.130z8.4 DS transmit power Ch4 (1.1954.8:0)

Bits 1.1954.8:0 are used to set the transmit level of the downstream OFDM channel 4, in units of 0.2 dBmV/6 MHz. These bits are a reflection of the *DS_PowerCh(4)* variable defined in 100.3.3.2.1. These bits are valid only for 10GBASS-XR-D PMA/PMD and are reserved for 10GBASS-XR-U PMA/PMD and always read as zero.

45.2.1.130z8.5 DS transmit power Ch5 (1.1955.8:0)

Bits 1.1955.8:0 are used to set the transmit level of the downstream OFDM channel 5, in units of 0.2 dBmV/6 MHz. These bits are a reflection of the *DS_PowerCh(5)* variable defined in 100.3.3.2.1. These bits are valid only for 10GBASS-XR-D PMA/PMD and are reserved for 10GBASS-XR-U PMA/PMD and always read as zero.

45.2.1.130z9 US receive power measurement registers (1.1956 through 1.1957)

The assignment of bits in the US receive power measurement registers is shown in Table 45–98az9.

Table 45–98az9—US receive power measurement registers bit definitions

Bit(s)	Name	Description	R/W[a]
1.1956.15	US receive power valid	Indicates the value in US receive power measurement is valid	RO
1.1956.14:9	Reserved	Value always 0	RO
1.1956.8:0	US receive power measurement	Indicate the measured receive power for the CNU identified by US receive power CNU	RO
1.1957:15	Reserved	Value always 0	RO
1.1957.14:0	US receive power CNU	Indicates the CNU on which to measure the receive power	R/W

[a]R/W = Read/Write, RO = Read only

45.2.1.130z9.1 US receive power valid (1.1956.15)

When read as one, bit 1.1956.15 indicates the value in the US receive power measurement is valid for the CNU identified by US receive power CNU. This bit is only valid for 10GBASS-XR-D PMA/PMD and is reserved for 10GBASS-XR-U PMA/PMD and always reads as zero. This bit is a reflection of the variable *RxPwrValid* defined in 100.4.3.1.

45.2.1.130z9.2 US receive power measurement (1.1956.8:0)

Bits 1.1956.8:0 report the received power, in units of 0.1 dBmV, for the CNU identified by US receive power CNU. These bits are only valid for 10GBASS-XR-D PMA/PMD and are reserved for

10GBASS-XR-U PMA/PMD and always read as zero. These bits are a reflection of the variable *RxPwr* defined in 100.4.3.1.

45.2.1.130z9.3 US receive power CNU (1.1957.14:0)

When set to a CNU_ID bits 1.1957.14:0 indicate which CNU the CLT is to measure the received power on. These bits are only valid for 10GBASS-XR-D PMA/PMD and are reserved for 10GBASS-XR-U PMA/PMD and always read as zero. These bits are a reflection of the variable *RxPwr_CNU_ID* defined in 100.4.3.1.

45.2.1.130z10 Reported power register (1.1958)

The assignment of bits in the Reported power register is shown in Table 45–98az10.

Table 45–98az10—Reported power registers bit definitions

Bit(s)	Name	Description	R/W[a]
1.1958.15:9	Reserved	Value always 0	RO
1.1958.8:0	Reported power	The reported output power for the PMA/PMD	RO

[a]RO = Read only

45.2.1.130z10.1 Reported power (1.1958.8:0)

Bits 1.1958.8:0 indicate the reported power output of the PMA/PMD in units of 0.25 dBmv. These bits are a reflection of the variable *ReportedPwr* defined in 100.3.4.3.1.

Insert 45.2.7a before 45.2.8 as follows:

45.2.7a OFDM PMA/PMD registers

The assignment of registers in the OFDM PMA/PMD MMD is shown in Table 45–211i.

Table 45–211i—OFDM PMA/PMD registers

Register address	Register name	Subclause
12.0	10GPASS-XR DS OFDM channel ID	45.2.7a.1
12.1 through 12.1023	10GPASS-XR DS profile descriptor control	45.2.7a.2
12.1024 through 12.2047	10GPASS-XR US profile descriptor control	45.2.7a.3
12.2048 through 12.10239	10GPASS-XR US pre-equalizer coefficients	45.2.7a.4
12.10240 through 12.10241	10GPASS-XR receive MER control	45.2.7a.5
12.10242 through 12.12287	10GPASS-XR receive MER measurement	45.2.7a.6
12.12288 through 12.32767	Reserved	

45.2.7a.1 10GPASS-XR DS OFDM channel ID register (Register 12.0)

The assignment of bits in the DS OFDM channel ID register is shown in Table 45–211j.

Table 45–211j—DS OFDM channel ID register bit definitions

Bit(s)	Name	Description	R/W[a]
12.0.15:3	Reserved	Value always 0	RO
12.0.2:0	DS OFDM channel ID	Identifies to which OFDM channel (1 to 5) registers 12.1 through 12.1023 currently apply	R/W

[a]RO = Read only, R/W = Read/Write

45.2.7a.1.1 DS OFDM channel ID (12.0.2:0)

Bits 12.0.2:0 form a pointer to one of the five possible OFDM channels in the downstream EPoC network. Thus when this register is set to a value of one registers 12.1 through 12.1023 reflect the OFDM profile descriptor for OFDM channel one. When this register is set to a value of two registers 12.1 through 12.1023 reflect the OFDM profile descriptor for OFDM channel two, etc. These bits are a reflection of the *DS_OFDM_ID* variable defined in 101.4.3.4.5.

45.2.7a.2 10GPASS-XR DS profile descriptor control 1 through 1023 (Registers 12.1 through 12.1023)

The 10GPASS-XR DS profile descriptor control registers determine the modulation parameters for each downstream OFDM subcarrier. Each register in the group controls 4 of the 4096 subcarriers that are transmitted over the OFDM channel. Register 12.1 describes modulation parameters for downstream OFDM subcarriers number 4 through 7. Register 12.2 describes modulation parameters for downstream OFDM subcarriers number 8 through 11. Finally, register 12.1023 describes modulation parameters for downstream OFDM subcarriers number 4092 through 4095. Note that the first four subcarriers (i.e., subcarriers number 0 through 3) are not specified and are always excluded.

The assignment of bits in register 12.1 is shown in Table 45–211k. The remaining registers 12.2 through 12.1023 have the same bit structure as that of register 12.1. Changing registers 12.1 through 12.1023 does not affect the active profile, only the inactive profile (see 102.2.3.1.1 for a description of the Configuration ID bits in the PHY Link frame for information on active profile control). Registers 12.1 through 12.1023 are a reflection of variables *DS_ModTypeSC(n)* defined in 101.4.3.4.5.

Table 45–211k—10GPASS-XR DS profile descriptor control 1 register bit definitions

Bit(s)	Name	Description	R/W[a]
12.1.15:12	DS modulation type SC7	Modulation profile for subcarrier 7	R/W
12.1.11:8	DS modulation type SC6	Modulation profile for subcarrier 6	R/W
12.1.7:4	DS modulation type SC5	Modulation profile for subcarrier 5	R/W
12.1.3:0	DS modulation type SC4	Modulation profile for subcarrier 4	R/W

[a]R/W = Read/Write

45.2.7a.2.1 DS modulation type SC7 (12.1.15:12)

Bits 12.1.15:12 indicate the modulation profile for downstream OFDM subcarrier number 7. These bits are a reflection of variable *DS_ModTypeSC(7)* defined in 101.4.3.4.5. See the variable definition for interpretation of individual bits.

45.2.7a.2.2 DS modulation type SC6 (12.1.11:8)

Bits 12.1.11:8 indicate the modulation profile for downstream OFDM subcarrier number 6. These bits are a reflection of variable *DS_ModTypeSC(6)* defined in 101.4.3.4.5. See the variable definition for interpretation of individual bits.

45.2.7a.2.3 DS modulation type SC5 (12.1.7:4)

Bits 12.1.7:4 indicate the modulation profile for downstream OFDM subcarrier number 5. These bits are a reflection of variable *DS_ModTypeSC(5)* defined in 101.4.3.4.5. See the variable definition for interpretation of individual bits.

45.2.7a.2.4 DS modulation type SC4 (12.1.3:0)

Bits 12.1.3:0 indicate the modulation profile for downstream OFDM subcarrier number 4. These bits are a reflection of variable *DS_ModTypeSC(4)* defined in 101.4.3.4.5. See the variable definition for interpretation of individual bits.

45.2.7a.3 10GPASS-XR US profile descriptor control 0 through 1023 registers (Registers 12.1024 through 12.2047)

The 10GPASS-XR US profile descriptor control 0 through 1023 registers determine the inactive modulation settings for the upstream OFDMA spectrum. Each register in the group controls 4 subcarriers of the 4096 subcarriers that are transmitted over the OFDMA channel, with the first register in the group (12.1024) controlling subcarriers 0 through 3 and the second register controlling subcarriers 4 through 7, etc. The assignment of bits in the first 10GPASS-XR US profile descriptor control register (register 12.1024) is shown in Table 45–211l. Bit assignment per subcarrier for the remaining registers is identical to that of register 12.1024. See 101.4.5 for details on each modulation type. Registers 12.1024 through 12.2047 are a reflection of variables *US_ModTypeSC(n)* defined in 101.4.4.4.4.

Table 45–211l—10GPASS-XR US profile descriptor control 0 register bit definitions

Bit(s)	Name	Description	R/W[a]
12.1024.15:12	US modulation type SC3	Modulation profile for subcarrier 3	R/W
12.1024.11:8	US modulation type SC2	Modulation profile for subcarrier 2	R/W
12.1024.7:4	US modulation type SC1	Modulation profile for subcarrier 1	R/W
12.1024.3:0	US modulation type SC0	Modulation profile for subcarrier 0	R/W

[a]R/W = Read/Write

45.2.7a.3.1 US modulation type SC3 (12.1024.15:12)

Bits 12.1024.15:12 indicate the modulation profile for upstream OFDM subcarrier number 3. These bits are a reflection of variable *US_ModTypeSC(3)* defined in 101.4.4.4.4. See the variable definition for interpretation of individual bits.

45.2.7a.3.2 US modulation type SC2 (12.1024.11:8)

Bits 12.1024.11:8 indicate the modulation profile for upstream OFDM subcarrier number 2. These bits are a reflection of variable *US_ModTypeSC(2)* defined in 101.4.4.4.4. See the variable definition for interpretation of individual bits.

45.2.7a.3.3 US modulation type SC1 (12.1024.7:4)

Bits 12.1024.7:4 indicate the modulation profile for upstream OFDM subcarrier number 1. These bits are a reflection of variable *US_ModTypeSC(1)* defined in 101.4.4.4.4. See the variable definition for interpretation of individual bits.

45.2.7a.3.4 US modulation type SC0 (12.1024.3:0)

Bits 12.1024.3:0 indicate the modulation profile for upstream OFDM subcarrier number 0. These bits are a reflection of variable *US_ModTypeSC(0)* defined in 101.4.4.4.4. See the variable definition for interpretation of individual bits.

45.2.7a.4 10GPASS-XR US pre-equalizer coefficients 0 through 4095 (Registers 12.2048 through 12.10239)

The 10GPASS-XR US pre-equalizer coefficients 0 through 4095 registers determine the real and imaginary parts of the pre-equalizer settings for the upstream transmitter. Each register pair in the group controls one subcarrier of the 4096 subcarriers that are transmitted over the OFDMA channel, with the first register in the group (12.2048) controlling the real number setting for subcarrier 0 and the second register (12.2049) controlling the imaginary number setting for subcarrier 0. The second register pair (12.2050 and 12.2051) respectively controls the real and imaginary settings for subcarrier 1. Thus the last register pair (12.10238 and 12.10239) controls the real and imaginary settings for subcarrier 4095. The value in each register is in a Q2.14 format. The assignment of bits in the first and second 10GPASS-XR US pre-equalizer coefficients registers (registers 12.2048 and 12.2049) is shown in Table 45–211m. Bit assignment per subcarrier for the remaining even and odd registers is identical to that of registers 12.2048 and 12.2049, respectively. See 101.4.4.9 for details on use of these registers. These registers are a reflection of the variables *EQ_CoefR(n)* and *EQ_CoefI(n)* defined in 101.4.4.9.2.

Table 45–211m—10GPASS-XR US pre-equalizer coefficients registers bit definitions

Bit(s)	Name	Description	R/W[a]
12.2048.15:0	Real pre-equalizer coefficient SC0	Real part of the pre-equalizer coefficient for subcarrier 0	R/W
12.2049.15:0	Imaginary pre-equalizer coefficient SC0	Imaginary part of the pre-equalizer coefficient for subcarrier 0	R/W

[a]R/W = Read/Write

45.2.7a.4.1 Real pre-equalizer coefficient SC0 (12.2048.15:0)

Bits 12.2048.15:0 indicate the real part of the pre-equalizer coefficient for subcarrier 0 for the upstream OFDMA channel. These bits are a reflection of the variable *EQ_CoefR(0)* defined in 101.4.4.9.2.

45.2.7a.4.2 Imaginary pre-equalizer coefficient SC0 (12.2049.15:0)

Bits 12.2049.15:0 indicate the imaginary part of the pre-equalizer coefficient for subcarrier 0 for the upstream OFDMA channel. These bits are a reflection of the variable *EQ_CoefI(0)* defined in 101.4.4.9.2.

45.2.7a.5 10GPASS-XR receive MER control registers (Registers 12.10240 and 12.10241)

The assignment of bits in the 10GPASS-XR receive MER control registers is shown in Table 45–211n.

Table 45–211n—10GPASS-XR receive MER control register bit definitions

Bit(s)	Name	Description	R/W[a]
12.10240.15:4	Reserved	Value always 0	RO
12.10240.3	MER measurement valid	1 = all values in the 10GPASS-XR receive MER measurement registers are valid 0 = some values in the 10GPASS-XR receive MER measurement registers are invalid	RO
12.10240.2:0	Receive MER channel ID	Identifies to which OFDM channel (1 to 5) registers 12.10242 through 12.12287 currently apply	R/W[b]
12.10241.15	Reserved	Value always 0	RO
12.10241.14:0	Receive MER CNU ID	Identifies to which CNU registers 12.10242 through 12.12287 currently apply	

[a]RO = Read only, R/W = Read/Write
[b]These bits are valid only in the CNU; in the CLT these bits are reserved and always 0.

45.2.7a.5.1 MER measurement valid (12.10240.3)

When read as one, bit 12.10240.3 indicates the 10GPASS-XR receive MER measurement registers are valid. When read as zero, this bit indicates that the 10GPASS-XR receive MER measurement registers are not valid. This bit is a reflection of the variable *RxMER_Valid* defined in 100.3.5.3.1.

45.2.7a.5.2 Receive MER Channel ID (12.10240.2:0)

Bits 12.10240.2:0 form a pointer to one of the five possible OFDM channels in the EPoC network. These bits are only valid for 10GBASS-XR-U PMA/PMD and are reserved for 10GBASS-XR-D PMA/PMD and always read as zero. These bits are a reflection of the variable *RxMER_ChID* defined in 100.3.5.3.1.

45.2.7a.5.3 Receive MER CNU ID (12.10241.14:0)

Bits 12.10241.14:0 indicate the CNU_ID of the CNU on which to measure the MER and report in registers 12.10242 through 12.12287. These bits are only valid for 10GBASS-XR-D PMA/PMD and are reserved for 10GBASS-XR-U PMA/PMD and always read as zero. These bits are a reflection of the variable *RxMER_CNU_ID* defined in 100.3.5.3.1.

45.2.7a.6 10GPASS-XR receive MER measurement registers (Registers 12.10242 through 12.12287)

The 10GPASS-XR receive MER measurement registers reflect the MER measured on each OFDM subcarrier for the OFDM channel indicated by the Receive MER Channel ID except subcarriers zero through three. Each register in the group reflects two of the 4096 subcarriers that are transmitted over the OFDM channel. Register 12.10242 reflects the receive MER measured on OFDM subcarriers number 4 and 5. Register 12.10243 reflects the receive MER measured on OFDM subcarriers number 6 and 7. Finally, register 12.12287 reflects the receive MER measured on OFDM subcarriers number 4094 and 4095. Note that the first four subcarriers (i.e., subcarriers number 0 through 3) are not reflected in register group 12.10242 through 12.12287 (10GPASS-XR receive MER measurement registers).

The assignment of individual bits in register 12.10242 is shown in Table 45–211o. The remaining registers 12.10243 through 12.12287 have the same bit structure as that of register 12.10242. These registers are a reflection of the variable *RxMER_SC(n)* defined in 100.3.5.3.1.

Table 45–211o—10GPASS-XR receive MER measurement register bit definitions

Bit(s)	Name	Description	R/W[a]
12.10242.15:8	Receive MER SC5	Receive MER measurement for subcarrier 5 on the OFDM channel indicated by the Receive MER Channel ID	RO
12.10242.7:0	Receive MER SC4	Receive MER measurement for subcarrier 4 on the OFDM channel indicated by the Receive MER Channel ID	RO

[a]RO = Read only

45.2.7a.6.1 Receive MER SC5 (12.10242.15:8)

Bits 12.10242.15:8 reflect the MER measured on OFDM subcarrier 5 for the OFDM channel indicated by the Receive MER channel ID.

45.2.7a.6.2 Receive MER SC4 (12.10242.7:0)

Bits 12.10242.7:0 reflect the MER measured on OFDM subcarrier 4 for the OFDM channel indicated by the Receive MER channel ID.

45.5 Protocol implementation conformance statement (PICS) proforma for Clause 45, Management Data Input/Output (MDIO) Interface[2]

45.5.3 Major capabilities/options

Insert one row at the bottom of Major capabilities/options table as follows:

Item	Feature	Subclause	Value/Comment	Status	Support
*EO	Implementation of OFDM MMD	45.2.7a		O	Yes [ ] No [ ]

45.5.3.2 PMA/PMD MMD options

Insert two rows into PMA/PMD MMD options table as follows:

Item	Feature	Subclause	Value/Comment	Status	Support
*10XR	Implementation of 10GPASS-XR PMA/PMD	45.2.1.4		PMA:O	Yes [ ] No [ ]
*10XRAR	Implementation of EPoC PMA/PMD ability register	45.2.1.14aa		PMA:O	Yes [ ] No [ ]

Insert 45.5.3.13a after 45.5.3.13 as follows:

45.5.3.13a OFDM management functions

Item	Feature	Subclause	Value/Comment	Status	Support
OFM1	Implementation of 10GPASS-XR DS OFDM channel ID	45.2.7a.1		EO:M	Yes [ ] N/A [ ]

[2]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

Item	Feature	Subclause	Value/Comment	Status	Support
OFM2	Implementation of 10GPASS-XR DS profile descriptor control	45.2.7a.2		EO:M	Yes [ ] N/A [ ]
OFM3	Implementation of 10GPASS-XR US profile descriptor control	45.2.7a.3		EO:M	Yes [ ] N/A [ ]
OFM4	Implementation of 10GPASS-XR US pre-equalizer coefficients	45.2.7a.4		EO:M	Yes [ ] N/A [ ]
OFM5	Implementation of 10GPASS-XR receive MER control	45.2.7a.5		EO:M	Yes [ ] N/A [ ]
OFM6	Implementation of 10GPASS-XR receive MER measurement	45.2.7a.6		EO:M	Yes [ ] N/A [ ]

56. Introduction to Ethernet for subscriber access networks

56.1 Overview

Change the first paragraph of 56.1 as follows, separating it into two paragraphs, with the second paragraph starting from the words "In addition, ...":

Ethernet for subscriber access networks, also referred to as "Ethernet in the First Mile," or EFM, combines a minimal set of extensions to the IEEE 802.3 Media Access Control (MAC) and MAC Control sublayers with a family of Physical Layers. These Physical Layers include optical fiber and voice grade copper cable Physical Medium Dependent sublayers (PMDs) for point-to-point (P2P) connections in subscriber access networks. EFM also introduces the concept of Ethernet Passive Optical Networks (EPONs), in which a point-to-multipoint (P2MP) network ~~topology~~ is implemented ~~with passive optical splitters~~ over an optical distribution network (ODN), along with extensions to the MAC Control sublayer and Reconciliation sublayer as well as optical fiber PMDs to support this topology. Furthermore, EFM introduces the concept of EPON Protocol over Coax (EPoC) networks, in which a P2MP network is implemented over a coax cable distribution network (CCDN), along with extensions to the MAC Control sublayer and Reconciliation sublayer as well as EPoC PMDs to support this topology.

In addition, a mechanism for network Operations, Administration, and Maintenance (OAM) is included to facilitate network operation and troubleshooting. 100BASE-LX10 extends the reach of 100BASE-X to achieve 10 km over conventional single-mode two-fiber cabling. The relationships between these EFM elements and the ISO/IEC Open System Interconnection (OSI) reference model are shown in Figure 56–1 for point-to-point topologies, Figure 56–2 for 1G-EPON topologies, Figure 56-3 for 10/10G-EPON topologies, ~~and~~ Figure 56–4 for 10/1G-EPON topologies, and Figure 56-4a for EPoC topologies.

Change the last paragraph of 56.1 as follows:

The EFM architecture is extended in Clause 75 and Clause 76 by the addition of 10G–EPON. 10G–EPON includes the 10/10G-EPON (10 Gb/s downstream and 10 Gb/s upstream) as well as 10/1G-EPON (10 Gb/s downstream and 1 Gb/s upstream) PONs. The EFM architecture is further extended in Clause 100, Clause 101, and Clause 102 by the addition of EPoC.

56.1.2 Summary of P2MP sublayers

Insert a new paragraph at the end of 56.1.2 as follows:

For P2MP coaxial topologies, EFM supports EPoC operating with a nominal bit rate of up to 10 Gb/s in the downstream direction and up to 1.6 Gb/s in the upstream direction. The P2MP EPoC PHYs use the 10GPASS-XR Physical Coding Sublayer (PCS), the Physical Medium Attachment (PMA) sublayer, and the mandatory forward error correction (FEC) function defined in Clause 101.

56.1.2.1 Multipoint MAC Control Protocol (MPCP)

Change 56.1.2.1 as follows, including the addition of two new paragraphs at the end of this subclause to describe the use of MPCP for EPoC:

The Multipoint MAC Control Protocol (MPCP) for 1G-EPON uses messages, state diagrams, and timers, as defined in Clause 64, to control access to a P2MP topology, while Clause 77 defines the messages, state diagrams, and timers required to control access to a P2MP ODN topology in 10G-EPON. The issues related to coexistence of 1G-EPON and 10G-EPON on the same fiber plant are described in 77.4.

Every P2MP ODN topology consists of one Optical Line Terminal (OLT) plus one or more ONUs, as shown in Figure 56–2, Figure 56-3, and Figure 56-4 for 1G-EPON, 10/10G-EPON and 10/1G-EPON, respectively.

One of several instances of the MPCP in the OLT communicates with the instance of the MPCP in the ONU. A pair of MPCPs that communicate between the OLT and ONU are a distinct and associated pair.

The MPCP for EPoC uses messages, state diagrams, and timers, as defined in Clause 103 to control access to a P2MP CCDN topology.

Every P2MP CCDN topology consists of one CLT plus one or more CNUs, as shown in Figure 56-4a. One of several instances of the MPCP in the CLT communicates with the instance of the MPCP in the CNU. A pair of MPCPs that communicate between the CLT and CNU are a distinct and associated pair.

56.1.2.2 Reconciliation Sublayer (RS) and media independent interfaces

Change 56.1.2.2 as follows:

The Clause 22 RS and MII, Clause 35 RS and GMII, and Clause 46 RS and XGMII are all employed for the same purpose in EFM, that being the interconnection between the MAC sublayer and the PHY sublayers. Extensions to the Clause 35 RS for P2MP topologies are described in Clause 65, ~~while~~ the RS for 10G-EPON P2MP topologies is described in Clause 76, and the RS for EPoC P2MP topologies is described in Clause 101.

The combination of MPCP and the extension of the Reconciliation Sublayer (RS) for P2P Emulation allows an underlying P2MP network to appear as a collection of point-to-point links to the higher protocol layers (at and above the MAC Client).

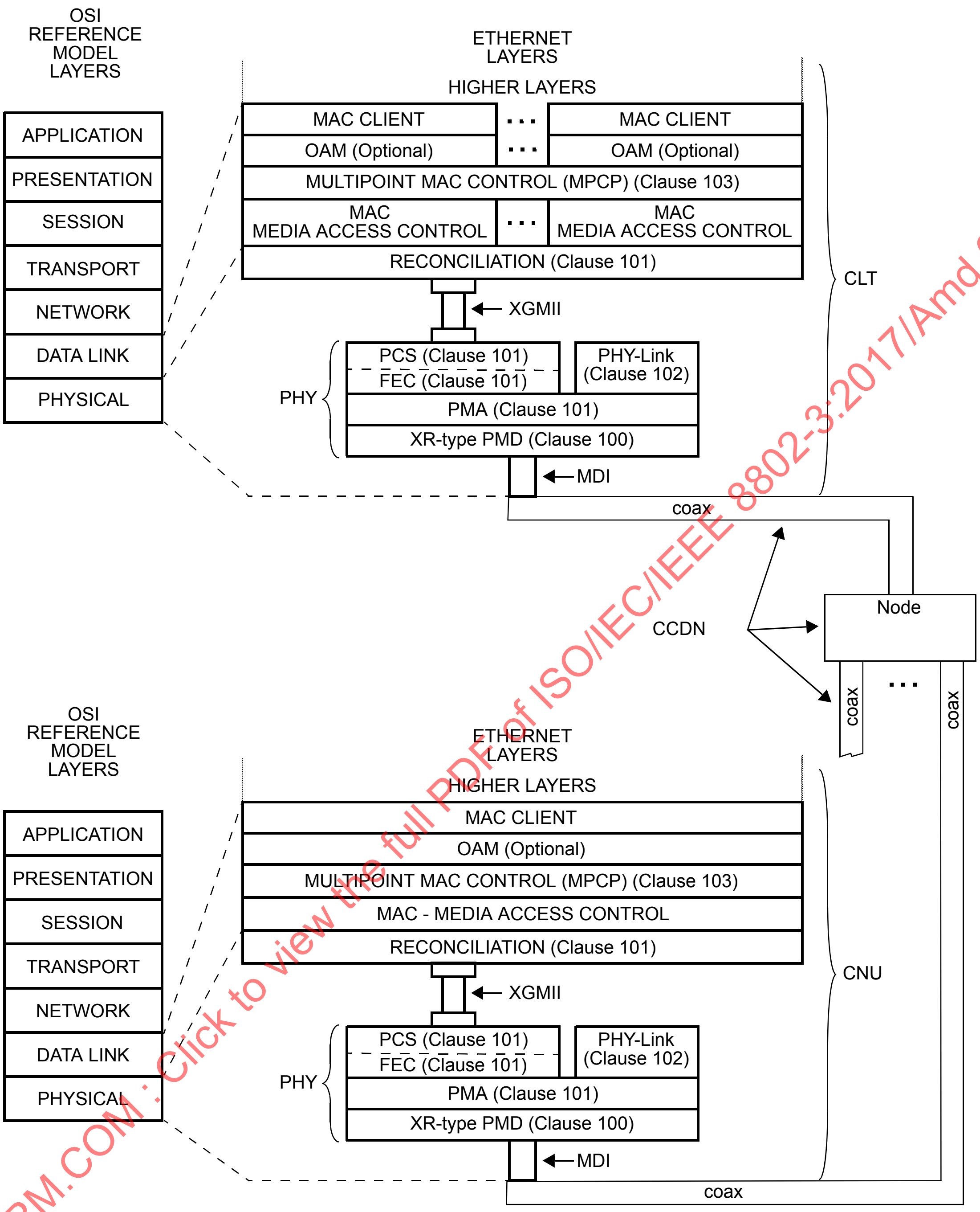
The MPCP achieves this by providing a Logical Link Identification (LLID) in each packet by replacing two octets of the preamble.

This is described in Clause 65 for EPON, ~~and~~ in Clause 76 for 10G-EPON, and in Clause 101 for EPoC. EFM Copper links use the MII of Clause 22 operating at 100 Mb/s. This is described in 61.1.4.1.2.

56.1.3 Physical Layer signaling systems

Insert the following new text into 56.1.3 after the existing paragraph 5 ("All 10G-EPON PMDs are defined in Clause 75"):

Moreover, EFM introduces a Physical Layer signaling system derived from 10GBASE-R, but which includes RS, PCS, and PMA sublayers adapted for EPoC, along with a mandatory FEC capability, as defined in Clause 101. This system employs the PMD defined in Clause 100. EPoC uses a PHY Link for Physical Layer signaling as defined in Clause 102.



XGMII= 10 GIGABIT MEDIA INDEPENDENT INTERFACE
MDI = MEDIUM DEPENDENT INTERFACE
OAM = OPERATIONS, ADMINISTRATION & MAINTENANCE
CCDN= COAX CABLE DISTRIBUTION NETWORK
CLT = COAXIAL LINE TERMINAL

CNU = COAXIAL NETWORK UNIT
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

Figure 56-4a—Architectural positioning of EFM: P2MP EPoC architecture (up to 10 Gb/s downstream, up to 1.6 Gb/s upstream)

Insert two rows at the end of Table 56-1, and add footnotes h and i following the existing footnotes:

Table 56–1—Summary of EFM Physical Layer signaling systems

Name	Location	Rate[a]	Nominal reach (km)	Medium	Clause
.....					
10GPASS-XR-D	CLT	Up to 10 Gb/s (tx)[h] Up to 1.6 Gb/s (rx)[h]	2.9[i]	One CCDN	100
10GPASS-XR-U	CNU[c]	Up to 1.6 Gb/s (tx)[h] Up to 10 Gb/s (rx)[h]	2.9[i]	One CCDN	100

[a]For 10/1G-EPON Physical Layer signaling systems transmit rate is denoted with the abbreviation "(tx)" to the location whereas the receive rate is denoted with the abbreviation "(rx)"
.....
[h]These rates are based on maximum mandatory modulation format in Table 100–3.
[i]Maximal differential distance between CNUs. Reach may vary depending on the CCDN.

Insert four new columns to the right of the existing columns, and two new rows at the end of Table 56-3 as follows (unchanged rows not shown):

Table 56–3—Nomenclature and clause correlation for P2MP systems[a]

Nomenclature	Clause													
	57	60				64	65		66	75	76	77	100	101	102	103
	OAM	1000BASE-PX10 PMD	1000BASE-PX20 PMD	1000BASE-PX30 PMD	1000BASE-PX40 PMD	P2MP MPMC	P2MP RS, PCS, PMA	FEC	1000BASE-X PCS, PMA	10/1GBASE–PRX or 10GBASE-PR PMDs	P2MP RS, PCS, PMA, FEC	10G-EPON P2MP MPMC	10GPASS-XR PMD	EPoC P2MP RS, PCS, PMA, FEC	EPoC PHY-Link	EPoC P2MP MPMC
....																
10GPASS-XR-D	O												M	M	M	M
10GPASS-XR-U	O												M	M	M	M

[a]O = Optional, M = Mandatory

56.1.5 Unidirectional transmission

Change 56.1.5 as follows:

In contrast to previous editions of IEEE Std 802.3, in certain circumstances a DTE is allowed to transmit frames while not receiving a satisfactory signal. It is necessary for an EPON~~1000BASE-PX-D~~ OLT or EPoC

CLT to do this to bring an ~~PON~~ODN or CCDN into operation (although it is highly inadvisable for an EPON~~1000BASE-PX-U~~ ONU or EPoC CNU to transmit without receiving). Clause 66 describes optional modifications to the 100BASE-X PHY, 1000BASE-X PHY and 10GBASE RS so that a DTE may signal remote fault using OAMPDUs. When unidirectional operation is not enabled, the sublayers in Clause 66 are precisely the same as their equivalents in Clause 24, Clause 36, and Clause 46.

67. System considerations for Ethernet subscriber access networks

67.1 Overview

Change Table 67–1 as follows:

Table 67–1—Characteristics of the various EFM network media segments

Media type	Rate (Mb/s)	Number of PHYs per segment	Nominal reach (km)
Optical 100 Mb/s fiber segment (100BASE-LX10, 100BASE-BX10)	100	2	10
Optical 1000 Mb/s fiber segment (1000BASE-LX10, 1000BASE-BX10)	1000	2	10
Optical 1000 Mb/s P2MP segment (1000BASE-PX10)	1000	17[a,b]	10
Optical 1000 Mb/s P2MP segment (1000BASE-PX20)	1000	17[a,b]	20
Copper high-speed segment (10PASS-TS)	10[c]	2	0.75
Copper long reach segment (2BASE-TL)	2[c]	2	2.7
EPoC coaxial segment (10GPASS-XR)	Up to 10 Gb/s downstream	variable[d]	2.9[e]
	Up to 1.6 Gb/s upstream	variable[d]	2.9[e]

[a]P2MP segments may be implemented with a trade off between link span and split ratio listed. Refer to 67.2.1.
[b]The number of PHYs in the EPON P2MP segment includes the OLT PHY.
[c]Nominal rate stated at the nominal reach in this table. Rate and reach can vary depending on the plant. For 2BASE-TL please refer to Annex 63B for more information. For 10PASS-TS, please refer to Annex 62A for more information.
[d] Based on the cable operator's CCDN configuration, the number of PHYs will be the CLT PHY plus each CNU PHY.
[e] Maximal differential distance between CNUs. Reach may vary depending on the CCDN.

67.2 Discussion and examples of EFM P2MP topologies

Change the text in 67.2 as follows:

This subclause discusses EFM P2MP topologies. For P2MP PON architecture, this subclause ~~It~~ details flexibility of trading off split ratio for link span. This subclause also shows some examples of different P2MP PON topologies.

Change the title and text in 67.2.1 as follows:

67.2.1 Trade off between link span and split ratio for P2MP PON architecture

While the P2MP PON PMDs are nominally described in terms of a link span of either 10 km or 20 km with a 1:16 split ratio, other link spans and split ratios can be implemented provided that the requirements of Table 60–1 are met.

Change the title and text in 67.2.2 as follows:

67.2.2 Single splitter topology for P2MP PON architecture

A P2MP PON topology implemented with a single optical splitter is shown in Figure 67-1.

Change the title and text in 67.2.3 as follows:

67.2.3 Tree-and-branch topology for P2MP PON architecture

A P2MP PON topology implemented with a tree-and-branches of optical splitters is shown in Figure 67-2.

67.6 Operations, Administration, and Maintenance

67.6.1 Unidirectional links

Change the second paragraph of 67.6.1 as follows:

This ability should be used only when the OAM sublayer is present and enabled for a 1000BASE-PX-D, 10/1GBASE-PRX, ~~or~~ 10GBASE-PR PHY, or 10GPASS-XR-D PHY. Otherwise, MAC Client frames will be sent across a unidirectional link potentially causing havoc with bridge and other higher layer protocols. The feature should not be enabled for 1000BASE-PX-U, 10/1GBASE-PRX-U, ~~or~~ 10GBASE-PR-U PHYs, or 10GPASS-XR-U PHYs in service, to avoid simultaneous transmission by more than one ONU or CNU.

67.6.3 Link status signaling in P2MP networks

Change the first paragraph of 67.6.3 as follows:

In P2MP networks the local_link_status parameter should reflect the status of a logical link associated with the underlying instance of Multipoint MAC Control. This is achieved by mapping the local_link_status parameter to variable 'registered' defined in 64.3.3.2 for ~~1 Gb/s P2MP and~~ 1G-EPON links, in 77.3.3.2 for ~~10 Gb/s links~~10G-EPON links, and in 103.3.3.2 for EPoC links as follows:

76. Reconciliation Sublayer, Physical Coding Sublayer, and Physical Media Attachment for 10G-EPON

76.2 Reconciliation Sublayer (RS) for 10G-EPON

76.2.6 Mapping of XGMII and GMII signals to PLS service primitives

76.2.6.1 Functional specifications for multiple MACs

76.2.6.1.3 RS Receive function

76.2.6.1.3.2 LLID

Change Table 76-4 as follows:

Table 76–4—Reserved LLID values

LLID value	Used in RS	Purpose
0x7FFF	1000BASE-PX	Downstream: 1 Gb/s SCB Upstream: ONU registration at 1 Gb/s
0x7FFE	10/1GBASE-PRX	Downstream: 10 Gb/s SCB Upstream: ONU registration at 1 Gb/s
	10GBASE-PR	Downstream: 10 Gb/s SCB Upstream: ONU registration at 10 Gb/s
	10GPASS-XR	Downstream: EPoC SCB Upstream: CNU registration
0x7FFD–0x7F00	—	Reserved for future use

Insert new Clause 100, Clause 101, Clause 102, and Clause 103 as follows:

100. Physical Medium Dependent (PMD) sublayer, and medium for coaxial distribution networks, type 10GPASS-XR

100.1 Overview

This clause describes the Physical Medium Dependent (PMD) sublayer for EPON Protocol over Coax (EPoC) PHYs operating at the line rate of up to 10 Gb/s in the downstream direction and up to 1.6 Gb/s in the upstream direction.

100.1.1 Terminology and conventions

EPoC operates over a point-to-multipoint (P2MP) topology composed of passive segments of coaxial media and passive taps/couplers, optionally interconnected with active coaxial amplifiers, and/or analog optical links creating a tree-and-branch topology.

The device connected at the root of the tree is called a Coaxial Line Terminal (CLT) and the devices connected as the leaves are referred to as Coaxial Network Units (CNUs). The direction of transmission from the CLT to CNUs is referred to as the *downstream direction*, while the direction of transmission from CNUs to the CLT is referred to as the *upstream direction*.

Unless otherwise noted, the notation $\lceil x \rceil$ represents a *ceiling* function, which returns the value of its argument x rounded up to the nearest integer.

The notation $\lfloor x \rfloor$ represents a *floor* function, which returns the value of its argument x rounded down to the nearest integer.

100.1.2 Positioning of the PMD sublayer within the IEEE 802.3 architecture

Figure 100–1 depicts the relationships of the asymmetric-rate EPoC PMD sublayer (shown hatched) with other sublayers and the ISO/IEC Open System Interconnection (OSI) reference model.

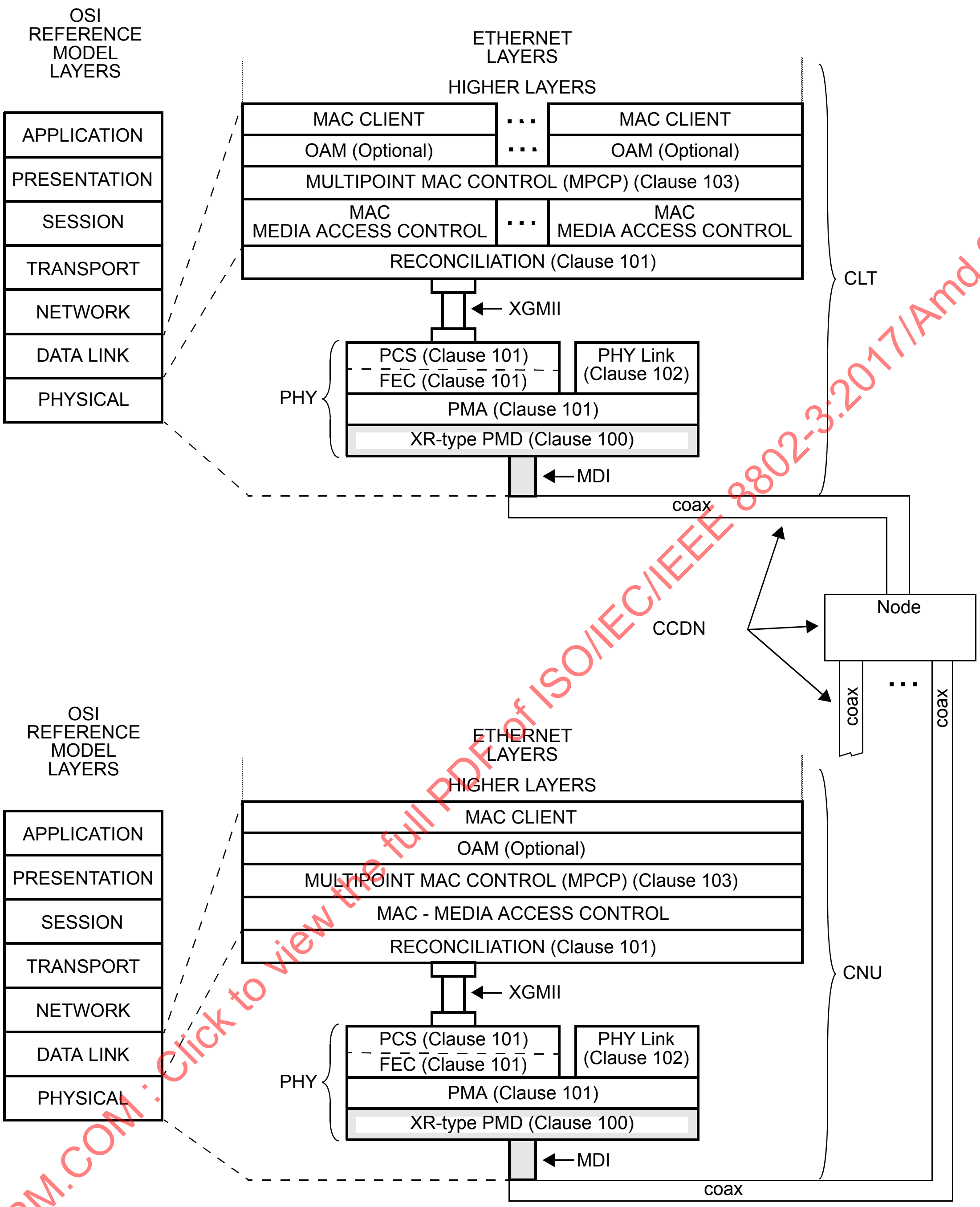
100.1.3 PMD types

In the downstream direction, the signal transmitted by the 10GPASS-XR-D type PMD is received by all 10GPASS-XR-U type PMDs. In the upstream direction, the 10GPASS-XR-D type PMD receives data bursts from each of the 10GPASS-XR-U type PMDs. The 10GPASS-XR-D and 10GPASS-XR-U PMDs both have a variable rate that is determined when configured. See Equation (100–1) and Equation (100–2) for additional information on the 10GPASS-XR-D and 10GPASS-XR-U data rates, respectively. See 102.4.3 for "reset on change" events that may affect rate calculations.

The asymmetric-rate 10GPASS-XR-D type PMD, transmitting in continuous mode and receiving in burst mode, is defined in this clause, with downstream data rate calculation in 100.3.2.1. The asymmetric-rate 10GPASS-XR-U type PMD, transmitting in burst mode and receiving in continuous mode, is defined in this clause, with upstream data rate calculation in 100.3.2.2. The data rate of a 10GPASS-XR PHY is dependent on network configuration.

100.1.4 Mapping of PMD variables

The optional MDIO capability described in Clause 45 defines several variables that may provide control and status information for and about the 10GPASS-XR PHY or are communicated between the CLT and the



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PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
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Figure 100–1—Relationship of EPoC P2MP PMD to the ISO/IEC OSI reference model and the IEEE 802.3 Ethernet LAN model

CNU via the PHY Link. The mapping of MDIO control and status variables to PMD variables is shown in Table 100–1. The least significant bit in each variable is mapped to the lowest numbered bit in the lowest numbered register for Clause 45 registers. These variables are used by the PHY Link for PHY management.

Table 100–1—MDIO register to PHY variable mapping

MDIO parameter name	MDIO register name	Register/bit number	PHY variable		
			Name	Index	Bits(s)
PHY discovery enable	10GPASS-XR control	1.1900.0	*PD_Enable*	0	0
DS rate mismatch	10GPASS-XR control	1.1900.11	*DS_RateMatchFail*	0	11
US rate mismatch	10GPASS-XR control	1.1900.12	*US_RateMatchFail*	0	12
DS cyclic prefix	DS OFDM control	1.1901.3:0	*DSNcp*	1	3:0
DS windowing	DS OFDM control	1.1901.6:4	*DSNrp*	1	6:4
CLT tx mute	DS OFDM control	1.1901.15	*CLT_TxMute*	1	15
DS OFDM freq ch 1	DS OFDM channel frequency control 1	1.1902.15:0	*DS_FreqCh(1)*	2	15:0
DS OFDM freq ch 2	DS OFDM channel frequency control 2	1.1903.15:0	*DS_FreqCh(2)*	3	15:0
DS OFDM freq ch 3	DS OFDM channel frequency control 3	1.1904.15:0	*DS_FreqCh(3)*	4	15:0
DS OFDM freq ch 4	DS OFDM channel frequency control 4	1.1905.15:0	*DS_FreqCh(4)*	5	15:0
DS OFDM freq ch 5	DS OFDM channel frequency control 5	1.1906.15:0	*DS_FreqCh(5)*	6	15:0
US cyclic prefix	US OFDM control	1.1907.3:0	*USNcp*	7	3:0
US windowing	US OFDM control	1.1907.6:4	*USNrp*	7	6:4
RB size	US OFDM control	1.1907.7	*RBsize*	7	7
DS PHY data rate fractional	DS PHY data rate	1.1927.2:0	*DS_DataRate(2:0)*	27	2:0
DS PHY data rate lower	DS PHY data rate	1.1927.15:3	*DS_DataRate(15:3)*	27	15:3
DS PHY data rate mid	DS PHY data rate	1.1928.15:0	*DS_DataRate(31:16)*	28	15:0
DS PHY data rate upper	DS PHY data rate	1.1929.4:0	*DS_DataRate(36:32)*	29	4:0
US PHY data rate fractional	US PHY data rate	1.1930.2:0	*US_DataRate(2:0)*	30	2:0
US PHY data rate lower	US PHY data rate	1.1930.15:3	*US_DataRate(15:3)*	30	15:3
US PHY data rate mid	US PHY data rate	1.1931.15:0	*US_DataRate(31:16)*	31	15:0

Table 100–1—MDIO register to PHY variable mapping *(continued)*

MDIO parameter name	MDIO register name	Register/bit number	PHY variable		
			Name	Index	Bits(s)
US PHY data rate upper	US PHY data rate	1.1932.5:0	*US_DataRate(36:32)*	32	5:0
US target receive power	US target receive power	1.1950.9:0	*CLT_TargetReceivePower*	50	9:0
DS transmit power Ch 1 through DS transmit power Ch 5	DS transmit power	1.1951.8:0 through 1.1955.8:0	*DS_PowerCh(1)* through *DS_PowerCh(5)*	51 through 55	8:0
US receive power measurement	US receive power measurement	1.1956.8:0	*RxPwr*	56	8:0
US receive power valid	US receive power valid	1.1956.15	*RxPwrValid*	56	15
US receive power CNU	US receive power CNU	1.1957.14:0	*RxPwr_CNU_ID*	57	14:0
Reported power	Reported Power	1.1958.8:0	*ReportedPwr*	58	8:0
DS OFDM channel ID	DS OFDM channel ID	*12.0.2:0*	*DS_OFDM_ID*	1000	2:0
DS Modulation type SC4	10GPASS-XR DS profile descriptor control 1	12.1.3:0	*DS_ModTypeSC(4)*	1001	3:0
DS Modulation type SC5	10GPASS-XR DS profile descriptor control 1	12.1.7:4	*DS_ModTypeSC(5)*	1001	7:4
DS Modulation type SC6	10GPASS-XR DS profile descriptor control 1	12.1.11:8	*DS_ModTypeSC(6)*	1001	11:8
DS Modulation type SC7	10GPASS-XR DS profile descriptor control 1	12.1.15:12	*DS_ModTypeSC(7)*	1001	15:12
DS Modulation type SC8 through DS Modulation type SC4095	10GPASS-XR DS profile descriptor control 2 through 10GPASS-XR DS profile descriptor control 1023	12.2 through 12.1023	*DS_ModTypeSC(8)* through *DS_ModTypeSC(4095)*	1002 through 2023	as in Index 1001
US Modulation type SC0	10GPASS-XR US profile descriptor control 0	12.1024.3:0	*US_ModTypeSC(0)*	2024	3:0
US Modulation type SC1	10GPASS-XR US profile descriptor control 0	12.1024.7:4	*US_ModTypeSC(1)*	2024	7:4
US Modulation type SC2	10GPASS-XR US profile descriptor control 0	12.1024.11:8	*US_ModTypeSC(2)*	2024	11:8
US Modulation type SC3	10GPASS-XR US profile descriptor control 0	12.1024.15:12	*US_ModTypeSC(3)*	2024	15:12
US Modulation type SC4 through US Modulation type SC4095	10GPASS-XR US profile descriptor control 1 through 10GPASS-XR US profile descriptor control 1023	12.1025 through 12.2047	*US_ModTypeSC(4)* through *US_ModTypeSC(4095)*	2025 through 3047	as in Index 2024

Table 100–1—MDIO register to PHY variable mapping *(continued)*

MDIO parameter name	MDIO register name	Register/bit number	PHY variable		
			Name	Index	Bits(s)
Real pre-equalizer coefficient SC0	10GPASS-XR US pre-equalizer coefficients 0	12.2048.15:0	*EQ_CoefR(0)*	3048	15:0
Imaginary pre-equalizer coefficient SC0	10GPASS-XR US pre-equalizer coefficients 0	12.2049.15:0	*EQ_CoefI(0)*	3049	15:0
Real pre-equalizer coefficient SC1 through Real pre-equalizer coefficient SC4095	10GPASS-XR US pre-equalizer coefficients 1 through 10GPASS-XR US pre-equalizer coefficients 4095	12.2050 12.2052 ... 12.10238	*EQ_CoefR(1)* through *EQ_CoefR(4095)*	3050 3052 ... 11238	15:0
Imaginary pre-equalizer coefficient SC1 through Imaginary pre-equalizer coefficient SC4095	10GPASS-XR US pre-equalizer coefficients 1 through 10GPASS-XR US pre-equalizer coefficients 4095	12.2051 12.2053 ... 12.10239	*EQ_CoefI(1)* through *EQ_CoefI(4095)*	3051 3053 ... 11239	15:0
MER measurement valid	10GPASS-XR receive MER Control	12.10240.3	*RxMER_Valid*	11240	3
Receive MER Channel ID	10GPASS-XR receive MER Control	12.10240.2:0	*RxMER_ChID*	11240	2:0
MER measurement CNU ID	10GPASS-XR receive MER Control	12.10241.14:0	*RxMER_CNU_ID*	11241	14:0
Receive MER SC2	10GPASS-XR receive MER measurement	12.10242.7:0	*RxMER_SC(2)*	11242	7:0
Receive MER SC3	10GPASS-XR receive MER measurement	12.10242.15:8	*RxMER_SC(3)*	11242	15:8
Receive MER SC4 through DS receive MER SC4095	10GPASS-XR receive MER measurement	12.10443 12.10244 ... 12.13288	*RxMER_SC(4)* through *RxMER_SC(4095)*	11443 through 14288	as in Index 11241

100.2 PMD functional specification

The 10GPASS-XR type PMDs perform the transmit and receive functions that convey data between the PMD service interface and the MDI. PMD functions are implementation-dependent and include digital-to-analog conversion, analog-to-digital conversion, interpolation, analog filtering, frequency conversion, and/or RF power amplification.

100.2.1 PMD service interface

The following specifies the services provided by Clause 100 PMDs. The service interface is described in an abstract manner and does not imply any particular implementation.

The PMD service interface supports the exchange of a continuous stream of OFDM/OFDMA time domain sampled waveform between the PMA and PMD entities. The samples are encoded as complex numbers, i.e., I/Q value pairs.

The PMD translates data received from the compatible PMA to and from signals suitable for the specified coaxial medium. The following primitives are defined:

— PMD_UNITDATA.request
— PMD_UNITDATA.indication
— PMD_SIGNAL.request

100.2.1.1 PMD_UNITDATA.request

This primitive defines the transfer of one modulated symbol encoded as an I/Q value pair from the Clause 101 PMA to the Clause 100 PMD.

The semantics of the service primitive are PMD_UNITDATA.request(*I_value*, *Q_value*, *ChNum*). The data conveyed by PMD_UNITDATA.request is a continuous stream of I/Q value pairs and target OFDM channel. Both *I_value* and *Q_value* are encoded as 32-bit signed integers. *ChNum* indicates the applicable channel.

The Clause 101 PMA continuously sends the stream of I/Q value pairs and OFDM channel number to the Clause 100 PMD for transmission on the medium, at the nominal rate of 204.8 million samples per second (Msps). Upon the receipt of this primitive, the PMD converts the received appropriately formatted I/Q value pairs into the appropriate signals at the MDI, effectively sending data across the coaxial media.

100.2.1.2 PMD_UNITDATA.indication

This primitive defines the transfer of I/Q value pair data from the Clause 100 PMD to the Clause 101 PMA.

The semantics of the service primitive are PMD_UNITDATA.indication(*I_value*, *Q_value, ChNum*). The data conveyed by PMD_UNITDATA.indication is a continuous stream of I/Q value pairs and received OFDM channel. Both *I_value* and *Q_value* are encoded as 32-bit signed integers. *ChNum* indicates the applicable channel.

The Clause 100 PMD continuously sends an appropriately formatted stream of I/Q value pairs and OFDM channel number to the Clause 101 PMA corresponding to the signals received from the MDI, at the nominal rate of 204.8 Msps.

100.2.1.3 PMD_SIGNAL.request

The semantics of the service primitive are PMD_SIGNAL.request(*Tx_Enable*). The *Tx_Enable* parameter can take on one of two values: ON or OFF, determining whether the PMD transmitter is on (enabled) or off (disabled). The Clause 101 PCS generates this primitive to indicate a change in the value of *Tx_Enable* parameter. Upon the receipt of this primitive, the Clause 100 PMD turns the transmitter on or off as appropriate.

As input to the PMD, PMD_SIGNAL.request is the OR product of the signal from PCS data detector (see 101.3.2.5.1) with that from the PHY Link (see 102.3.1.3) signaling RF power amplifier turn on to the PMD; either the PCS data detector or the PHY Link may signal ON. When both the PCS and the PHY Link set the value to OFF, this signals RF power amplifier turn off to the PMD.

100.2.2 Delay constraints

The PMD shall introduce a transmit delay variation of no more than 0.5 time_quanta, and a receive delay variation of no more than 0.5 time_quanta. A description for the time_quantum can be found in 77.2.2.1.

100.2.3 PMD transmit function

The PMD Transmit function conveys the I/Q value pairs requested by the PMD service interface message PMD_UNITDATA.request(*I_value, Q_value, ChNum*) to the MDI according to the PMD to MDI RF specifications in 100.3.3 and 100.3.4.

In the upstream direction, the flow of appropriately formatted stream of I/Q value pairs is interrupted according to PMD_SIGNAL.request(*Tx_Enable*).

100.2.4 PMD receive function

The PMD Receive function conveys the bits received from the MDI to the PMD service interface using the message PMD_UNITDATA.indication(*I_value, Q_value*), creating appropriately formatted stream of I/Q value pairs and OFDM channel information.

100.2.5 PMD transmit enable function

The PMD_SIGNAL.request(*Tx_Enable*) message is defined for the CNU PMD specified in this clause. The PMD_SIGNAL.request(*Tx_Enable*) message is asserted prior to data transmission by the CNU PMDs. Note PMD_SIGNAL.request(*Tx_Enable*) message is not defined for the CLT; CLT PMD data transmission is always enabled.

100.3 PMD operational requirements

100.3.1 CLT and CNU modulation formats

The CLT and CNU transmitters and receivers shall support the mandatory modulation formats as specified in Table 100–2.

Table 100–2—Modulation formats

Modulation format[a]	MAC data path		PHY Link data path	
	CLT Tx CNU Rx	CNU Tx CLT Rx	CLT Tx CNU Rx	CNU Tx CLT Rx
BPSK[b]	M	M	M	M
QPSK	N/S	M[c]	N/S	N/S
8-QAM	O	M[c]	N/S	N/S
16-QAM	O	M	M	M
32-QAM	O	M	N/S	M
64-QAM	M	M	N/S	M
128-QAM	M	M	N/S	M
256-QAM	M	M	N/S	N/S
512-QAM	M	M	N/S	N/S
1024-QAM	M	M	N/S	N/S

Table 100–2—Modulation formats *(continued)*

Modulation format[a]	MAC data path		PHY Link data path	
	CLT Tx CNU Rx	CNU Tx CLT Rx	CLT Tx CNU Rx	CNU Tx CLT Rx
2048-QAM	M	O	N/S	N/S
4096-QAM	M	O	N/S	N/S
8192-QAM	O	N/S	N/S	N/S
16384-QAM	O	N/S	N/S	N/S

[a] M = mandatory, O = optional, N/S = not supported.
[b] Used for pilots, burst markers, preambles, and probes.
[c] This modulation format is required only for low density pilots.

See 102.2.1.2 and 102.3.1.2, respectively, for a description of downstream and upstream PHY Link modulation.

The CNU reports supported optional modulations to the CLT via *US_ModAbility* variable see 101.4.4.4.4.

100.3.2 Data rates

In baseline channel conditions, as defined in Annex 100A, a 192 MHz OFDM channel supports a data rate of at least 1.6 Gb/s at the MAC/PLS interface. The MAC data rate scales linearly with the number of OFDM channels, for the same baseline channel conditions in the upstream OFDMA channel and each downstream OFDM channel.

100.3.2.1 Downstream PHY data rate

The CLT calculates the downstream PMA data rate after any configuration update that changes the downstream profile descriptor variables *DS_ModTypeSC(n)* or for any change to the cyclic prefix size *DSNcp*. See 101.4.3.4.5 and 101.4.3.12.1. Specifically after any configuration change and after the continuous and scattered pilot map has been updated (see 101.4.3.6), the CLT shall update the value of the variable *DS_DataRate*.

The downstream PMA OFDM superframe repeats every 128 symbols. The superframe length is determined using the *DS_Extended_OFDM_Symbol* based on size of the selected cyclic prefix.

$$DS\_Frame\_Length = 128 \times DS\_Extended\ OFDM\ Symbol\ (\mu s)$$

$$DS\_Extended\_OFDM\_Symbol = 20 + DSNcp\ \text{(downstream)}\ (\mu s)$$

The downstream OFDM frame data load (bits) is a summation over all active downstream OFDM channels, as defined by *DS_ChCnt*, over 128 symbols, the summation of bit per subcarrier for all active subcarriers (subcarriers that are not configured as excluded are active subcarriers).

$$DS\_Frame\_Data\_Load = \sum_{c=1}^{DS\_ChCnt} \text{active channel}_c\left(\sum_{s=1}^{128} \text{symbol}_s\left(\sum_{sc=0}^{4095} \text{bits per symbol}_{sc}\right)\right)$$

PHY Link, excluded, and unused subcarriers and continuous and scattered pilots are skipped. Note that in the definition of *DS_ModTypeSC(n)* the values binary 0011 (3 decimal) through 1110 (14 decimal) directly represent the number of data bits per active subcarrier (see 101.4.3.4.5).

DS_Frame_Data_Load has the same value every downstream OFDM frame, therefore *DS_DataRate* remains the same for any given downstream profile descriptor configuration as shown in Equation (100–1):

$$DS\_DataRate = DS\_Frame\_Data\_Load / DS\_Frame\_Length \text{ (b/s)} \qquad (100\text{–}1)$$

Equation (100–1) establishes nominal data rate for CLT PMA_UNITDATA.request service interface.

Based on the current profile, the CLT calculates *DS_DateRate* and communicates this to the CNU. The CNU also calculates *DS_DataRate* based on the configured profile. If the CNU calculation differs from the CLT value by more than 10 b/s, the CNU sets *DS_RateMatchFail* to TRUE indicating mismatch; otherwise it is set to FALSE.

100.3.2.2 Upstream PHY data rate

The CLT calculates the upstream PMA data rate after any configuration update that changes the upstream profile descriptor variables *US_ModTypeSC(n)* or for any change to the cyclic prefix size *USNcp*. See 101.4.4.4.4 and 101.4.4.10.1. Specifically after any configuration change and after the Type I and Type II pilot map has been updated (see 101.4.4.6), the CLT shall update the value of the variable *US_DataRate*.

The upstream PMA RB Superframe repeats every 256 + 6 symbols, where the Probe region is 6 symbols in length. The superframe length is determined using the *US_Extended_OFDM_Symbol* based on size of the selected cyclic prefix size (µs).

$$US\_Frame\_Length = (256 + 6) \times US\_Extended\ OFDM\ Symbol \text{ (µs)}$$

$$US\_Extended\_OFDM\_Symbol = 20 + USNcp \text{ (µs)}$$

The upstream OFDM frame data load (bits) is a summation over the 256 symbols, the summation of bits per Resource Element. For a low density type “L” pilot Resource Element, the value is the *US_ModTypeSC(n)* value minus 4 (decimal) or 1, whichever is higher. The probe region symbols are not included in this summation.

$$US\_Frame\_Data\_Load = \sum_{s=1}^{256} \text{symbol}_s \left(\sum_{RE=0}^{4095} \text{resource element}_{RE} \right)$$

PHY Link, excluded, and unused subcarriers and type “P” pilot Resource Elements are skipped. Note that in the definition of *US_ModTypeSC(n)* the values binary 0011 (3 decimal) through 1110 (14 decimal) directly represent the number of data bits per active subcarrier (see 101.4.4.4.4).

A Resource Element is a single subcarrier over the duration of a single symbol. A Resource Block is a group of 8 or 16 adjacent Resource Elements in the same subcarrier as defined by the variable *RBsize* (see 101.4.4.3.1).

US_Frame_Data_Load has the same value every upstream RB Superframe; therefore, *US_DataRate* remains the same for any given upstream profile descriptor configuration as shown in Equation (100–2):

$$US\_DataRate = US\_Frame\_Data\_Load / US\_Frame\_Length \text{ (b/s)} \qquad (100\text{–}2)$$

Note that *US_DataRate* does not include PCS or burst marker overheads.

This establishes nominal data rate for CLT PMA_UNITDATA.request service interface and also serves as the negotiated upstream PHY data rate for each CNU.

Based on the current profile, the CLT calculates *US_DateRate* and communicates this to the CNU. The CNU also calculates *US_DataRate* based on the configured profile. If the CNU calculation differs from the CLT value by more than 10 b/s, the CNU sets *US_RateMatchFail* to TRUE indicating mismatch; otherwise it is set to FALSE.

100.3.2.3 PHY Link managed variables

DS_ChCnt
: TYPE: 3-bit unsigned integer
: This variable indicates the number of downstream OFDM channels in use. The value of *DS_ChCnt* is between 1 and 5.

DS_DataRate
: TYPE: UQ34.3 format
: This variable indicates the downstream data rate in units of b/s and is calculated as shown in Equation (100–1).

DS_FreqCh(n)
: TYPE: 16-bit unsigned integer
: This variable specifies the center frequency, in units of 50 kHz, of subcarrier 0 for the downstream OFDM channel n ($1 \le n \le 5$). Subcarriers are numbered from 0 to 4095 with subcarrier 0 at the lowest frequency. This definition equates to a subcarrier 0 center frequency of 54 MHz to 3276.75 MHz. The minimum value for this register is 1080. See Table 100–3 for additional details.

DS_RateMatchFail
: TYPE: Boolean
: This variable is set to TRUE if the CNU calculation of *DS_DataRate* differs from the *DS_DataRate* calculation communicated from the CLT by more than 10 b/s; otherwise, the variable is set to FALSE.

US_DataRate
: TYPE: UQ34.3 format
: This variable indicates the upstream data rate in units of b/s and is calculated as shown in Equation (100–2).

US_FreqCh1
: TYPE: 16-bit unsigned integer
: This variable specifies the center frequency, in units of 50 kHz, of subcarrier 0 for the upstream OFDMA channel. Subcarriers are numbered from 0 to 4095 with subcarrier 0 at the lowest frequency. This definition equates to a subcarrier 0 center frequency of 0 MHz to 3276.75 MHz. The minimum value for this register is 148 to accommodate starting at 7.4 MHz. See Table 100–11 for additional details.

US_RateMatchFail
: TYPE: Boolean
: This variable is set to TRUE if the CNU calculation of *US_DataRate* differs from the *US_DataRate* calculation communicated from the CLT by more than 10 b/s; otherwise, the variable is set to FALSE.

100.3.3 CLT transmitter requirements

100.3.3.1 OFDM channel power definitions

This subclause defines the terms and concepts used when specifying the CLT RF output requirements. For an OFDM channel there is a) the number of equivalent 6 MHz channels (*Neq*), b) the encompassed spectrum, c) the modulated spectrum, and d) the number of active equivalent 6 MHz channels (*Neq*').

The number of equivalent 6 MHz channels, *Neq*, is constant and calculated for a single OFDM channel size of 192 MHz as follows: 192/6 = 32.

Neqport at the MDI is the sum of the individual *Neq* of each OFDM channel.

The total number of OFDM channels, *NOFDM* is 5. Thus, *Neqport* is 5 × 32 = 160.

The encompassed spectrum is the difference between a) the center frequency of the highest frequency active subcarrier of the highest frequency OFDM channel and b) the center frequency of the lowest frequency active subcarrier of the lowest frequency OFDM channel, plus the subcarrier spacing of 0.05 MHz (all expressed in MHz). The encompassed spectrum of a single OFDM channel is the difference between the center frequency of the highest frequency active subcarrier and the center frequency of the lowest frequency active subcarrier in the OFDM channel, plus the subcarrier spacing.

Occupied spectrum (*Occupiedspectrum*) as shown in Equation (100–3) is the accumulation of the bandwidth (RF spectrum) in all channel frequency allocations (e.g., 6 MHz *channelsize*) that are occupied by the OFDM channel (*OFDMchannelbandwidth*).

$$Occupiedspectrum = channelsize \times \lceil OFDMchannelbandwidth / channelsize \rceil \qquad (100–3)$$

The occupied spectrum is a multiple of 6 MHz and consists of all 6 MHz channels that are included in the encompassed spectrum, plus the taper region shaped by the OFDM channels' transmit windowing; the out-of-band spurious emissions requirements in 100.3.3.5 (except for interior exclusion band spurious emissions requirements) apply outside the occupied spectrum. With a 1 MHz taper region on each band edge of the OFDM channel, shaped by the transmit windowing function, an encompassed spectrum of 190 MHz of active subcarriers has 192 MHz of occupied spectrum.

An exclusion band is a contiguous block of excluded spectrum that is 1 MHz wide or greater. An individually excluded subcarrier is any excluded subcarrier in a contiguous block of excluded spectrum less than 1 MHz.

The modulated spectrum of a single OFDM channel is the encompassed spectrum minus the total spectrum in the internal excluded subbands of the OFDM channel, where the total spectrum in the internal excluded subbands is equal to the number of subcarriers in all of the internal excluded subbands of the OFDM channel multiplied by the subcarrier spacing of the OFDM channel. For example, with 190 MHz encompassed spectrum, if there are 188 subcarriers total in three internal exclusion subbands, then the total spectrum in the internal excluded subbands (in MHz) is 188 × 0.05 = 9.4 MHz, and the modulated spectrum is 190 MHz – 9.4 MHz = 180.6 MHz.

The modulated spectrum at the MDI (TP1, see 100.4) is the sum of the modulated spectrum of each OFDM channel.

The number of active equivalent 6 MHz channels, *Neq'*, for an OFDM channel is a function of the modulated spectrum (MHz) of a channel as calculated in Equation (100–4).

$$Neq' = \lceil modulated\ spectrum\ of\ a\ single\ channel / channelsize \rceil \quad (100\text{–}4)$$

Neqport' at the MDI is the sum of the *Neq*' of each OFDM channel.

The CLT shall comply with all CLT transmitter requirements (see 100.3.3) operating with all *Neqport* channels on the MDI and with all requirements for the device operating with *Neqport*' active channels on the MDI for all values of *Neqport*' less than *Neqport*.

100.3.3.2 CLT output electrical requirements

For OFDM, all modulated subcarriers in an OFDM channel are set to the same average power (except pilots that are boosted by 6 dB). For the purposes of meeting spurious emissions requirements, for each OFDM channel:

— Configure the OFDM channel power using the commanded average power of an equivalent 6 MHz channel for the first OFDM channel, which is *DS_PowerCh*(1) (see Table 100–5) as follows:

—CLT calculates power for data subcarrier and pilots using the subcarriers in the 6 MHz band centered on the PHY Link.

NOTE—The configured average power of an equivalent 6 MHz channel for the first OFDM channel is defined as the power for the 6 MHz band centered on the PHY Link.

— For the second OFDM channel, let *X* dB be the commanded average power of an equivalent 6 MHz channel for the second OFDM channel minus commanded average power of an equivalent 6 MHz channel for the first OFDM channel; i.e., X dB $= DS\_PowerCh(2) - DS\_PowerCh(1)$. Then set the data subcarrier power for the second channel equal to data subcarrier power for the first channel plus *X* dB.

— Data subcarrier power for the third, fourth, and fifth OFDM channels are computed relative to the first OFDM channel in the same fashion.

A CLT shall output an OFDM RF modulated signal with the characteristics defined in Table 100–3, Table 100–5, and Table 100–6. These requirements are to be met under the conditions where the configured average power of an equivalent 6 MHz channel is the same for each OFDM channel, with the exception of the following: single channel active phase noise, diagnostic carrier suppression, OFDM phase noise, OFDM diagnostic suppression, and power difference requirements, and as described for out-of-band noise and spurious requirements.

Table 100–3—CLT RF output requirements

Parameter	Value	Units
Downstream 10.24 MHz Master Clock frequency	10.24	MHz
Frequency band	258 to 1218	MHz
OFDM channel bandwidth (*OFDMchannelbandwidth*)	24 to 192	MHz
Encompassed spectrum	22 to 190	MHz
Subcarrier spacing	50	kHz
OFDM symbol rate FFT duration	20	µs
FFT size	4096	FFT bins
Maximum number of active subcarriers per FFT	3800	subcarriers
Level	See Table 100–5	

Table 100–3—CLT RF output requirements *(continued)*

Parameter	Value	Units
Modulation format	See Table 100–2	
Transmit MUTE when TRUE.[a] See 100.4.1.	≥ 73	dBc
Inband spurious, distortion, and noise[d]		
For measurements below 600 MHz[a]	≤ –50	dBr
For measurements from 600 MHz to 1002 MHz[a]	≤ –47	dBr
For measurements 1002 MHz to 1218 MHz[b]	≤ –45	dBr
MER in 192 MHz OFDM channel occupied spectrum 528 MHz total occupied spectrum, 88 equivalent 6 MHz channels[c, d, e, f, g]		
For measurements below 600 MHz:		
Any single subcarrier	≥ 48	dB
Average over the complete OFDM channel[h]	≥ 50	dB
For measurements from 600 MHz to 1002 MHz:		
Any single subcarrier	≥ 45	dB
Average over the complete OFDM channel[g]	≥ 47	dB
For measurements 1002 MHz to 1218 MHz:		
Any single subcarrier	≥ 43	dB
Average over the complete OFDM channel[g]	≥ 45	dB
MER in 24 MHz OFDM channel occupied spectrum, single OFDM channel only, 24 MHz total occupied spectrum.[b, c, d, i] Average over the complete OFDM channel:		
For measurements below 600 MHz	≥ 48	dB
For measurements from 600 MHz to 1002 MHz	≥ 45	dB
For measurements 1002 MHz to 1218 MHz	≥ 43	dB
Output impedance	75	Ω
Output return loss. Specified for within an active output OFDM channel or in every inactive OFDM channel as noted.		
88 MHz to 750 MHz; active	> 14	dB
750 MHz to 870 MHz; active	> 13	dB
870 MHz to 1218 MHz; active	> 12	dB
54 MHz to 870 MHz; inactive	> 12	dB
870 MHz to 1218 MHz; inactive	> 10	dB
MDI Connector	F connector per ISO/IEC-61169-24 or SCTE 02	

[a]RF output power below the operationally configured aggregate power of the RF modulated signal, in every 6 MHz channel from 258 MHz to 1218 MHz.

[b]Average over center 400 kHz subcarriers within gap.
[c]Receiver OFDM channel estimation is applied in the test receiver; test receiver does best estimation possible. Transmit windowing is applied to potentially interfering channel and selected to be sufficient to suppress cross channel interference.
[d]Modulation error ratio (MER) is determined by the cluster variance caused by the transmit waveform at the output of the ideal receive matched filter. MER includes all discrete spurious, noise, subcarrier leakage, clock lines, synthesizer products, distortion, and other undesired transmitter products. Phase noise up to ± 50 kHz of the subcarrier's center frequencies is excluded from inband specification, to separate the phase noise and inband spurious requirements as much as possible. In measuring MER, record length or carrier tracking loop bandwidth may be adjusted to exclude low-frequency phase noise from the measurement. MER requirements assume measuring with a calibrated test instrument with its residual MER contribution removed.
[e]Phase noise up to 10 MHz offset is mitigated in test receiver processing or by test equipment (latter using hardline carrier from modulator, which requires special modulator test port and functionality).
[f] Up to five subcarriers in one OFDM channel can be excluded from this requirement.
[g] When the estimated channel impulse response used by the test receiver is limited to half of length of smallest transmit cyclic prefix then there is a 2 dB relief for above requirements (e.g., MER > 48 dB becomes MER > 46 dB).
[h]See 100.4.2 for average MER calculation method.
[i]A single subcarrier in the OFDM channel can be excluded from this requirement, no windowing is applied and minimum CP is selected.

100.3.3.2.1 PHY Link managed variables

DS_PowerCh(n)
TYPE: 9-bit unsigned integer.
This variable specifies the downstream CLT transmit power, in units of 0.2 dBmV/6 MHz, for OFDM channel n ($1 \le n \le 5$). The value is set according to the requirements in Table 100–5.

100.3.3.3 Phase noise requirements

The CLT transmitted signal for each OFDM channel shall meet the phase noise requirements as per Table 100–4.

Table 100–4—Downstream phase noise requirements

Parameter	Value	Units
Phase noise, integrated double-sided maximum, 1002 MHz or lower:		
1 kHz to 10 kHz	–48	dBc
10 kHz to 100 kHz	–56	dBc
100 kHz to 1 MHz	–60	dBc
1 MHz to 10 MHz	–54	dBc
10 MHz to 100 MHz	–60	dBc

100.3.3.4 Power per OFDM channel for CLT

The CLT shall adjust the RF transmit power per Table 100–5. In Table 100–5 the value for N^*, the adjusted number of active channels combined per MDI, is calculated using Equation (100–5).

$$\text{If}\left(Neqport' < \frac{Neqport}{4}\right)\text{ then }\left(N^* = \text{minimum}\left(4Neqport', \left\lceil\frac{Neqport}{4}\right\rceil\right)\right)$$
$$\text{If}\left(Neqport' \ge \frac{Neqport}{4}\right)\text{ then }(N^* = Neqport') \tag{100–5}$$

The applicable maximum power per OFDM channel and spurious emissions requirements are defined for the CLT using the value of N^* per Equation (100–5).

Table 100–5—CLT RF output power requirements

Parameter	Value[a,b,c]	Units
Maximum value of OFDM channel power in the OFDM channel occupied spectrum normalized to 6 MHz ((OFDM signal power/occupied spectrum) × 6 MHz:		
Neqport' OFDM channels combined onto a single MDI for $Neqport' \geq Neqport/4$	$60 - \lceil 3.6 \times \log_2(N^*) \rceil$ [d]	dBmV/6 MHz
Neqport' OFDM channels combined onto a single MDI for $4 \leq Neqport' < Neqport/4$[c]	$60 - \lceil 3.6 \times \log_2(N^*) \rceil$ [d]	dBmV/6 MHz
Range of commanded transmit power for each OFDM channel, at least 8 dB below the required power level specified above, maintaining full fidelity over the range	≥ 8	dB
Commanded power per OFDM channel step size. Strictly monotonic.	≤ 0.2	dB
Power difference between any two adjacent OFDM channels in the 108 MHz to 1218 MHz downstream spectrum[e]	≤ 0.5	dB
Power difference (normalized for bandwidth) between any two channels' OFDM channel blocks in the 108 MHz to 1218 MHz downstream spectrum[e]	≤ 2	dB
Power per channel absolute accuracy	± 2	dB

[a]Add 3 dB relaxation to the values specified above for noise and spurious emissions requirements in all channels with 603 MHz ≤ center frequency ≤ 999 MHz. For example –73 dBc becomes –70 dBc. Also see 100.3.3.5.
[b]Add 1 dB relaxation to the values specified above for noise and spurious emissions requirements in gap channels with center frequency below 600 MHz. For example –73 dBc becomes –72 dBc. Also see 100.3.3.5.
[c]Add 5 dB relaxation to the values specified above for noise and spurious emissions requirements in all channel with 999 MHz < center frequency of the noise measurement ≤ 1215 MHz. For example –73 dBc becomes –68 dBc. Also see 100.3.3.5.
[d]These ceiling functions round to the nearest 0.5.
[e]The power difference in this context is the accuracy of measured differential power between two channels of interest as compared to the configured differential power between those two channels.

100.3.3.5 Out-of-band noise and spurious requirements for the CLT

Table 100–6 lists the out-of-band spurious requirements. In cases where the configured average power of an equivalent 6 MHz channel is not the same for each OFDM channel, 0 dBc for the spurious emissions requirements corresponds to the largest configured average power of an equivalent 6 MHz channel among all the active OFDM channels. When the configured average power of an equivalent 6 MHz channel is the same for each OFDM channel, 0 dBc should be interpreted as the measured power of the 6 MHz band centered on the PHY Link contained in OFDM channel 1.

The 10GBASE-XR-D PMD shall satisfy the out-of-band spurious emissions requirements of Table 100–6 in measurements below 600 MHz and outside the encompassed spectrum when the active OFDM channels are contiguous or when the ratio of modulated spectrum to gap spectrum within the encompassed spectrum is

4:1 or greater. Gap spectrum is spectrum between active OFDM channel's occupied spectrum and excluded bands within OFDM channel's occupied spectrum.

The 10GBASE-XR-D PMD shall satisfy the out-of-band spurious emissions requirements of Table 100–6 in gap spectrum between OFDM channels of at least 6 MHz and within exclusion bands within OFDM channels of at least 8 MHz, except for the 1 MHz of excluded subcarriers on each edge of any exclusion band, with relaxations as described in the following paragraphs when applicable.

The 10GBASE-XR-D PMD shall satisfy the out-of-band spurious emissions requirements of Table 100–6, with 1 dB relaxation, in measurements within gap spectrum in modulated spectrum below 600 MHz and within the encompassed spectrum when the ratio of modulated spectrum to gap spectrum within the encompassed spectrum is 4:1 or greater.

The 10GBASE-XR-D PMD shall satisfy the out-of-band spurious emissions requirements of Table 100–6, with 3 dB relaxation, when the ratio of modulated spectrum to gap spectrum within the encompassed spectrum is 4:1 or greater, in measurements from 603 MHz to 999 MHz inclusive, outside the encompassed spectrum or in gap spectrum within the encompassed spectrum.

The 10GBASE-XR-D PMD shall satisfy the out-of-band spurious emissions requirements of Table 100–6, with 5 dB relaxation, when the ratio of modulated spectrum to gap spectrum within the encompassed spectrum is 4:1 or greater, in measurements from 999 MHz to 1209 MHz inclusive, outside the encompassed spectrum or in gap spectrum within the encompassed spectrum.

The 10GBASE-XR-D PMD shall satisfy the out-of-band spurious emissions requirements of Table 100–6, in addition to contributions from theoretical transmit windowing, with permissible configurations of lower edge and upper edge subband exclusions of at least 1 MHz each, cyclic prefix length (*DSNcp*) and windowing roll-off period (*DSNrp*) values. The test limit for determining compliance to the spurious emissions requirements is the power sum of the spurious emissions requirements, taken in accordance with Table 100–6 and the contributions from the theoretical transmit windowing for the configured transmissions.

The full set of *Neqport*' active equivalent 6 MHz channels is referred to throughout this specification as the modulated OFDM channels or the active OFDM channels. However, for purposes of determining the spurious emissions requirements for non-contiguous transmitted OFDM channels, each separate contiguous sub-block of channels within the active OFDM channels is identified, and the number of OFDM channels in each contiguous sub-block is denoted as *Neqi*, for $i = 1$ to K, where K is the number of contiguous blocks. Therefore,

$$Neqport' \le \sum_{i=1}^{K} Neqi \qquad (100\text{–}6)$$

Because exclusion subbands may be as small as 1 MHz with two or more contiguous sub-blocks within an OFDM channel, the number of active equivalent 6 MHz channels in each contiguous sub-block may add to more than the number of active equivalent 6 MHz channels in the full OFDM channel. Any double-counting of active subcarriers near small exclusion bands is acceptable in calculating the spurious emissions requirements; the equipment has to meet spurious emissions requirements in cases where Equation (100–6) is met with equality and the small relaxation in requirements which results from inequality is thus not compelling.

Note that $K = 1$ when and only when the entire set of active OFDM channels is contiguous. Also note that an isolated transmit OFDM channel, i.e., a transmit channel with empty adjacent OFDM channels, is described by $Neqi = 1$ and constitutes a block of one contiguous OFDM channel. Any number of the contiguous blocks may have such an isolated transmit OFDM channel; if each active OFDM channel was an isolated channel, then $K = Neq'$.

When the *Neqport'* combined active OFDM channels are not contiguous and the ratio of modulated spectrum to gap spectrum within the encompassed spectrum is 4:1 or greater, the spurious emissions requirements are determined by summing the spurious emissions power allowed in a given *Measurement Bandwidth* by each of the contiguous blocks among the occupied spectrum. In the gap spectrum within the encompassed spectrum and below 600 MHz there is a 1 dB relaxation in the spurious emissions requirements, so that within the encompassed spectrum the spurious emissions requirements (in absolute power) are 26% higher power in the measurement band determined by the summing of the contiguous blocks spurious emissions requirements. In all OFDM channels above 600 MHz there is a 3 dB relaxation in the spurious emissions requirements, so that the spurious emissions requirements (in absolute power) are double the power in the measurement band determined by the summing of the contiguous blocks spurious emissions requirements.

The details of the spurious emissions requirements for non-contiguous OFDM channel operation outside the encompassed spectrum are as follows. Note that within the encompassed spectrum the same details apply, except there is an additional 1 dB allowance below 600 MHz and a 3 dB allowance is applied above 600 MHz for all OFDM channels.

- The noise and spurious power requirements for all contiguous blocks of transmitted channels are determined from Table 100–6, even if the block contains fewer than *Neqport*/4 active OFDM channels. The noise and spurious power requirements for the *i*th contiguous block of transmitted channels is determined from Table 100–6 using the value *Neqi* for the number of active OFDM channels combined per MDI, and using dBc relative to the highest commanded power level of a 6 MHz equivalent channel among all the active OFDM channels, and not just the highest commanded power level in the *i*th contiguous block, in cases where the *Neqport'* combined OFDM channels are not commanded to the same power. The noise and spurious emissions power in each measurement band, including harmonics, from all *K* contiguous blocks, is summed (absolute power, NOT in dB) to determine the composite noise floor for the non-contiguous channel transmission condition. For the measurement OFDM channels adjacent to a contiguous block of channels, the spurious emissions requirements from the non-adjacent blocks are divided on an equal per Hz basis for the narrow and wide adjacent measurement bands.
- For a measurement channel positioned between two contiguous blocks, adjacent to each, the measurement channel is divided into three measurement bands: one wider in the middle and two narrower bands each abutting one of the adjacent transmit channels. The wideband spurious and noise requirement is split into two parts, on an equal per Hz basis, to generate the allowed contribution of power to the middle band and to the farthest narrowband.

In Table 100–6 the value for N^* is calculated using Equation (100–5). Item 1 through item 4 list the requirements in channels adjacent to the active channels. Item 5 lists the requirements in all other channels further from the active channels. Some of these “other” channels are allowed to be excluded from meeting the item 5 specification. All the exclusions, such as 2nd and 3rd harmonics of the modulated channel, are fully identified in the table. Item 6 lists the requirements on the 2*Neqport'* 2nd harmonic channels and the 3*Neqport'* 3rd harmonic channels.

Table 100–6—CLT output out-of-band noise and spurious emissions requirements

Item	Band	Requirement (in dBc)[a,b,c]
1	Adjacent channel up to 750 kHz from channel block edge	For $N^* = 1: \le -58$ For $N^* = 2: \le -58$ For $N^* = 3: \le -58$ For $N^* = 4: \le -58$ For $N^* \ge 5: \le 10 \times \log_{10} [10^{-58/10} + (0.75/6) \times (10^{-65/10} + (N^*-2) \times 10^{-73/10})]$
2	Adjacent channel (750 kHz from channel block edge to 6 MHz from channel block edge)	For $N^* = 1: \le -62$ For $N^* \ge 2: \le 10 \times \log_{10} [10^{-62/10} + (5.25/6) \times (10^{-65/10} + (N^*-2) \times 10^{-73/10})]$
3	Next-adjacent channel (6 MHz from channel block edge to 12 MHz from channel block edge)	$\le 10 \times \log_{10} [10^{-65/10} + (N^*-1) \times 10^{-73/10}]$
4	Third-adjacent channel (12 MHz from channel block edge to 18 MHz from channel block edge)	For $N^* = 1: \le -73$ For $N^* = 2: \le -70$ For $N^* = 3: \le -67$ For $N^* = 4: \le -65$ For $N^* = 5: \le -64.5$ For $N^* = 6: \le -64$ For $N^* = 7: \le -64$ For $N^* \ge 8: \le -73 + 10 \times \log_{10} (N^*)$
5	Noise in other channels (47 MHz to 1218 MHz) measured in each 6 MHz channel excluding the following: a) Desired channel(s) b) 1st, 2nd, and 3rd adjacent channels (see items 1, 2, 3, 4 in this table) c) Channels coinciding with 2nd and 3rd harmonics (see item 6 in this table)	For $N^* = 1: \le -73$; For $N^* = 2: \le -70$; For $N^* = 3: \le -68$; For $N^* = 4: \le -67$; For $N^* \ge 5: \le -73 + 10 \times \log_{10} (N^*)$
6	In each of 2*Neqport*' contiguous 6 MHz channels or in each of 3*Neqport*' contiguous 6 MHz channels coinciding with 2nd harmonic and with 3rd harmonic components, respectively (up to 1218 MHz)	$\le -73 + 10 \times \log_{10} (N^*)$ or –63, whichever is greater
7	Lower out of band noise in the band of 5 MHz to 47 MHz, measured in 6 MHz channel bandwidth	$\le -50 + 10 \times \log_{10}(N^*)$
8	Higher out of band noise in the band of 1218 MHz to 3000 MHz, measured in 6 MHz channel bandwidth	For $N^* \le 8: \le -55 + 10 \times \log_{10}(N^*)$ For $N^* > 8: \le -60 + 10 \times \log_{10}(N^*)$

[a]Add 3 dB relaxation to the values specified above for noise and spurious emissions requirements in all channels with 603 MHz ≤ center frequency ≤ 999 MHz. For example –73 dBc becomes –70 dBc.
[b]Add 5 dB relaxation to the values specified above for noise and spurious emissions requirements in all channels with 999 MHz < center frequency ≤ 1209 MHz. For example –73 dBc becomes –68 dBc.
[c]Add 1 dB relaxation to the values specified above for noise and spurious emissions requirements in gap channels with center frequency below 600 MHz. For example –73 dBc becomes –72 dBc.

100.3.3.6 CLT transmitter output requirements

The CLT shall provide for independent selection of center frequency with the ratio of modulated spectrum to gap spectrum in the encompassed spectrum being at least 2:1.

The CLT shall disable transmitter output when *PD_Enable* is equal to FALSE and continue in normal transmitter operation when *PD_Enable* is equal to TRUE.

100.3.4 CNU transmitter requirements

100.3.4.1 Burst timing convention

The start time of an OFDMA transmission by a CNU is referenced to an upstream Superframe boundary that begins with a Probe region (6 OFDMA symbols) followed by 256 OFDMA symbols. The 256 OFDMA symbols are divided into 32 8-symbol Resource Blocks, or 16 16-symbol Resource Blocks, as configured by *RBsize* (see 101.4.4.3.1).

The upstream time reference is defined as the first sample of the first symbol of an upstream Superframe, pointed to by the dashed arrow of Figure 100–2. The parameter N_{FFT} refers to the length of the FFT duration of 4096, and the parameter *USNcp* is the length of the configurable cyclic prefix. The sample rate is 204.8 Msps.

The upstream time reference for construction of each OFDMA symbol is defined as the first sample of each FFT duration of each OFDMA symbol, as illustrated in Figure 100–2.

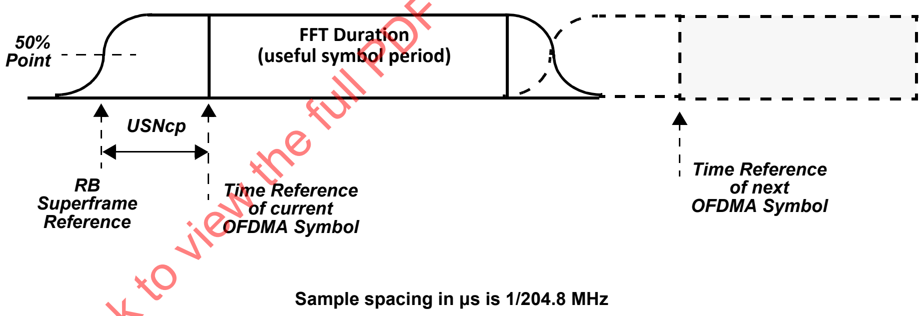


Figure 100–2—Time references for OFDMA symbol and RB Superframe

100.3.4.2 Transmit power requirements

The OFDMA channel power is defined as the average power when all active subcarriers in an OFDMA symbol are granted to the CNU. The normalized channel power of an OFDMA channel is the average power of the OFDMA subcarriers in 1.6 MHz bandwidth with no exclusions. This normalized channel power of an OFDMA channel is denoted as $P_{1.6}$. The transmit power requirements are a function of the occupied spectrum of the OFDMA channel.

The maximum value of the total power output of the CNU P_{Max} is at least 65 dBmV.

For the upstream OFDMA channel, N_{eq} is calculated per Equation (100–7).

$$N_{eq} = \lceil (BW_{OFDMA})/1.6 \rceil \tag{100–7}$$

BW_{OFDMA} (MHz) is the sum of the bandwidth of the modulated spectrum of the OFDMA channel.

Maximum equivalent channel power ($P_{1.6Max}$) is calculated as shown in Equation (100–8).

$$P_{1.6Max} = P_{Max} - 10 \times \log_{10}(N_{eq}) \tag{100–8}$$

The CLT shall limit the configured $P_{1.6Max}$ to no more than 53.2 + (P_{Max} – 65) dBmV if the bandwidth of the modulated spectrum is ≤ 24 MHz. This enforces a maximum power spectral density of P_{Max} dBmV per 24 MHz.

The minimum equivalent channel power ($P_{1.6Min}$) for OFDMA channels is 17 dBmV.

During PHY Discovery ranging a CNU shall initiate communications starting from lowest power, which is set by the CLT using *PdRespInitPwr* (see 102.4.1.4). Therefore it should be noted that transmissions may use power per subcarrier that is as much as 9 dB lower than indicated by $P_{1.6Min}$ during PHY Discovery.

100.3.4.3 OFDMA transmit power calculations

The CNU determines individual subcarrier transmit power and maintains reported power level $P_{1.6r}$ in dBmV.

The CNU updates its reported power, *ReportedPwr*, by the following steps:

a) 1.$P_{1.6r} = P_{1.6r} + \Delta P$ (add power level adjustment to reported power level).
b) The CNU shall report its transmit power using the variable *ReportedPwr* when requested by the CLT.

The value for $P_{1.6r}$ has the following limits:

— $P_{1.6r} \le P_{1.6Max}$ (clip at max power limit).
— $P_{1.6r} \ge P_{1.6Min}$ (clip at min power limit per channel).

The CNU shall then transmit each data subcarrier with target power as calculated by Equation (100–9).

$$P_{t\_sc\_i} = P_{1.6r} + Pre\text{-}Eq_i - 10 \times \log_{10}(32) \tag{100–9}$$

where

Pre-Eq$_i$ is the magnitude of the *i*th subcarrier pre-equalizer coefficient (dB)
32 is the number of subcarriers in 1.6 MHz

That is, the reported power, normalized to 1.6 MHz, minus compensation for the pre-equalization for the subcarrier, less a factor taking into account the number of subcarriers in 1.6 MHz.

The CNU transmit power, P_t, in an upstream RB Frame is the sum of the individual transmit powers $P_{t\_sc\_i}$ of each subcarrier where the sum is performed using absolute power quantities in the non-dB domain.

The transmitted power level varies dynamically as the number and type of allocated subcarriers varies.

100.3.4.3.1 PHY Link managed variables

ReportedPwr
TYPE: 9-bit unsigned integer
This variable reports the CNU transmit power, in units of 0.25 dBmV, for the upstream OFDMA channel.

100.3.4.4 OFDMA fidelity requirements

100.3.4.4.1 Spurious emissions

The noise and spurious power generated by the CNU shall not exceed the levels given in Table 100–7, Table 100–8, and Table 100–9. Up to five discrete spurs[3] can be excluded from the emissions requirements listed in Table 100–7, Table 100–8 and Table 100–9 and have to be less than –42 dBc relative to a single subcarrier power level.

The parameter *SpurFloor* is related to the ratio of the number of subcarriers being modulated by a CNU in an OFDMA symbol to the maximum number of subcarriers available (3840) including guard bands and is calculated in dBc per Equation (100–10).

$$SpurFloor = \max\{-57 + 10 \times \log_{10}(N_{S\_Max}/3840), -60\} \quad (100–10)$$

where N_{S_Max} is the number of modulated subcarriers in an OFDMA symbol.

Maximum number of simultaneous transmitters is defined as shown in Equation (100–11).

$$N_{T\_Max} = \lfloor 0.2 + 10^{((-44 - SpurFloor)/10)} \rfloor \quad (100–11)$$

The parameter *Under-grant Subcarriers* (number of subcarriers) is defined as shown in Equation (100–12).

$$Under\text{-}grant\ Subcarriers = N_{S\_Max}/N_{T\_MAX} \quad (100–12)$$

When a CNU is transmitting with fewer subcarriers than the *Under-grant Subcarriers* the spurious emissions requirement limit is the power value (in dBmV), corresponding to the specifications for the power level associated with a grant number of subcarriers equal to *Under-grant Subcarriers*. In addition, when a CNU is transmitting such that the total power of the CNU, P_t, is less than 17 dBmV, but other requirements are met, then the CNU spurious emissions requirements limit is the power value (in dBmV) computed with all conditions and relaxations factored in, plus an amount X dB where:

$$X \text{ dB} = 17 \text{ dBmV} - P_t$$

In Table 100–7, inband spurious emissions includes noise, carrier leakage, clock lines, synthesizer spurious products, and other undesired transmitter products. It does not include ISI. The *Measurement Bandwidth* for inband spurious for OFDM is equal to the Subcarrier Clock frequency (50 kHz) and is not a synchronous measurement. The signal reference power for OFDMA inband spurious emissions is the total transmit power measured and adjusted (if applicable), and then apportioned to a single active subcarrier (see Table 100–8 and Table 100–9).

[3]Discrete (narrowband) spurious emissions, such as a continuous wave (CW) sinusoid or other signal with significant power concentrated in small bandwidth.

The *Measurement Bandwidth* is 160 kHz for Between Bursts specifications of Table 100–6, except where called out as 4 MHz or 250 kHz.

The signal reference power for Between Bursts transmissions is the reported power as in 100.3.4.3.

The Transmitting Burst specifications apply during the transmission of Resource Blocks and for 20 µs before the first symbol of the OFDMA transmission and for 20 µs after the last symbol of an OFDMA transmission. The Between Bursts specifications apply except during transmission of Resource Blocks and for 20 µs before the first symbol of the OFDMA transmission and for 20 µs after the last symbol of an OFDMA transmission. The signal reference power for Transmitting Burst transmissions, other than inband, is the total transmit power measured and adjusted (if applicable) as described in this subclause.

For the purpose of spurious emissions definitions, a burst refers to a burst of Resource Blocks to be transmitted at the same time from the same CNU.

For PHY Discover Ranging spurious emissions requirements use Table 100–7, Table 100–8, and Table 100–9, with *100% Grant Spectrum* equal to the bandwidth of the *modulated spectrum* of the transmission.

The spurious emissions requirements over the entire upstream spectrum given in Table 100–7 for transmission of $N_{S\_Max}/10$ or fewer subcarriers may be relaxed by 2 dB in an amount of spectrum equal to the following equation:

$$\mathit{Measurement\ Bandwidth} \times \lceil (\mathit{100\%\ Grant\ Spectrum/10}\ )/\mathit{Measurement\ Bandwidth} \rceil$$

where the *Measurement Bandwidth* value is defined in Table 100–8 and Table 100–9.

The 2 dB relaxation applies in the *Measurement Bandwidth*. This relaxation does not apply to between bursts emission requirements. The relaxation is added to the spurious emissions power limits calculated for the *Measurement Bandwidths* of Table 100–8 and Table 100–9 for *Measurement Bandwidth* values comprising roughly 10% of the upstream spectrum when the granted spectrum is less than 10% of the *100% Grant Spectrum*.

Table 100–7—Spurious emissions

Parameter	Transmitting	Between bursts
Inband	–45 dBc OFDMA 100% grant [a, b] –51 dBc OFDMA 5% grant [a, b]	N/S
Adjacent band	See Table 100–9	N/S
Within the upstream operating range 5 MHz to 204 MHz (excluding modulated spectrum and adjacent spectrum)	See Table 100–8	5 MHz to 20 MHz: –69 dBc[c] 20 MHz to 204 MHz: –72 dBc[c]
CNU integrated spurious emissions limits (all in 4 MHz, includes discrete spurs)[d]		

Table 100–7—Spurious emissions *(continued)*

Parameter	Transmitting	Between bursts
204 MHz to 258 MHz	–50 dBc	–72 dBc
258 MHz to 1218 MHz	–45 dBmV	max(–45 dBmV, –40 dB reference downstream)[d]
CNU discrete spurious emissions limits[e]		
204 MHz to 258 MHz	–50 dBc	–36 dBmV
258 MHz to 1218 MHz	–50 dBmV	–50 dBmV

[a]Up to five subcarriers within the entire upstream bandwidth with discrete spurs may be excluded from the MER calculation if they fall within transmitted bursts. These five spurs are the same spurs that may be excluded for spurious emissions and not an additional or different set.
[b]Receive equalization is allowed if an MER test approach is used, to take ISI out of the measurement; measurements other than MER-based to find spurs or other unwanted power may be applied to this requirement.
[c]The signal reference power, 0 dBc, is the total transmit power defined in 100.3.4.4.1.
[d]"dB reference downstream" is relative to the received downstream signal level. Some spurious outputs are proportional to the receive signal level.
[e]These spec limits exclude a single discrete spur related to the tuned received channel; this single discrete spur is to be no greater than –40 dBmV.

100.3.4.4.2 Spurious emissions in the upstream frequency range

Table 100–8 lists the allowed spurious emissions for *Under-grant Hold Bandwidth* conditions. The initial measurement interval at which to start measuring the spurious emissions (from the transmitted burst's modulation edge) is 400 kHz from the edge of the transmission's modulation spectrum. Measurements should start at the initial distance and be repeated at increasing distance from the carrier until the upstream band edge or spectrum adjacent to other modulated spectrum is reached.

For OFDMA transmissions with non-zero transmit windowing, the CNU shall meet the required performance measured within the 2 MHz adjacent to the modulated spectrum using slicer values from a CLT burst receiver or equivalent, synchronized to the downstream transmission provided to the CNU.

In the remainder of the upstream spectrum, the CNU shall meet the required performance measured with a bandpass filter (e.g., an unsynchronized measurement).

For OFDMA transmissions with zero transmit windowing, CNU shall meet the required performance using synchronized measurements across the complete upstream spectrum.

The calculation for far out spurious emissions for specification in the interval values in Table 100–8 is shown in Equation (100–13).

$$\mathrm{Round}(\mathit{SpurFloor} + 10 \times \log_{10}(\mathit{Measurement\ Bandwidth}/\mathit{Under\text{-}grant\ Hold\ Bandwidth})) \quad (100\text{–}13)$$

The notation Round(x) as used in Equation (100–13), represents a rounding function that returns the value of its argument x rounded to the nearest 0.1.

The calculation for *SpurFloor* values in Table 100–8 and Table 100–9 is shown in Equation (100–14).

$$\mathit{SpurFloor} = \max\{-57 + 10 \times \log_{10}(\mathit{100\%\ Grant\ Spectrum}/192), -60\} \quad (100\text{–}14)$$

The calculation for *Under-grant Hold #Users* in Table 100–8 and Table 100–9 is shown in Equation (100–15).

$$Under\text{-}grant\ Hold\ \#Users = \lfloor 0.2 + 10^{((-44 - SpurFloor)/10)} \rfloor \quad (100\text{–}15)$$

Grant Spectrum is the spectrum of the grant (number of Resource Blocks multiplied by the bandwidth of a single Resource Block) allocated to a CNU in a given upstream RB Frame (see 101.4.4.3.1). *Grant Spectrum* may vary from one RB Frame to another. *100% Grant Spectrum* is the bandwidth of the entire upstream transmission resource, which occurs with probes, that incorporate all Resource Blocks and unused subcarriers (see 101.4.4.3.1).

Under-grant Hold Bandwidth in Table 100–8 and Table 100–9 is shown in Equation (100–16).

$$Under\text{-}grant\ Hold\ Bandwidth = 100\%\ Grant\ Spectrum/Under\text{-}grant\ Hold\ \#Users \quad (100\text{–}16)$$

For transmission bursts with modulation spectrum less than the *Under-grant Hold Bandwidth*, the spurious power requirement is calculated as in Equation (100–16), but increased by $10 \times \log_{10}$ (*Under-grant Hold Bandwidth*/*Grant Spectrum*).

Table 100–8—Spurious emissions requirements in the upstream frequency range for grants of Under-grant Hold Bandwidth and larger[a]

100% Grant Spectrum (MHz)	*SpurFloor* (dBc[b])	*Under-grant Hold #Users*	*Under-grant Hold Bandwidth* (MHz)	*Measurement Bandwidth* (MHz)[c]	Specification in the Interval (dBc[b])
Up to 64 [e.g., 22 MHz] (see note) [e.g., 46 MHz]	–60	40	100% Grant Spectrum/40 [0.55 MHz](see note) [1.15 MHz]	1.6	Eq (100–13) [–55.4](see note) [–58.6]
Greater than 64, up to 96 [e.g., 94 MHz]	–60	40	100% Grant Spectrum/40 [2.35 MHz]	3.2	Eq (100–13) [–58.7]
Greater than 96, up to 192 [e.g., 142 MHz] [e.g., 190 MHz]	Eq (100–14) [–58.3] [–57]	Eq (100–15) [27] [20]	Eq (100–16) [5.3] [9.5]	9.6	Eq (100–13) [–55.47 [–57]
Greater than 192 [e.g., 200 MHz]	Eq (100–14) [–56.8]	Eq (100–15) [19]	Eq (100–16) [10.5]	12.8	Eq (100–13) [–58.7]

NOTE—Each row of bracketed values represent a set of calculated examples. The value in the first column is an example value for 100% Grant Spectrum (MHz). The remaining columns are the result of the calculations for that column.

[a]Spurious emissions requirements in the upstream frequency range relative to the per channel transmitted burst power level for each channel for grants of *Under-grant Hold Bandwidth* and larger.
[b]The signal reference power, 0 dBc, is the total transmit power defined in 100.3.4.4.1.
[c]The *Measurement Bandwidth* is a contiguous sliding measurement window.

The CNU shall control transmissions such that (within the *Measurement Bandwidth* of Table 100–8) spurious emissions measured for individual subcarriers contain no more than +3 dB power larger than the required average power of the spurious emissions in the full *Measurement Bandwidth*. When non synchronous measurements are made, only 25 kHz *Measurement Bandwidth* is used.

100.3.4.4.3 Adjacent channel spurious emissions

Table 100–9 lists the required adjacent channel spurious emission levels when there is a transmitted burst with bandwidth at the *Under-grant Hold Bandwidth*. The measurement is performed in an adjacent channel interval of 400 kHz adjacent to the transmitted burst modulation spectrum. For OFDMA transmissions, the measurement is performed starting on an adjacent subcarrier of the transmitted spectrum (both above and below), using the slicer values from a CLT burst receiver or equivalent synchronized to the downstream transmission provided to the CNU.

Note that the *Measurement Bandwidth* for Table 100–9 is less than the *Measurement Bandwidth* values in Table 100–8. Thus comparing the two tables in terms of the specification "dBc" values requires appropriate scaling. Table 100–9 provides specification "dBc" only for grants of a specific amount for each row, while Table 100–8 provides "dBc" specification for grants of all sizes from the *Under-grant Hold Bandwidth* to 100%.

For transmission bursts with the *Grant Spectrum* less than the *Under-grant Hold Bandwidth*, the spurious power requirement is calculated as above, but increased by $10 \times \log_{10}$ (*Under-grant Hold Bandwidth*/*Grant Spectrum*).

For transmission bursts with modulation spectrum greater than the *Under-grant Hold Bandwidth*, the spurious power requirement in the adjacent 400 kHz is calculated by converting the requirement to absolute power "dBmV" for a grant of precisely *Under-grant Hold Bandwidth* from Table 100–9, and similarly computing the absolute power "dBmV" from Table 100–8 for a grant equal to the following:

Grant Spectrum – Under-grant Hold Bandwidth

Then the absolute power calculated from Table 100–8 is scaled back in exact proportion of 400 kHz compared to the *Measurement Bandwidth* in Table 100–8. Then the power from Table 100–9 is added to the scaled apportioned power from Table 100–8 to produce the requirement for the adjacent 400 kHz measurement with a larger grant than the *Under-grant Hold Bandwidth*. The requirement for adjacent spurious power in adjacent 400 kHz is as follows:

P1 (*Grant Spectrum-Under-grant Hold Bandwidth*) = absolute power derived from Table 100–8 dBmV

P2 (*Under-grant Hold Bandwidth*) = absolute power derived from Table 100–9 dBmV

$P1_{scaled} = P1 \times (0.4)/($*Measurement Bandwidth* used in Table 100–8) dBmV

$P_{spec\_limit} = P1_{scaled} + P2$ dBmV

Equation (100–17) is used in Table 100–9 for calculating the table column: "Specification in Adjacent 400 kHz with Grant of *Under-grant Hold Bandwidth* (dBc)."

$$\mathrm{Round}(10 \times \log_{10}((10^{(SpurFloor/10)} + (10^{(-57/10)})) \times (0.4/\mathit{Under\text{-}grant\ Hold\ Bandwidth}))) \quad (100\text{–}17)$$

The notation Round(x) as used in Equation (100–17), represents a rounding function that returns the value of its argument x rounded to the nearest 0.1.

Table 100–9—Adjacent channel spurious emissions requirements relative to the per channel transmitted burst power level for each channel

100% Grant Spectrum (MHz)	*SpurFloor* (dBc[a])	*Under-grant Hold #Users*	*Under-grant Hold Bandwidth* (MHz)	*Measurement Bandwidth* (MHz)	Specification in Adjacent 400 kHz with Grant of *Under-grant Hold Bandwidth* (dBc[a])
Up to 64 [e.g., 22 MHz][(see note)] [e.g,: 46 MHz]	–60	40	100% Grant Spectrum/40 [0.55 MHz][(see note)] [1.15 MHz]	0.4 MHz	Eq (100–17) [–56.6][(see note)] [–59.8]
Greater than 64, up to 96 [e.g., 94 MHz]	–60	40	100% Grant Spectrum/40 [2.35 MHz]	0.4 MHz	Eq (100–17) [–62.9]
Greater than 96 [e.g., 142 MHz] [e.g., 190 MHz] [e.g., 200 MHz]	Eq (100–14) Round nearest 0.1 dB [–58.3] [–57] [–56.8]	Eq (100–15) [27] [20] [19]	Eq (100–16) [5.3] [9.5] [10.5]	0.4 MHz	Eq (100–17) [–65.8] [–67.7] [–68.1]
NOTE—Each row of bracketed values represent a set of calculated examples. The value in the first column is an example value for 100% Grant Spectrum (MHz). The remaining columns are the result of the calculations for that column.					

[a]The signal reference power, 0 dBc, is the total transmit power defined in 100.3.4.4.1.

100.3.4.4.4 Spurious emissions during burst on/off transients

The CNU shall control spurious emissions prior to and during RF power amplifier turn on, during and following turn off, and before and after a burst. See 100.3.4.7.

The CNU's on/off spurious emissions, such as the change in voltage at the upstream transmitter output, due to enabling or disabling transmission, shall be no more than 50 mV.

The CNU's voltage step at the MDI (TP2, see 100.4) shall be dissipated no faster than 4 µs of constant slewing when the CNU is transmitting at +55 dBmV or more.

At transmit levels below +55 dBmV, the CNU's maximum change in voltage shall decrease by a factor of 2 for each 6 dB decrease of power level, from +55 dBmV down to a maximum change of 3.5 mV at 31 dBmV and below. The amplifier turn on and turn off transients of this subclause (100.3.4.4.4) are not applicable when the entire CNU is being powered on or off.

100.3.4.5 Transmit MER requirements

Transmit MER measures the cluster variance caused by the CNU during upstream transmission due to transmitter imperfections. The terms "equalized MER" and "unequalized MER" refer to a measurement with linear distortions equalized or not equalized, respectively, by the test equipment receive equalizer. The requirements in this subclause refer only to unequalized MER, as described for each requirement. MER is measured on each modulated data subcarrier and pilot (MER is computed based on the pilot power) in a Resource Block of a burst and averaged for all the subcarriers in each Resource Block. MER includes the effects of Inter-Carrier Interference, spurious emissions, phase noise, noise, distortion, and all other undesired transmitter degradations with an exception for a select number of discrete spurs impacting a select number of subcarriers. Compliance with MER requirements is verified with the use of a calibrated test instrument that synchronizes to the OFDMA signal, applies a receive equalizer in the test instrument that removes MER contributions from nominal channel imperfections related to the measurement equipment, and calculates the value. The equalizer in the test instrument is calculated, applied and frozen for the CNU testing. Receiver equalization of CNU linear distortion is not provided; hence this is considered to be a measurement of unequalized MER, even though the test equipment contains a fixed equalizer setting.

100.3.4.5.1 Definitions

The transmitted RF waveform at the F connector of the CNU (after appropriate down conversion) is filtered, converted to baseband, sampled, and processed using standard OFDMA receiver methods, with the exception that receiver equalization is not provided. The processed values are used in Equation (100–18) and Equation (100–19). No external noise (AWGN) is added to the signal.

The carrier frequency offset, carrier amplitude, carrier phase offset, and timing are adjusted during each burst to maximize MER as follows:

a) One carrier amplitude adjustment common for all subcarriers and OFDM symbols in burst.
b) One carrier frequency offset common for all subcarriers resulting in phase offset ramping across OFDM symbols in bursts.
c) One timing adjustment resulting in phase ramp across subcarriers.
d) One carrier phase offset common to all subcarriers per OFDM symbol in addition to the phase ramp.

MER per Resource Block (RB_{MER} in dB) is computed as shown in Equation (100–18).

$$RB_{MER} = 10 \times \log_{10}\left(\frac{E_{avg}}{\left(\frac{1}{RBlen}\left(\sum_{k=1}^{RBlen} \left|e_{j,k}\right|^2\right)\right)}\right) \quad (100–18)$$

where

E_{avg} is the average constellation energy for equally likely symbols
$RBlen$ is a value of 8 when *RBsize* is FALSE and a value of 16 when *RBsize* is TRUE
$e_{j,k}$ is the error vector from the *j*th subcarrier in the burst and *k*th received symbol to the ideal transmitted QAM symbol of the appropriate modulation order

MER per burst ($BURST_{MER}$ in dB) is computed as shown in Equation (100–19).

$$BURST_{MER} = \frac{1}{N}\sum_{j=1}^{N}(RB_{MER}j) \quad (100–19)$$

where

j is the *j*th subbcarrier in the burst
E_{avg} is the average constellation energy for equally likely symbols
N is the number of Resource Blocks in a burst

A sufficient number of OFDMA symbols should be included in the time average so that the measurement uncertainty from the number of symbols is less than other limitations of the test equipment.

MER with a 100% grant is defined as the condition when all OFDMA subcarriers are granted to the CNU.

MER with a 5% grant is defined as the condition when less than or equal to 5% of the available OFDMA subcarriers have been granted to the CNU.

100.3.4.5.2 Requirements

Unless otherwise stated, the CNU shall meet or exceed the following MER limits in Table 100–10 over the full transmit power range, all modulation orders, all grant configurations and over the full upstream frequency range.

The measurements indicated in Table 100–10 are made with flat channel (as nearly flat as practical in a laboratory test environment), after the pre-equalization coefficients have been set to their optimum values. The receiver uses best effort synchronization to optimize the MER measurement.

Table 100–10—Upstream MER requirements (with pre-equalization)

Parameter	Value	Units
MER (100% grant), each burst	≥ 44[a]	dB
MER (5% grant), each burst	≥ 50[a]	dB
Pre-equalizer constraints	Pre-equalization not used	

[a]Up to five subcarriers within the entire upstream bandwidth with discrete spurs may be excluded from the MER calculation if they fall within transmitted bursts. These five spurs are the same spurs that may be excluded for spurious emissions and not an additional or different set.

100.3.4.6 CNU Transmitter output requirements

The CNU shall output an RF Modulated signal with characteristics defined in Table 100–11.

Table 100–11—CNU RF output requirements

Parameter	Value	Units
Frequency band Equipment may be adapted to all or part of this frequency band to suit regional requirements. See 100.5.4.1.2.	7.4 to 204	MHz
OFDMA channel bandwidth	10 to 192	MHz
Subcarrier channel spacing	50	kHz
OFDM symbol rate FFT duration	20	µs
FFT size	4096	FFT bins
Maximum number of data subcarriers	3800	subcarriers
Total average transmit output power	up to 65	dBmV
Modulation format	See Table 100–2	

Table 100–11—CNU RF output requirements *(continued)*

Parameter	Value	Units
R_{on} max (see 100.3.4.7)	100	µs
R_{off} max (see 100.3.4.7)	100	µs
Output impedance	75	Ω
Output return loss 7.4 MHz to f_{max} MHz (42/65/85/117/204 MHz)	> 6	dB
MDI Connector	F connector per ISO/IEC 61169-24 or SCTE 02	

100.3.4.7 CNU RF power amplifier requirements

In EPoC, the upstream CNU PMD RF power amplifier (PA) may be turned off between bursts as shown in Figure 100–3. PMD_SIGNAL.request(ON) is asserted when the first bit of the burst is conveyed from the PCS to the PMA via PMA_UNITDATA.request() (see 101.4.2.1). The delay time through the EPoC PMA (T_{PMA}) is no less than the sum of the *RBframe* size multiplied by the OFDM symbol time *RBlen*(*RBsize)* of 8 times or 16 times 20 µs, see 100.3.4.1) plus the implementation specific processing time of the IDFT (nominal range 10 µs to 40 µs). For any given implementation and upstream profile configuration, T_{PMA} is fixed and the CNU is required to meet the PMD delay variance requirements in 100.2.2. The time to turn on and stabilize the PA for meeting burst transmission fidelity requirements (see 100.3.4.2) is represented by R_{on}. The time from PMD_SIGNAL.request(ON) to initiate PA turn on is implementation specific. PMD_SIGNAL.request(OFF) is asserted when the last bit of the burst is conveyed from the PCS to the PMA. PA turn off is initiated after the T_{PMA} delay and after the last OFDM symbol of the burst. The time for the PA to turn off is represented by R_{off}.

The RF transmission of burst energy begins at the beginning of the grant after R_{on}. The R_{on} time period of one CNU may overlap completely with the R_{off} time period of another CNU. Turning the PA off achieves two purposes: to meet the energy efficiency requirements of 100.6 and to minimize the cumulative impact on CLT receiver SNR by avoiding all CNU PAs powered on 100% of the time.

R_{on} and R_{off} times are not included in burst overhead calculations (see 103.3.5). T_{PMA} in either *RBsize* configuration is longer than R_{on} maximum (see Table 100–11) and does not impact adjusting grant lead time (see 103.3.5).

The CNU shall disable transmitter output when *PD_Enable* is equal to FALSE and continue in normal transmitter operation when *PD_Enable* is equal to TRUE. This requirement has precedence over the requirements in this subclause.

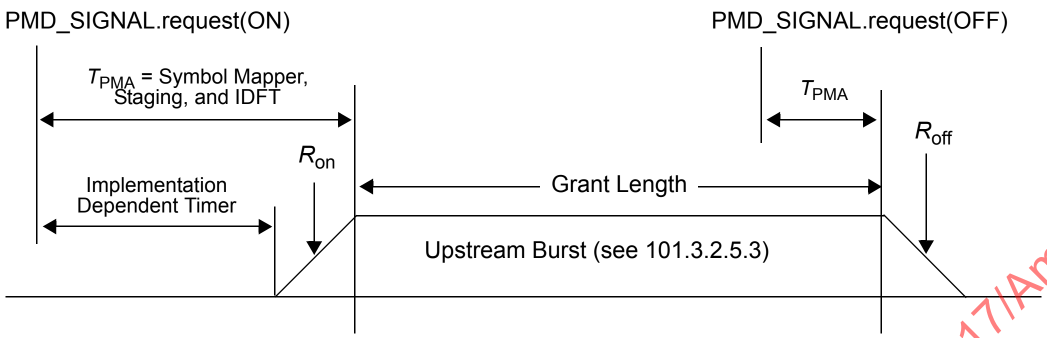


Figure 100–3—Details of RF power amplifier turn on and turn off timing

100.3.5 CLT receiver requirements

100.3.5.1 CLT receiver input power requirements

The CLT Upstream Demodulator shall operate with an average input signal level, including ingress and noise to the upstream demodulator, up to 31 dBmV. Operation above this level is not specified.

The CLT shall be configured according to Table 100–12 for intended received power normalized to 6.4 MHz of bandwidth.

When using the modulation formats and power set points shown, the CLT upstream demodulator shall operate within its defined performance specifications when received bursts are within the ranges specified in Table 100–12.

Table 100–12—Upstream OFDMA channel demodulator input power characteristics

Modulation	Minimum set point[a] (dBmV)	Maximum set point[a] (dBmV)	Range (dB)
QPSK	–4	10	–9 to +3
8-QAM	–4	10	–9 to +3
16-QAM	–4	10	–9 to +3
32-QAM	–4	10	–9 to +3
64-QAM	–4	10	–9 to +3
128-QAM	0	10	–9 to +3
256-QAM	0	10	–9 to +3
512-QAM	0	10	–3 to +3
1024-QAM	0	10	–3 to +3
2048-QAM	7	10	–3 to +3
4096-QAM	10	10	–3 to +3

[a]With respect to 6.4 MHz.

The CLT shall provide upstream power measurements with a standard deviation of 0.33 dB or better under the test conditions given in 100.4.3.

100.3.5.1.1 PHY Link managed variables

CLT_TargetReceivePower
TYPE: signed 10-bit integer
This variable specifies the CLT receive power, in units of 0.1 dBmV/6.4 MHz. The value is set according to the requirements in Table 100–12.

100.3.5.2 CLT receiver error performance in AWGN channel

This subclause describes the conditions at which the CLT PMD when connected to a compliant PMA and PCS is required to meet the error performance in an AWGN channel.

The CLT shall achieve a received frame loss ratio of less than or equal to 10^{-6} when all of the following input load and channel conditions are met:

- A single transmitter, pre-equalized and ranged.
- A single OFDMA 192 MHz channel, using all 3800 subcarriers.
- Ranging with same CNR and input level to CLT as with data bursts, and with 6-symbol probes.
- Any valid transmit combination (frequency, transmit window, cyclic prefix, upstream OFDMA Superframe length, Resource Block size pilot patterns, etc.) as defined in this specification.
- Input power level per constellation is the minimum set point as defined in Table 100–12.
- Received signal having a CNR greater than or equal to that shown in Table 100–13.
- OFDMA phase noise and frequency offset are at the max limits as defined for the CLT transmission specification.
- Ideal AWGN channel with no other artifacts (reflections, burst noise, tilt, etc.).
- Large bursts consisting of frames of any allowed sizes, including bursts consisting only of minimum size frames (4A.2.3.2.4) and bursts consisting only of maximum size frames (4A.2.4.2).

Table 100–13—CLT minimum CNR performance in AWGN channel

Modulation	CNR[a,b] (dB)	Set point[c] (dBmV)	Offset (dB)
QPSK	11	–4	0
8-QAM	14	–4	0
16-QAM	17	–4	0
32-QAM	20	–4	0
64-QAM	23	–4	0
128-QAM	26	0	0
256-QAM	29	0	0
512-QAM	32.5	0	0
1024-QAM	35.5	0	0

Table 100–13—CLT minimum CNR performance in AWGN channel *(continued)*

Modulation	CNR[a,b] (dB)	Set point[c] (dBmV)	Offset (dB)
2048-QAM	39	7	0
4096-QAM	43	10	0

[a]CNR is defined here as the ratio of average signal power in occupied spectrum to the average noise power in the occupied spectrum given by the noise power spectral density integrated over the same occupied spectrum.
[b]Channel CNR is adjusted to the required level by measuring the source inband noise including phase noise component and adding the required delta noise from an external AWGN generator.
[c] With respect to 6.4 MHz.

100.3.5.3 CLT upstream receive modulation error ratio requirements

This subclause provides measurements of the upstream receive modulation error ratio (RxMER) for each subcarrier. The CLT measures the RxMER using an upstream probe. For the purposes of RxMER measurement at the CLT, RxMER is defined as the ratio of the average power of the ideal BPSK constellation to the average error-vector power. The error vector is the difference between the equalized received probe value and the known correct probe value.

The CLT shall be capable of providing measurements of RxMER for all active subcarriers for any single specified CNU in the upstream OFDMA channel, using probe symbols. The CLT can use a sufficient number of upstream probe symbols for a reliable estimate of RxMER.

100.3.5.3.1 PHY Link managed variables

RxMER_ChID
TYPE: 3-bit integer
This variable is a pointer to one of the five possible OFDM channels in the EPoC network. When set in the CNU the values in *RxMER_SC(n)* reflect the measurements of OFDM channel number *RxMER_ChID* when *RxMER_Valid* goes TRUE. In the CNU this register may have a value of between 1 and 5 inclusive. In the CLT this variable is read only and will always have a value of one.

RxMER_CNU_ID
TYPE: unsigned 14-bit integer
This variable identifies for the CLT the CNU for which the CLT is to measure the upstream RxMER. When set in the CLT the values in *RxMER_SC(n)* reflect the measurements of the CNU whose *CNU_ID* matches *RxMER_CNU_ID* when *RxMER_Valid* goes TRUE. In the CNU this variable is read only and will always have a value of one.

RxMER_SC(n)
TYPE: array of 8-bit unsigned integer
This variable represents the measured receive modulation error ratio (RxMER) for subcarrier index *n* for an OFDM channel in increments of 0.25 dB with a value range from 0 dB (0x00) to 63.5 dB (0xFE). Subcarriers (such as exclusion bands) that cannot be measured indicate a value of 0xFF. The default (initial) value of RxMER is 0xFF for all subcarriers.

RxMER_Valid
TYPE: Boolean
When TRUE this variable indicates that the values *RxMER_SC(n)* for the CNU indicated by *RxMER_CNU_ID* for the OFDM channel indicated by *RxMER_ChID* are valid. When FALSE this variable indicates the some values in *RxMER_SC(n)* may be invalid.

100.3.6 CNU receiver requirements

100.3.6.1 Input signal characteristics at CNU receiver

The CNU shall meet electrical parameters and all performance specifications when receiving a signal conformant to the parameters shown in Table 100-14.

Table 100–14—Electrical input to CNU

Parameter	Value	Units
Total input power, 54 MHz to 1.794 GHz	< 40	dBmV
OFDM channel input level range (24 MHz min occupied spectrum) Note that level range does not imply anything about BER performance or capability vs. QAM. CNU BER performance is separately described.	–9 to +21	dBmV/24 MHz
Maximum average power per MHz input to the CNU from 54 MHz to 1.794 GHz For additional Demodulated Bandwidth, B_{demod} :[a] For additional Non-Demodulated Bandwidth, $B_{no\text{-}demod}$[b] and for up to 12 MHz of occupied spectrum (analog, out of band (OOB), QAM, OFDM): For all remaining spectrum:[c]	 $\leq$ Min [X – 10×log$_{10}$(24) + 10; 21 – 10×log$_{10}$(24)] $\leq$ Min [X – 10×log$_{10}$(24) + 10; 26 – 10×log$_{10}$(24)] $\leq$ Min [X – 10×log$_{10}$(24) + 10; 21 – 10×log$_{10}$(24)] where X = Average power of lowest power 24 MHz of modulated spectrum for demodulation	dBmV/MHz
Input impedance	75	Ω
Input return loss 258 MHz to 1218 MHz	> 6	dB

[a]Additional Demodulated Bandwidth represented by B_{demod} is any 1 MHz of spectrum defined by the downstream profile (see 101.4.2) for the CNU that is outside the 24 MHz of the downstream profile that has the lowest average power.
[b]Additional Non-Demodulated Bandwidth represented by $B_{no\text{-}demod}$ is any 1 MHz of spectrum outside the downstream profile (101.4.2) see for the CNU.
[c]Remaining bandwidth in 54 MHz to 1.794 GHz, excluding both the Additional Demodulated Bandwidth and the Additional Non-Demodulated Bandwidth.

100.3.6.2 CNU error performance in AWGN channel

This subclause describes the conditions at which the CNU PMD when connected to a compliant PMA and PCS is required to meet the error performance in an AWGN channel.

The CNU shall achieve a received frame loss ratio of less than or equal to 10^{-6} under the following input load and channel conditions:

— Any valid transmit combination (frequency, Subcarrier Clock frequency, transmit window, cyclic prefix, pilot, PHY Link, subcarrier exclusions, interleaving depth, modulation profile configuration, etc.) as defined in this standard.
— P_{6AVG} (the measured OFDM channel power divided by number of occupied 6 MHz channels) ≤ 15 dBmV.
— Up to fully loaded spectrum. Note that the frame loss ratio requirements are levied on all active OFDM channels. Those requirements are to be met with a single channel operating in isolation and up to and including all of the other OFDM channels being operated. This is what is meant by “Up to fully loaded spectrum”.
— Power in (both above and below) four adjacent 6 MHz channels ≤ P_{6AVG} + 3 dB.
— Power in any 6 MHz channel over the modulated spectrum ≤ P_{6AVG} + 6 dB.
— Peak envelope power in any analog channel over the modulated spectrum ≤ P_{6AVG} + 6 dB.
— Average power per channel across modulated spectrum ≤ P_{6AVG} + 3 dB.
— Received signal having a CNR greater than or equal to that shown in Table 100–15.
— OFDM channel phase noise as per Table 100–3 and Table 100–6.
— Large bursts consisting of frames of any allowed sizes, including bursts consisting only of minimum size frames (4A.2.3.2.4) and bursts consisting only of maximum size frames (4A.2.4.2).
— No other artifacts (reflections, burst noise, tilt, etc.).

Table 100–15—CNU minimum CNR performance in AWGN channel

Constellation	CNR[a] (dB) Up to 1 GHz	CNR[a] (dB) 1 GHz to 1.2 GHz	Min P_{6AVG} dBmV
4096	41	41.5	–6
2048	37	37.5	–9
1024	34	34	–12
512	30.5	30.5	–12
256	27	27	–15
128	24	24	–15
64	21	21	–15
16	15	15	–15

[a]CNR is defined here as total signal power in occupied spectrum divided by total noise in occupied spectrum. OFDM channel CNR is adjusted to the required level by measuring the source inband noise including phase noise component and adding the required delta noise from an external AWGN generator. Applicable to an OFDM channel with 192 MHz of occupied spectrum.

100.3.6.3 Receive modulation error ratio requirements

The CNU provides measurements of downstream receive modulation error ratio (RxMER) for all active subcarrier locations for each OFDM downstream channel, using pilots and PHY Link preamble symbols.

The CNU measures the RxMER using scattered pilots and PHY Link preamble symbols. Note that if a scattered pilot falls on top of a continuous pilot, it is still considered as a scattered pilot for these measurements. For the purposes of RxMER measurement at the CNU, RxMER is defined as the ratio of the average power of the ideal QAM constellation to the average error-vector power. The error vector is the difference between the equalized received pilot or preamble value and the known correct pilot value or preamble value. As a defining test case, for an ideal AWGN channel, an OFDM channel containing a mix of QAM constellations, with data-subcarrier CNR = 35 dB CNR on the QAM subcarriers, yielding an RxMER measurement of nominally 35 dB averaged over all subcarrier locations. If some subcarriers (such as exclusion bands) cannot be measured by the CNU, the CNU indicates that condition in the measurement data for those subcarriers as a value of 0xFF.

RxMER may be more clearly defined in mathematical notation in accordance with Figure 100–4, which shows an ideal transmit and receive model, with no intent to imply an implementation. Let p represent the pilot or PHY Link preamble symbol before transmit IDFT, H represents the channel coefficient for a given subcarrier frequency, n represents noise, and y is the unequalized received symbol after receive FFT:

$$y = (H \times p) + n$$

The receiver computes G as an estimate of H, and computes the equalized received symbol r as follows:

$$r = y / G$$

Using the known modulation value of the pilot or preamble symbol p, the receiver computes the equalized error vector e as follows:

$$e = r - p$$

All the above quantities are complex numbers for a given subcarrier. To compute RxMER, the receiver computes E as the time average of $|e|^2$ (squared absolute value) over many visits of the pilot to the given subcarrier (or PHY Link preamble symbol as applicable), and $E\_dB = 10 \times \log_{10}(E)$. Let S_dB be the average power of the ideal QAM data subcarrier constellation (not including pilots) expressed in dB. The CNU reports $RxMER\_dB = S\_dB - E\_dB$.

The CNU shall provide RxMER measurements with $RxMER\_std \leq 0.5$ dB under conditions specified in 100.4.2.

Define $delta\_RxMER$ = ($RxMER\_mean$ at CNR_data_subcarrier = 35 dB) – ($RxMER\_mean$ at CNR_data_-subcarrier = 30 dB). The CNU shall provide RxMER measurements such that 4 dB ≤ $delta\_RxMER$ ≤ 6 dB under the above specified condition.

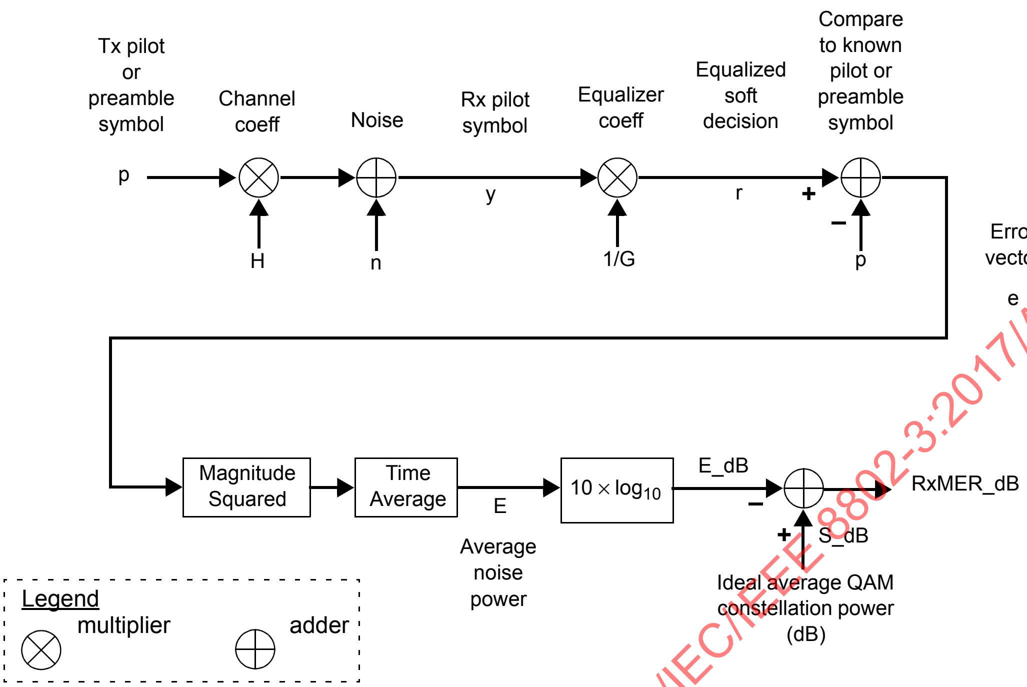


Figure 100–4—Computation of received modulation error ratio (RxMER) for a given subcarrier

100.3.7 Channel band rules

During OFDM and OFDMA channel planning, the following rules are to be observed to ensure proper operation of the CLT and CNU.

100.3.7.1 Downstream channel bandwidth rules

The encompassed spectrum of each 192 MHz downstream OFDM channel cannot exceed 190 MHz and does not exceed 3800 active subcarriers (see Table 100–3). The CLT uses the subcarriers in the range specified for IDFT Equation (101–25).

At least 1 MHz of exclusion band between the spectral edge any non-OFDM channel and the center frequency of the nearest OFDM subcarrier is required. This non-OFDM channel may be external to the OFDM channel or may be embedded within the OFDM channel.

100.3.7.2 Downstream exclusion band rules

The downstream exclusion band rules listed below apply to each OFDM channel and the composite downstream channel inclusive of OFDM and other signals using downstream spectrum concurrently with EPoC, e.g., video channels. The CLT and CNU are not expected to meet performance and fidelity requirements when the system configuration does not comply with the following downstream exclusion band rules:

- There has to be at least one contiguous modulated OFDM bandwidth of 22 MHz or greater.
- Exclusion bands may separate contiguous modulation bands.
- All contiguous modulation bands are to be 2 MHz or greater.

- The only exception to the above is for exclusion bands that are allowed to occupy 405.925 MHz to 406.176 MHz in alignment with FCC regulations as per CFR 76. Unique FCC egress requirements exist for these bands separate from the general exclusion bands requirements.
- Exclusion bands plus individually excluded subcarriers are limited to 20% or less of the encompassed spectrum of any individual OFDM channel and modulated spectrum is to be at least 80% of the encompassed spectrum of all active channels.
- The number of individually excluded subcarriers is limited by the following:
  - The total spectrum of individually excluded subcarriers cannot exceed 5% of any contiguous modulation spectrum.
  - The total spectrum of individually excluded subcarriers cannot exceed 5% of a 6 MHz moving window across the contiguous modulation spectrum.
  - The total spectrum of individually excluded subcarriers cannot exceed 20% of a 1 MHz moving window across the contiguous modulation spectrum.
- The 6 MHz of contiguous spectrum reserved for the PHY Link cannot have any exclusion bands or excluded subcarriers.

100.3.7.3 Upstream channel bandwidth rules

The encompassed spectrum of the upstream OFDMA channel cannot exceed 190 MHz and does not exceed 3800 active subcarriers (see Table 100–11). The CLT uses the subcarriers in the range specified for IDFT Equation (101–25).

100.3.7.4 Upstream exclusions and unused subcarriers rules

The CLT and CNU are not expected to meet performance and fidelity requirements when the system configuration does not comply with the following downstream exclusion band rules:

- Subcarriers that lie outside the Encompassed Spectrum are excluded.
- Upstream exclusion bands may include one or more subcarriers.
- There is no restriction on the number or placement of excluded and unused subcarriers between Resource Blocks (see 101.4.4.3.1).

100.4 Test requirements and measurement methods

All testing and measurement is performed in a coax cable distribution network that conforms to Annex 100A. The test point for the CLT is located at the MDI and labeled TP1 as shown in Figure 101–1 and Figure 101–4. The test point for the CNU is located at the MDI and labeled TP2 as shown in Figure 101–2 and Figure 101–3.

100.4.1 CLT RF output muting requirement

The specified limit of 73 dB below the operationally configured aggregate power (see *CLT_TxMute* below and Table 100–3) applies with all active OFDM channels commanded to the same transmit power level. Starting with all channels commanded to the same power level, then commanding a reduction in the transmit level of any, or all but one, of the active OFDM channels does not change the specified limit for measured muted power in 6 MHz. The output return loss at TP1/MDI of the muted device complies with the Output Return Loss requirements for inactive OFDM channels given in Table 100–3.

CLT_TxMute
TYPE: Boolean
When this variable is set to TRUE the CLT sets the RF output power = 73 dBc (see Table 100–3)

below the operationally configured aggregate power of the RF modulated signal, in every 6 MHz channel from 258 MHz to 1218 MHz. When set to FALSE the CLT is in it's normal operating state.

100.4.2 CNU receive modulation error ratio testing

Performance requirements for downstream RxMER measurements are defined under the following list of specified conditions:

- Channel loading consists of a single OFDM channel with no other signals.
- The OFDM channel being measured has a fixed configuration with a 192 MHz channel bandwidth with 190 MHz modulated spectrum and no excluded subcarriers other than at band edges.
- The channel is flat without impairments other than AWGN.
- AWGN level is set to two values giving data-subcarrier CNR = 30 dB and 35 dB at the MDI (F connector) of the CNU across all data subcarriers in the OFDM channel.
- Signal level is fixed at a nominal receive level of 6 dBmV per 6 MHz.
- A minimum warm-up time of 30 min occurs before measurements are made.
- Each measurement consists of the frequency average across all subcarriers of the reported time-averaged individual subcarrier RxMER values as defined above. Frequency averaging is performed by external computation.
- An ensemble of M frequency-averaged RxMER measurements (M large enough for reliable statistics, i.e., such that the result lies within a given confidence interval) are taken in succession (e.g., over a period of up to 10 min) at both CNR values. The mean, *RxMER_mean* in dB, and standard deviation, *RxMER_std* in dB, are computed over the M measurements at both CNR values. The statistical computations are performed directly on the dB values.

The CNU shall provide RxMER measurements with *RxMER_std* ≤ 0.5 dB under the specified conditions in the previous list.

Define *delta_RxMER* = (*RxMER_mean* at CNR_data_subcarrier = 35 dB) – (*RxMER_mean* at CNR_data_-subcarrier = 30 dB). The CNU shall provide RxMER measurements such that 4 dB ≤ *delta_RxMER* ≤ 6 dB under the above specified condition.

100.4.3 Upstream channel power

The purpose of the upstream OFDMA channel power metric is to provide an estimate of the total received power at the F connector input of the CLT (see "TP1 / MDI" Figure 101–4) for a single specified upstream CNU. The measurement is based on upstream probes. While digital power measurements are inherently accurate, the measurement referred to the analog input depends on available calibration accuracy.

NOTE—It is recommended that the CLT provide configurable averaging over a range at least including 1 to 32 probes.

The CLT provides upstream power measurements with a standard deviation of 0.33 dB or better under the following test conditions:

- Center frequency is fixed.
- Probe being measured has a fixed configuration containing at least 256 active subcarriers.
- Channel is without impairments other than AWGN at 25 dB CNR.
- Signal level is fixed at a value within ± 6 dB relative to a nominal receive level of 0 dBmV.
- A minimum warm up time of 5 min occurs before power measurements are made.
- Averaging is set to $N = 8$ probes per measurement.
- M measurements (M large enough for reliable statistics) are taken in succession (e.g,. over a period of up to 10 min). The standard deviation is computed over the M measurements, where each measurement is the average of N probes.

100.4.3.1 PHY Link managed variables

RxPwr

TYPE: 9-bit signed integer

This variable is used to report the received power for the CNU indicated by *RxPwr_CNU_ID* in units of 0.1 dBmV.

RxPwr_CNU_ID

TYPE: 14-bit integer

When set to a CNU_ID this variable indicates which CNU is to be measured for receive power reporting using *RxPwr*.

RxPwrValid

TYPE: Boolean

When TRUE this flag indicates that the value of *RxPwr* is valid for the CNU indicated by *RxPwr_CNU_ID*. Any write to *RxPwr_CNU_ID* sets this variable to FALSE.

100.4.4 Guidelines for verifying compliance with downstream phase noise requirements

The CLT transmitted signal for each OFDM channel shall meet the test phase noise requirements as per Table 100–16. These are transmitter requirements only.

Table 100–16—Downstream phase noise test requirements

Parameter	Value	Units
Phase noise, integrated double sided maximum, full power CW signal 1002 MHz or lower:		
1 kHz to 10 kHz	–48	dBc
10 kHz to 100 kHz	–56	dBc
100 kHz to 1 MHz	–60	dBc
1 MHz to 10 MHz	–54	dBc
10 MHz to 100 MHz	–60	dBc
Full power 192 MHz OFDM channel block with 6 MHz in center as internal exclusion subband + 0 dBc CW signal in center, with block not extending beyond 1002 MHz.		
1 kHz to 10 kHz	–48	dBc
10 kHz to 100 kHz	–56	dBc
Full power 192 MHz OFDM channel block with 24 MHz in center as internal exclusion subband + 0 dBc CW signal in center, with block not extending beyond 1002 MHz.		
100 kHz to 1 MHz	–60	dBc
Full power 192 MHz OFDM channel block with 30 MHz in center as internal exclusion subband + 7 dBc CW signal in center, with block not extending beyond 1002 MHz.		
1 MHz to 10 MHz	–53	dBc

A CW signal can be generated via an FFT, where the CW signal is constructed as a continuous pilot selected to be on a subcarrier in proper coordination with the cyclic prefix; so there are no phase glitches on the subcarrier in transitioning from one OFDM symbol to another. In this configuration the EPoC OFDM continuous pilot is in fact phase continuous in the time domain; in general the continuous pilots are not phase continuous in the time domain. Continuous pilot means that subcarrier is continuously used as a pilot and in general does not mean that the phase is continuous. Placing a continuous pilot using a subcarrier where the continuous pilot does in fact have continuous phase in the time domain serves as the CW signal in the phase noise tests and allow the full FFT processing associated with compliant OFDM transmissions to be engaged (compliant except for a single active subcarrier with large power in the middle of a large exclusion subband). This is the preference for verifying phase noise requirements.

If a continuous pilot is not used (as above), the OFDM channel has real data in the non-excluded subcarriers, FFT processing is occurring for those data subcarriers. The OFDM transmitter needs to generate a time continuous phase signal on the CW signal subcarrier that is synchronous with the data subcarriers RF and OFDM Clock. The OFDM test receiver need to be functionally equivalent to: 1) phase/noise test equipment that filters out data subcarriers and 2) a modified compliant receiver that validates the data subcarriers are operating properly. This latter step can be done non-real time.

100.4.4.1 Test mode 1

A CLT shall provide a test mode of operation, for out-of-service testing, configured for *N* channels but generating one CW signal per channel, one channel at a time at the center frequency of the selected channel; all other combined channels are suppressed. One purpose of this test mode is to support one method for testing the phase noise requirements of Table 100–4 and Table 100–16. As such, the CLT generation of a CW signal test tone should exercise the signal generation chain to the fullest extent practicable, in such a manner as to exhibit phase noise characteristics typical of actual operational performance; for example, repeated selection of a constellation symbol with power close to the constellation RMS level would seemingly exercise much of the modulation and up-conversion chain in a realistic manner. The CLT test mode shall be capable of generating the CW signal tone over the full range of Center Frequency in Table 100–16. In addition, the CLT shall be configurable in either one or both of the following conditions:

— Two CW signals on a single out-of-service downstream OFDM channel, at selectable valid subcarrier center frequencies 20 MHz to 100 MHz apart within the selected channel. All other subcarriers within the selected out-of-service downstream OFDM channel are suppressed.

— One CW signal on each of two separate but synchronized downstream OFDM channels at selectable valid subcarrier center frequencies 20 MHz to 100 MHz apart within the selected channels. All other subcarriers within the selected out-of-service downstream OFDM channel are suppressed.

The purpose of this test mode is to support the ability to measure the downstream OFDM Clock jitter requirements of Table 101–7, whereby the two CW signals are mixed to create a difference product CW signal at frequency ($f_2 - f_1$), for which the jitter is measure directly and compared to the requirements stated in that section.

100.4.4.2 Test mode 2

A CLT shall provide a test mode of operation, for out-of-service testing, generating one-CW-per-channel, at the center frequency of the selected channel, with all other N – 1 of the combined channels active and containing valid data modulation at operational power levels. One purpose for this test mode is to support one method for testing the phase noise requirements of Table 100–16. As such, the generation of the CW test tone should exercise the signal generation chain to the fullest extent practicable, in such manner as to exhibit phase noise characteristics typical of actual operational performance. For example, a repeated selection of a constellation symbol, with power close to the constellation RMS level, would seemingly exercise much of the modulation and up-conversion chain in a realistic manner. For this test mode, it is acceptable that all channels operate at the same average power, including each of the N – 1 channels in valid operation, and the single channel with a CW tone at its center frequency.

100.5 Environmental, safety, and labeling

100.5.1 General safety

All equipment subject to this clause shall conform to IEC 60950–1.

100.5.2 Installation

It is recommended that proper installation practices, as defined by applicable local codes and regulation, be followed in every instance in which such practices are applicable.

100.5.3 Environment

Normative specifications in this clause should be designed to be met by a system integrating 10GPASS-XR over the life of the product while the product operates within the manufacturer's range of environmental, power, and other specifications.

It is recommended that manufacturers indicate in the literature associated with the PHY the operating environmental conditions to facilitate selection, installation, and maintenance.

It is recommended that manufacturers indicate, in the literature associated with the components of the RF link, the distance and operating environmental conditions over which the specifications of this clause will be met.

100.5.4 PMD labeling

It is recommended that each PHY (and supporting documentation) be labeled in a manner visible to the user, with at least the applicable safety warnings and the applicable port type designation (e.g., 10GPASS-XR).

100.5.4.1 Frequency plan

Equipment conforming to this standard shall be clearly labeled with information about the supported downstream and upstream frequency ranges.

100.5.4.1.1 Downstream frequency plan

The CLT transmitter and CNU receiver are expected to support a frequency range from 258 MHz to 1218 MHz as defined in Table 100–3. Equipment may be adapted to all or part of this frequency band to suit regional requirements.

100.5.4.1.2 Upstream frequency plan

The CNU transmitter and CLT receiver are expected to support a frequency range from 7.4 MHz to 204 MHz as defined in Table 100–11. Equipment may be adapted to all or part of this frequency band to suit regional requirements.

100.6 EEE capability

For the 10GPASS-XR-U PHY the CNU shall enable Energy-Efficient Ethernet (EEE) capability to conserve energy by deactivating power-consuming PMD Functions (e.g., RF power amplifier) between bursts using PMD_SIGNAL.request (see 100.2.1.3).

100.7 Protocol implementation conformance statement (PICS) proforma for Clause 100, Physical Medium Dependent (PMD) sublayer and medium for coaxial cable distribution networks, type 10GPASS-XR[4]

The supplier of a protocol implementation that is claimed to conform to Clause 100, Physical Medium Dependent (PMD) sublayer and medium for passive optical networks type 10GPASS-XR shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

100.7.1 Identification

100.7.1.1 Implementation identification

Supplier[1]	
Contact point for inquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1,3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

100.7.1.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3bn-2016, Clause 100, Physical Medium Dependent (PMD) Sublayer for 10GPASS-XR
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3bn-2016.)	

Date of Statement	

[4]*Copyright release for PICS proformas*: Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

100.7.2 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
DC	Delay constraints	100.2.2	Device conforms to delay constraints	M	Yes [ ]
DMM	Downstream modulation rates	100.3.1	Provides mandatory rates specified in Table 100–2	M	Yes [ ]
CLTO1	Downstream modulation rate 8-QAM	100.3.1	Optional rate in Table 100–2	CLT:O	Yes [ ] No [ ] N/A [ ]
CNUO1	Downstream modulation rate 8-QAM	100.3.1	Optional rate in Table 100–2	CNU:O	Yes [ ] No [ ] N/A [ ]
CLTO2	Downstream modulation rate 16-QAM	100.3.1	Optional rate in Table 100–2	CLT:O	Yes [ ] No [ ] N/A [ ]
CNUO2	Downstream modulation rate 16-QAM	100.3.1	Optional rate in Table 100–2	CNU:O	Yes [ ] No [ ] N/A [ ]
CLTO3	Downstream modulation rate 32-QAM	100.3.1	Optional rate in Table 100–2	CLT:O	Yes [ ] No [ ] N/A [ ]
CNUO3	Downstream modulation rate 32-QAM	100.3.1	Optional rate in Table 100–2	CNU:O	Yes [ ] No [ ] N/A [ ]
CLTO4	Downstream modulation rate 8192-QAM	100.3.1	Optional rate in Table 100–2	CLT:O	Yes [ ] No [ ] N/A [ ]
CNUO4	Downstream modulation rate 8192-QAM	100.3.1	Optional rate in Table 100–2	CNU:O	Yes [ ] No [ ] N/A [ ]
CLTO5	Downstream modulation rate 16384-QAM	100.3.1	Optional rate in Table 100–2	CLT:O	Yes [ ] No [ ] N/A [ ]
CNUO5	Downstream modulation rate 16384-QAM	100.3.1	Optional rate in Table 100–2	CNU:O	Yes [ ] No [ ] N/A [ ]
UMM	Upstream modulation rates	100.3.1	Provides mandatory rates specified in Table 100–2	M	Yes [ ]
CLTO6	Upstream modulation rate 2048-QAM	100.3.1	Optional rate in Table 100–2	CLT:O	Yes [ ] No [ ] N/A [ ]
CNUO6	Uptream modulation rate 2048-QAM	100.3.1	Optional rate in Table 100–2	CNU:O	Yes [ ] No [ ] N/A [ ]

Item	Feature	Subclause	Value/Comment	Status	Support
CLTO7	Upstream modulation rate 4096-QAM	100.3.1	Optional rate in Table 100–2	CLT:O	Yes [ ] No [ ] N/A [ ]
CNUO7	Upstream modulation rate 4096-QAM	100.3.1	Optional rate in Table 100–2	CNU:O	Yes [ ] No [ ] N/A [ ]

100.7.3 PICS proforma tables for Physical Medium Dependent (PMD) sublayer for coax cable distribution networks, type 10GPASS-XR

100.7.3.1 PMD functional specifications

Item	Feature	Subclause	Value/Comment	Status	Support
FN1	Transmit function	100.2.3	Conveys I/Q value pairs from PMD service interface to MDI	M	Yes [ ]
FN2	Receive function	100.2.4	Conveys I/Q value pairs from MDI to PMD service interface	M	Yes [ ]
DSRU	Update DS_DataRate	100.3.2.1	Updates after configuration or pilot change	CLT:M	Yes [ ] No [ ]
USRU	Update DS_DataRate	100.3.2.2	Updates after profile or pilot change	CLT:M	Yes [ ] No [ ]
CLTRF	CLT modulated RF signal	100.3.3.2	Meets specifications in Table 100–3, Table 100–5, and Table 100–6	CLT:M	Yes [ ] No [ ]
CLTPN	CLT phase noise	100.3.3.3	Meets specifications as per Table 100–4	CLT:M	Yes [ ] No [ ]
CLTCP	CLT power per OFDM channel	100.3.3.4	Comply with all requirements in 100.3.3	CLT:M	Yes [ ] No [ ]
CLTSE1	CLT out-of-band spurious emissions below 600 MHz	100.3.3.5	Satisfy requirements of Table 100–6 below 600 MHz or when or when ratio of modulated to gap spectrum ≥ 4:1	CLT:M	Yes [ ] No [ ]
CLTSE2	CLT out-of-band spurious emissions of at least 600 MHz	100.3.3.5	Satisfy requirements of Table 100–6 of ≥ 6 MHz and with exclusion bands within OFDM channels of at least 8 MHz	CLT:M	Yes [ ] No [ ]
CLTSE3	CLT out-of-band spurious emissions with 1 dB relaxation	100.3.3.5	Satisfy requirements of Table 100–6 in measurements within gap spectrum < 600 MHz and within encompassed spectrum	CLT:M	Yes [ ] No [ ]
CLTSE4	CLT out-of-band spurious emissions with 3 dB relaxation	100.3.3.5	Satisfy requirements of Table 100–6 when ratio of modulated to gap spectrum is ≥ 4:1 from 603 MHz to 999 MHz	CLT:M	Yes [ ] No [ ]

Item	Feature	Subclause	Value/Comment	Status	Support
CLTSE5	CLT out-of-band spurious emissions with 5 dB relaxation	100.3.3.5	Satisfy requirements of Table 100–6 when ratio of modulated to gap spectrum is ≥ 4:1 from 999 MHz to 1209 MHz	CLT:M	Yes [ ] No [ ]
CLTSE6	CLT out-of-band spurious emissions with all cylic prefix and windowing roll-off period configurations	100.3.3.5	Satisfy requirements of Table 100–6 of a least 1 MHz for all combinations of *DSNcp* and *DSNrp* values	CLT:M	Yes [ ] No [ ]
CLTCF	CLT independent selection of center frequency	100.3.3.6	Meets ratio of number of active OFDM channels to gap spectrum in encompass spectrum of a least 2:1 as per 100.3.3.6	CLT:M	Yes [ ] No [ ]
CLTPD	CLT transmitter output	100.3.3.6	Disable transmitter output when *PD_Enable* is equal to FALSE and continue in normal transmitter operation when *PD_Enable* is equal to TRUE	CLT:M	Yes [ ] No [ ]
CLTPL	CLT power limit	100.3.4.2	Limit $P1.6_{Max}$ to no more than 53.2 dBmV+ (P_{Max} – 65) if the bandwidth of the modulated spectrum is ≤ 24 MHz	CLT:M	Yes [ ] No [ ]
CNULP	CNU initial power	100.3.4.2	Initiate PHY Discovery using lowest power as set by CLT using *PdRespInitPwr*	CNU:M	Yes [ ] No [ ]
CNUTP	CNU target power for each subcarrier	100.3.4.2	Meets Equation (100–9)	CNU:M	Yes [ ] No [ ]
CNURP	CNU reported power	100.3.4.3	CNU reports its transmit power using the variable *ReportedPwr* when requested by the CLT	CNU:M	Yes [ ] No [ ]
CNUSE1	CNU noise and spurious emissions RF PA turn on and off	100.3.4.4	Meets specifications in Table 100–7, Table 100–8, and Table 100–9 during RF power amplifier turn on and turn off	CNU:M	Yes [ ] No [ ]
CNUSE2	CNU noise and spurious emissions change in voltage	100.3.4.4	No more then 50 mV due to enabling or disabling transmission	CNU:M	Yes [ ] No [ ]
CNUSE3	CNU voltage step	100.3.4.4	No faster than 4 µs when transmitting ≥ +55 dBmV	CNU:M	Yes [ ] No [ ]
CNUSE4	CNU maximum change in voltage	100.3.4.4	Decrease by a factor of 2 for each 6 dB decrease from +55 dBmV to a maximum change of 3.5 mV ≤ 31 dBmV	CNU:M	Yes [ ] No [ ]
CNUTM	CNU transmit MER	100.3.4.5	Meets requirements in Table 100–10	CNU:M	Yes [ ] No [ ]
CNURF	CNU modulated RF signal	100.3.4.6	Meets specifications in Table 100–11	CNU:M	Yes [ ] No [ ]

Item	Feature	Subclause	Value/Comment	Status	Support
CNUPD	CNU transmitter output	100.3.4.7	Disable transmitter output when *PD_Enable* is equal to FALSE and continue in normal transmitter operation when *PD_Enable* is equal to TRUE	CNU:M	Yes [ ] No [ ]
CLTRX1	CLT receiver input signal level	100.3.5.1	Operate with an average up to 31 dBmV	CLT:M	Yes [ ] No [ ]
CLTRX2	CLT receiver configuration	100.3.5.1	As per Table 100–12 for intended received power normalized to 6.4 MHz of bandwidth	CLT:M	Yes [ ] No [ ]
CLTRPW	CLT power measurements	100.3.5.1	Provide upstream power measurements with a standard deviation of 0.33 dB or better conditions given in 100.4.3	CNU:M	Yes [ ] No [ ]
CLTEP	CLT receiver error performance	100.3.5.2	Meets specifications in Table 100–13	CLT:M	Yes [ ] No [ ]
CLTRM1	CLT receiver MER all active subcarriers	100.3.5.3	Measurements of receive MER for all active subcarriers	CLT:M	Yes [ ] No [ ]
CNUSR	CNU signal reception	100.3.6.1	Meets specifications in Table 100–14	CNU:M	Yes [ ] No [ ]
CNUER	CNU receive post-FEC error ratio	100.3.6.2	$\leq 10^{-6}$ frame loss ratio when meeting specifications in 100.3.6.2 and Table 100–15	CNU:M	Yes [ ] No [ ]
CNURM2	CNU receive MER	100.3.6.3	Receive MER_std $\leq$ 0.5 dB and delta receiver $\leq$ 4 dB and $\geq$ 6 dB when operating conditions specified in 100.4.2	CNU:M	Yes [ ] No [ ]
EE	Energy savings	100.6	Turn off RF power amplifier between bursts	CNU:M	Yes [ ] No [ ]

100.7.3.2 Definition of parameters and measurement methods

Item	Feature	Subclause	Value/Comment	Status	Support
TST1	CLT transmitter mute	100.4.1	Support *CLT_TxMute* as per 100.4.1	CLT:M	Yes [ ] No [ ]
TST2	CLT transmitter phase noise tests	100.4.4	Meet specifications in Table 100–16	CLT:M	Yes [ ] No [ ]
TST3	CLT test mode 1	100.4.4.1	Provide a test mode as per 100.4.4.1	CLT:M	Yes [ ] No [ ]
TST3	CLT test mode 2	100.4.4.2	Provide a test mode as per 100.4.4.2	CLT:M	Yes [ ] No [ ]

100.7.3.3 Environmental specifications

Item	Feature	Subclause	Value/Comment	Status	Support
ES1	General safety	100.5.1	Conforms to IEC 60950–1	M	Yes [ ]
ES2	Installation	100.5.2	Meets applicable local codes and regulation	M	Yes [ ]
ES3	Documentation	100.5.3	Explicitly defines requirements and usage restrictions to meet environment and safety certifications	M	Yes [ ] No [ ]
ES4	Labeling	100.5.4.1	Frequency plan labeled in a manner visible to the user	M	Yes [ ] No [ ]

101. Reconciliation Sublayer, Physical Coding Sublayer, and Physical Media Attachment for EPoC

101.1 Overview

This clause describes the Reconciliation Sublayer (RS), Physical Coding Sublayer (PCS) with FEC, and Physical Medium Attachment (PMA) used with 10GPASS-XR point-to-multipoint (P2MP) networks. These are multipoint coaxial cable distribution networks (CCDN) that connect multiple DTEs using a single shared coaxial link. The architecture is asymmetric, based on a tree and branch topology utilizing coaxial taps and splitters. This type of network requires that the Multipoint MAC Control sublayer exists above MAC instances, as described in Clause 103.

101.1.1 Conventions

The notation used in the state diagrams in this clause follows the conventions in 21.5. Should there be a discrepancy between a state diagram and descriptive text, the state diagram prevails. The notation "++" after a counter indicates it is to be incremented by 1. The notation "––" after a counter indicates it is to be decremented by 1. Code examples given in this clause adhere to the style of the "C" programming language.

For equations used in this clause the symbol $\lceil x \rceil$ represents a ceiling function that rounds up its argument x to the next highest integer. The notation $\lfloor x \rfloor$ represents a *floor* function, which returns the value of its argument x rounded down to the nearest integer.

101.1.2 Constraints for delay through RS, PCS, and PMA

The operation of EPoC Multipoint Control Protocol (MPCP), as defined in Clause 103, relies on strict timing based on the distribution of timestamps. The actual delay is implementation-dependent but an implementation shall maintain a combined delay variation through RS, PCS, and PMA sublayers of no more than 1 time_quantum (see 64.2.2.1) so as not to interfere with the MPCP timing and operation.

101.1.3 Mapping of PCS, and PMA variables

The optional MDIO capability described in Clause 45 defines several variables that may provide control and status information for and about the 10GPASS-XR PHY or are communicated between the CLT and the CNU via the PHY Link. The mapping of MDIO control and status variables to PCS/PMA variables is shown in Table 101–1. The least significant bit in each variable is mapped to the lowest numbered bit in the lowest numbered register for Clause 45 registers. These variables are used by the PHY Link for PHY management.

101.1.4 Functional blocks supporting 10GPASS-XR PCS, PMA, and PMD sublayers

Figure 101–1 and Figure 101–4 illustrate functional blocks within the CLT PCS, PMA, and PMD sublayers, and interactions between them in the transmit direction and in the receive direction, respectively. Figure 101–2 and Figure 101–3 illustrate functional blocks within the CNU PCS, PMA, and PMD sublayers, and interactions between them in the transmit direction and in the receive direction, respectively. Clause 100 focuses on functions of the PMD sublayer, Clause 101 focuses on PCS and PMA, and Clause 102 focuses on PHY Link.

Table 101–1—MDIO register to PHY variable mapping

MDIO parameter name	MDIO register name	Register/bit number	PHY variable		
			Name	Index	Bits(s)
CRC40 errored blocks	10GPASS-XR control and status	1900.2	*CRC40ErrCtrl*	0	2
Continuous pilot scaling factor	10GPASS-XR control and status	1.1900.9:3	*CntPltSF*	0	9:3
Time sync capable	10GPASS-XR control and status	1.1900.13	*TimeSyncCapable*	0	13
DS cyclic prefix	DS OFDM control	1.1901.3:0	*DSNcp*	1	3:0
DS windowing	DS OFDM control	1.1901.6:4	*DSNrp*	1	6:4
DS time interleaving	DS OFDM control	1.1901.11:7	*DS_TmIntrlv*	1	11:7
DS OFDM channels	DS OFDM control	1.1901.14:12	*DS_ChCnt*	1	14:12
DS OFDM freq ch 1	DS OFDM channel frequency control 1	1.1902.15:0	*DS_FreqCh(1)*	2	15:0
DS OFDM freq ch 2	DS OFDM channel frequency control 2	1.1903.15:0	*DS_FreqCh(2)*	3	15:0
DS OFDM freq ch 3	DS OFDM channel frequency control 3	1.1904.15:0	*DS_FreqCh(3)*	4	15:0
DS OFDM freq ch 4	DS OFDM channel frequency control 4	1.1905.15:0	*DS_FreqCh(4)*	5	15:0
DS OFDM freq ch 5	DS OFDM channel frequency control 5	1.1906.15:0	*DS_FreqCh(5)*	6	15:0
Resource Block size	US OFDM control	1.1907.7	*RBsize*	7	7
US windowing	US OFDM control	1.1907.6:4	*USNrp*	7	6:4
US cyclic prefix	US OFDM control	1.1907.3:0	*USNcp*	7	3:0
Type 2 repeat	US OFDMA pilot pattern	1.1909.14:12	*Type2_Repeat*	9	14:12
Type 2 start	US OFDMA pilot pattern	1.1909.11:8	*Type2_Start*	9	11:8
Type 1 repeat	US OFDMA pilot pattern	1.1909.6:4	*Type1_Repeat*	9	6:4
Type 1 start	US OFDMA pilot pattern	1.1909.3:0	*Type1_Start*	9	3:0
DS PHY data rate lower	DS PHY data rate	1.1927.15:3	*DS_DataRate(15:3)*	27	15:3
DS PHY data rate fractional	DS PHY data rate	1.1927.2:0	*DS_DataRate(2:0)*	27	2:0
DS PHY data rate mid	DS PHY data rate	1.1928.15:0	*DS_DataRate(31:16)*	28	15:0
DS PHY data rate upper	DS PHY data rate	1.1929.4:0	*DS_DataRate(36:32)*	29	4:0
US PHY data rate lower	US PHY data rate	1.19230.15:3	*US_DataRate(15:3)*	30	15:3
US PHY data rate fractional	US PHY data rate	1.1930.2:0	*US_DataRate(2:0)*	30	2:0

Table 101–1—MDIO register to PHY variable mapping *(continued)*

MDIO parameter name	MDIO register name	Register/bit number	PHY variable		
			Name	Index	Bits(s)
US PHY data rate mid	US PHY data rate	1.1931.15:0	*US_DataRate(31:16)*	31	15:0
US PHY data rate upper	US PHY data rate	1.1932.4:0	*US_DataRate(36:32)*	32	4:0
FEC codeword counter lower	10GPASS-XR FEC codeword counter	1.1933.15:0	*FecCodeWordCount (15:0)*	33	15:0
FEC codeword counter upper	10GPASS-XR FEC codeword counter	1.1934.15:0	*FecCodeWordCount (31:16)*	34	15:0
FEC codeword success counter lower	10GPASS-XR FEC codeword success counter	1.1935.15:0	*FecCodeWordSuccess (15:0)*	35	15:0
FEC codeword success counter upper	10GPASS-XR FEC codeword success counter	1.1936.15:0	*FecCodeWordSuccess (31:16)*	36	15:0
FEC codeword fail counter lower	10GPASS-XR FEC codeword fail counter	1.1937.15:0	*FecCodeWordFail (15:0)*	37	15:0
FEC codeword fail counter upper	10GPASS-XR FEC codeword fail counter	1.1938.15:0	*FecCodeWordFail (31:16)*	38	15:0
US modulation ability	10GPASS-XR modulation ability	1.1948.9:8	*US_ModAbility*	48	9:8
DS OFDM channel ability	10GPASS-XR modulation ability	1.1948.7:5	*DS_OFDM_ChAbility*	48	7:5
DS modulation ability	10GPASS-XR modulation ability	1.1948.4:0	*DS_ModAbility*	48	4
DS OFDM channel ID	DS OFDM channel ID register	12.0.2:0	*DS_OFDM_ID*	1000	2:0
DS Modulation type SC7	10GPASS-XR DS profile descriptor control 1	12.1.15:12	*DS_ModTypeSC(7)*	1001	15:12
DS Modulation type SC6	10GPASS-XR DS profile descriptor control 1	12.1.11:8	*DS_ModTypeSC(6)*	1001	11:8
DS Modulation type SC5	10GPASS-XR DS profile descriptor control 1	12.1.7:4	*DS_ModTypeSC(5)*	1001	7:4
DS Modulation type SC4	10GPASS-XR DS profile descriptor control 1	12.1.3:0	*DS_ModTypeSC(4)*	1001	3:0
DS Modulation type SC8 through DS Modulation type SC4095	10GPASS-XR DS profile descriptor control 2 through 10GPASS-XR DS profile descriptor control 1023	12.2 through 12.1023	*DS_ModTypeSC(8)* through *DS_ModTypeSC(4095)*	1002 through 2023	as in index 1001
US Modulation type SC3	10GPASS-XR US profile descriptor control 0	12.1024.15:12	*US_ModTypeSC(3)*	2024	15:12
US Modulation type SC2	10GPASS-XR US profile descriptor control 0	12.1024.11:8	*US_ModTypeSC(2)*	2024	11:8

Table 101–1—MDIO register to PHY variable mapping *(continued)*

MDIO parameter name	MDIO register name	Register/bit number	PHY variable		
			Name	Index	Bits(s)
US Modulation type SC1	10GPASS-XR US profile descriptor control 0	12.1024.7:4	*US_ModTypeSC(1)*	2024	7:4
US Modulation type SC0	10GPASS-XR US profile descriptor control 0	12.1024.3:0	*US_ModTypeSC(0)*	2024	3:0
US Modulation type SC4 through US Modulation type SC4095	10GPASS-XR US profile descriptor control 1 through 10GPASS-XR US profile descriptor control 1023	12.1025 through 12.2047	*US_ModTypeSC(4)* through *US_ModTypeSC(4095)*	2025 through 3047	as in index 1024
Real pre-equalizer coefficient SC0	10GPASS-XR US pre-equalizer coefficients 0	12.2048.15:0	*EQ_CoefR(0)*	3048	15:0
Imaginary pre-equalizer coefficient SC0	10GPASS-XR US pre-equalizer coefficients 0	12.2049.15:0	*EQ_CoefI(0)*	3049	15:0
Real pre-equalizer coefficient SC1 through Real pre-equalizer coefficient SC4095	10GPASS-XR US pre-equalizer coefficients 1 through 10GPASS-XR US pre-equalizer coefficients 4095	12.2050 12.2052 ... 12.10238	*EQ_CoefR(1)* through *EQ_CoefR(4095)*	3050 3052 ... 11238	15:0
Imaginary pre-equalizer coefficient SC1 through Imaginary pre-equalizer coefficient SC4095	10GPASS-XR US pre-equalizer coefficients 1 through 10GPASS-XR US pre-equalizer coefficients 4095	12.2051 12.2053 ... 12.10239	*EQ_CoefI(1)* through *EQ_CoefI(4095)*	3051 3053 ... 11239	15:0

Clause 103 defines Multipoint MAC Control Protocol (MPCP) for operation in EPoC, extending Clause 77 model as necessary.

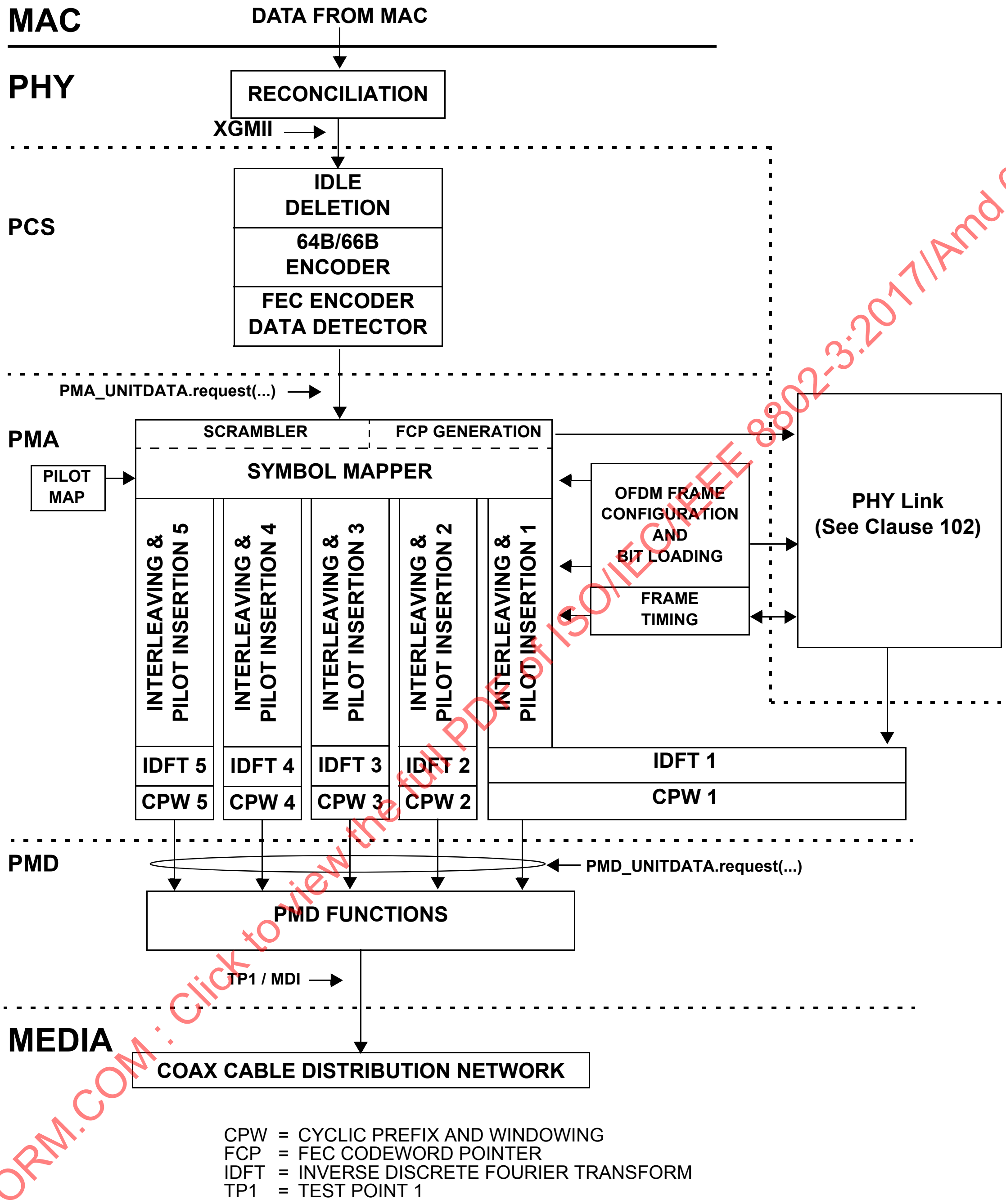
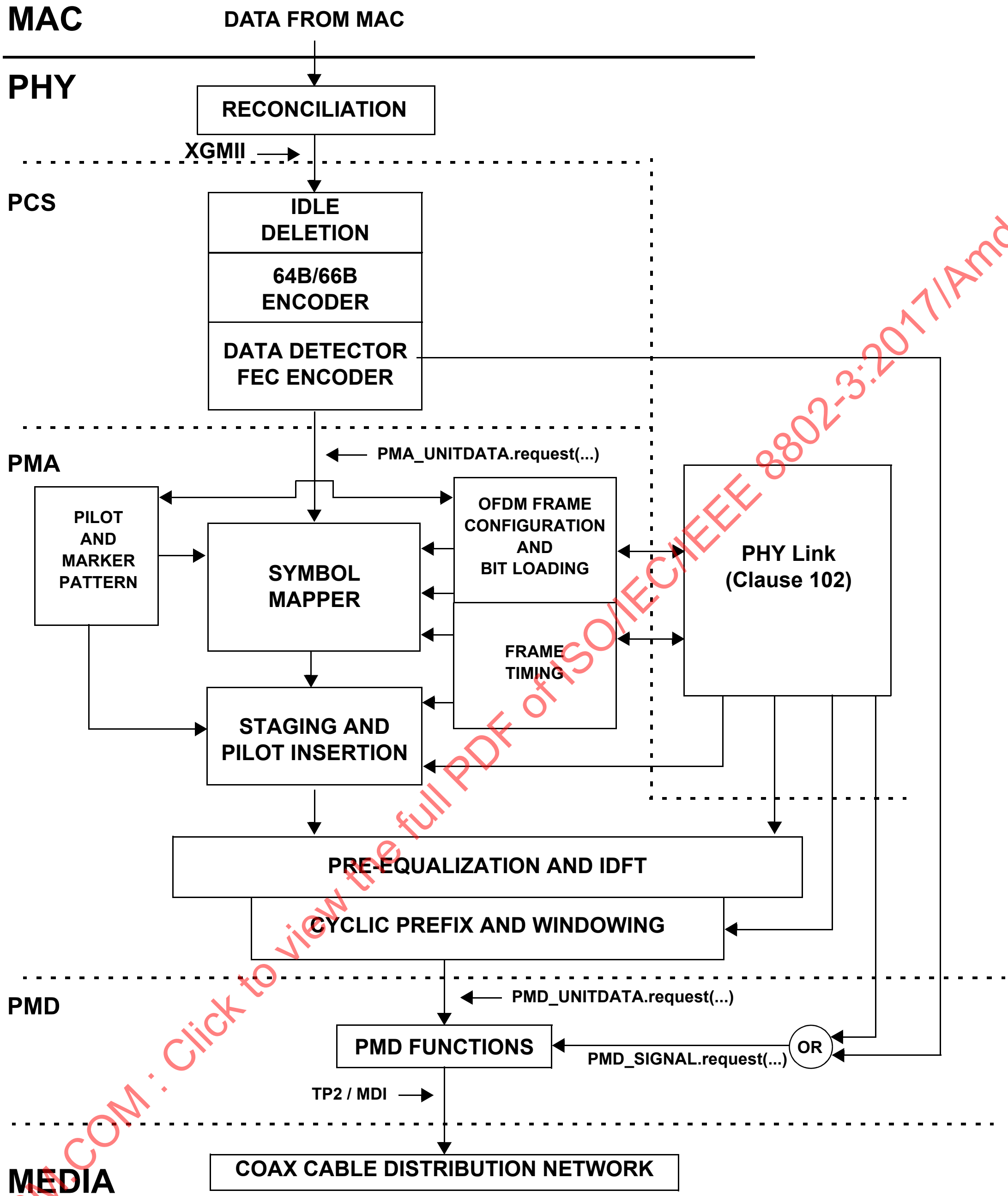
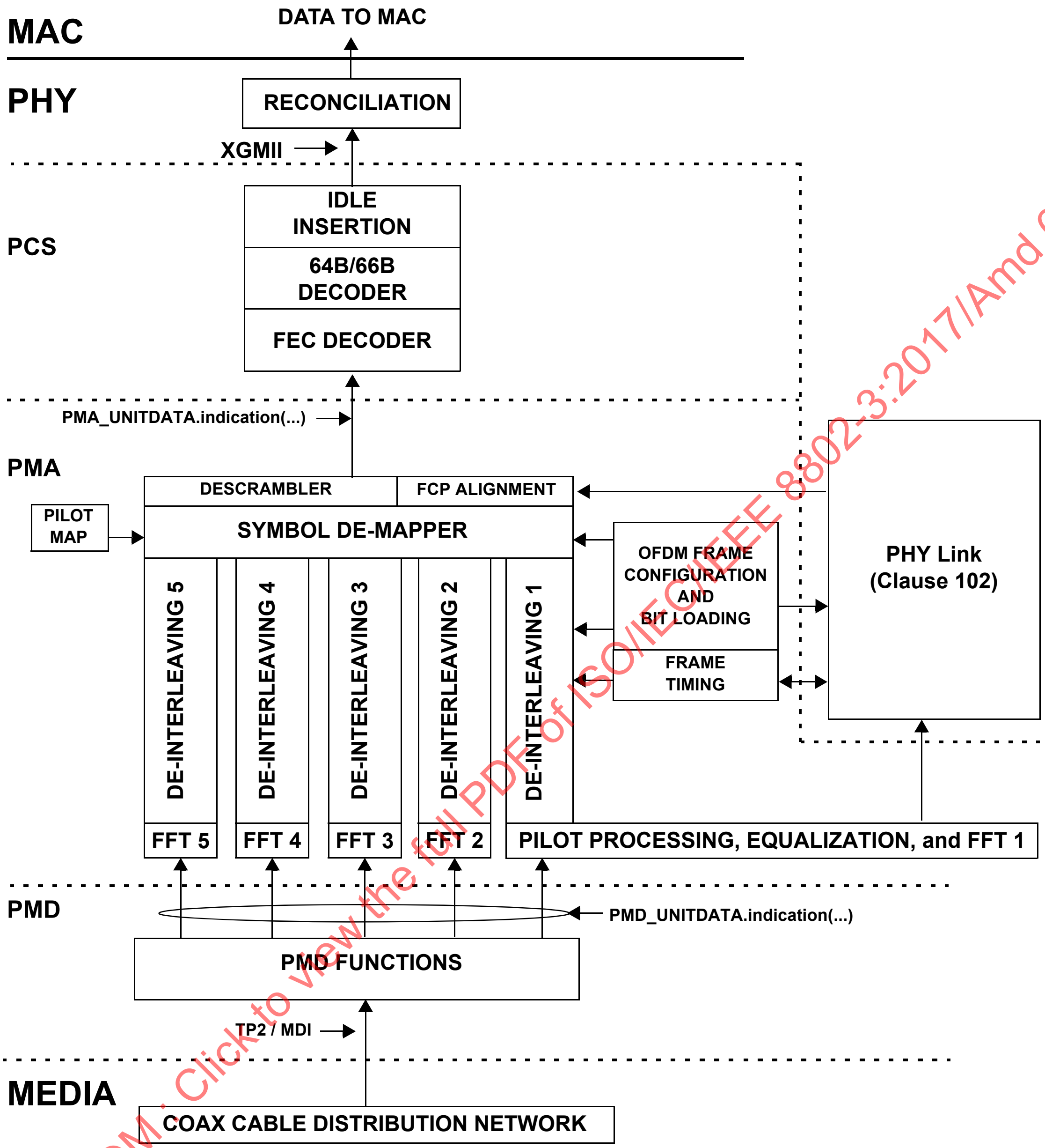


Figure 101–1—Functional blocks within 10GPASS-XR-D CLT PCS, PMA, and PMD sublayers, transmit direction



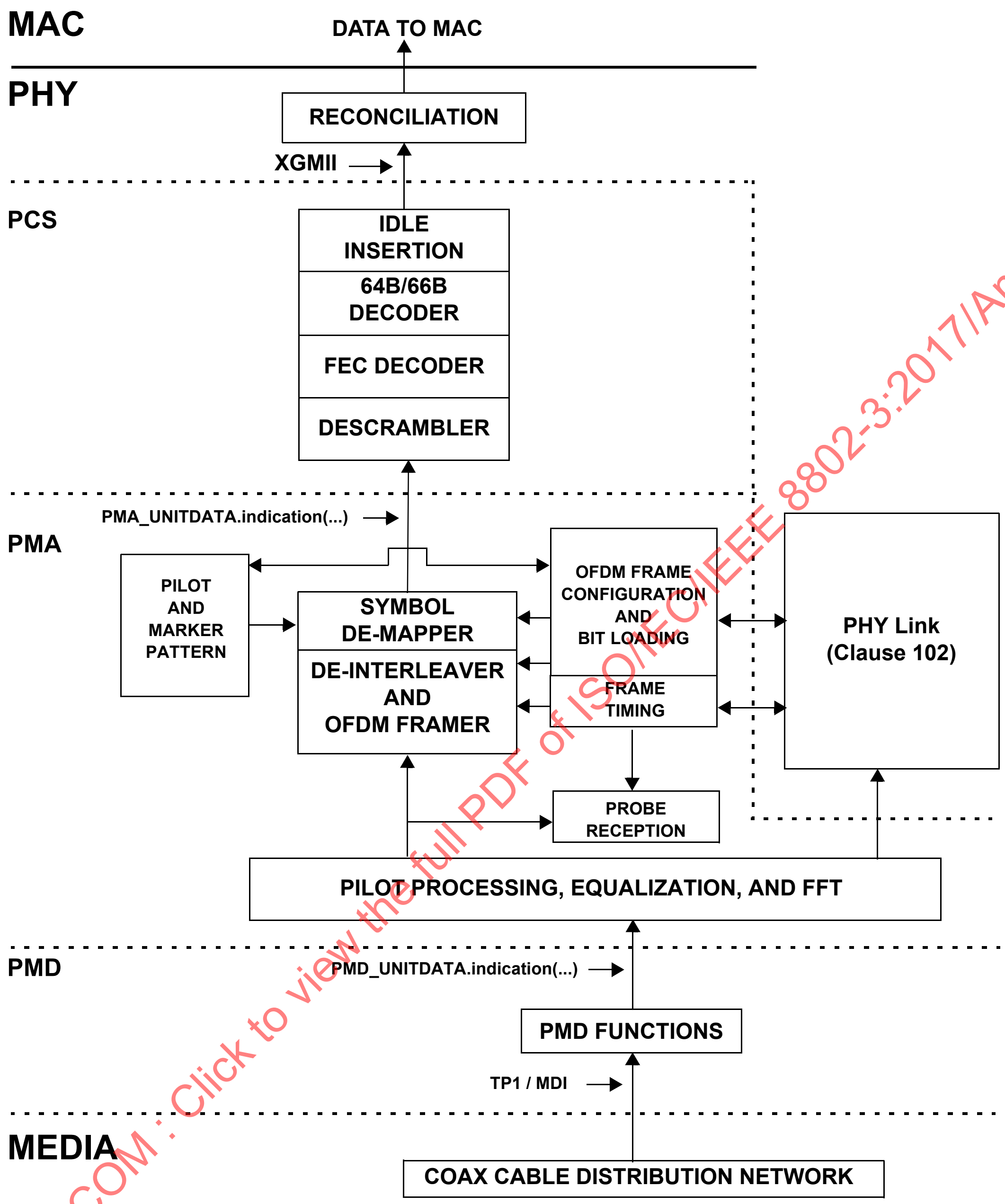
IDFT = INVERSE DISCRETE FOURIER TRANSFORM
TP2 = TEST POINT 2

Figure 101–2—Functional blocks within 10GPASS-XR-U CNU PCS, PMA, and PMD sublayers, transmit direction



FCP = FEC CODEWORD POINTER
FFT = FAST FOURIER TRANSFORM
TP2 = TEST POINT 2

Figure 101–3—Functional blocks within 10GPASS-XR-D CNU PCS, PMA, and PMD sublayers, receive direction



FFT = FAST FOURIER TRANSFORM
TP1 = TEST POINT 1

Figure 101–4—Functional blocks within 10GPASS-XR-U CLT PCS, PMA, and PMD sublayers, receive direction

101.2 Reconciliation Sublayer (RS) for EPoC

The Reconciliation sublayer used for 10GPASS-XR is identical to that described in 76.2.

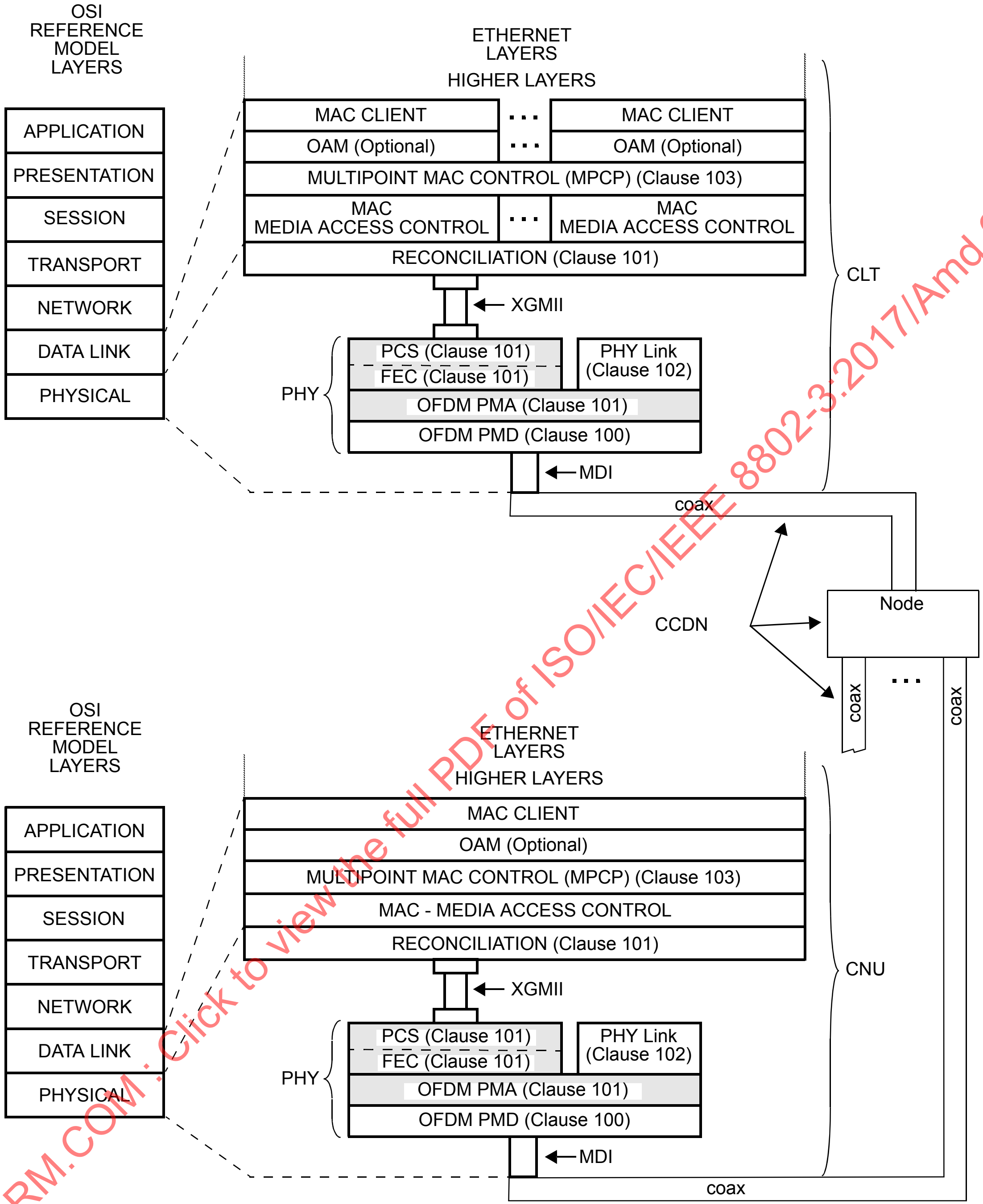
101.3 Physical Coding Sublayer (PCS) for EPoC

101.3.1 Overview

This subclause defines the Physical Coding Sublayer (PCS) for 10GPASS-XR, supporting operation over the point-to-multipoint coaxial cable distribution network. The EPoC PCS is specified to support the operation of up to 10 Gb/s in the downstream direction and up to 1.6 Gb/s in the upstream direction, where the upstream and downstream data rates are configured independently.

This subclause also specifies a forward error correction (FEC) as well as Idle control character insertion and deletion mechanisms. The FEC mechanism increases the available link budget. The FEC codeword additionally includes a CRC40 to ensure that mean time to false frame acceptance of 4.4×10^{17} seconds is met. The Idle control character insertion and deletion mechanisms accommodates rate adaptation between the MAC and MAC Control Clients operating at 10 Gb/s and the EPoC PCS and PMD sublayers operating at data rates below 10 Gb/s.

Figure 101–5 shows the relationship between the EPoC PCS sublayer and the ISO/IEC OSI reference model. Figure 101–1 illustrates the CLT transmitter functional block diagram, including the PCS, while Figure 101–2 illustrates the CNU transmitter functional block diagram. Figure 101–3 and Figure 101–4 illustrate the functional block diagram of the receive path in the CLT PCS and CNU PCS, respectively.



XGMII= 10 GIGABIT MEDIA INDEPENDENT INTERFACE
MDI = MEDIUM DEPENDENT INTERFACE
OAM = OPERATIONS, ADMINISTRATION & MAINTENANCE
CCDN= COAX CABLE DISTRIBUTION NETWORK
CLT = COAXIAL LINE TERMINAL

CNU = COAXIAL NETWORK UNIT
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

Figure 101–5—Relationship of EPoC PCS and PMA to the ISO/IEC OSI reference model and the IEEE 802.3 Ethernet LAN model

101.3.2 PCS transmit function

In the CLT, the PCS transmit function operates in a continuous fashion at the data rate of up to 10 Gb/s. In the CNU, the PCS transmit function operates in a burst mode at the data rate of up to 1.6 Gb/s. Figure 101–1 illustrates the CLT transmitter functional block diagram, while Figure 101–2 illustrates the CNU transmitter functional block diagram.

In the transmit direction, the EPoC PCS includes an Idle Deletion function that performs data rate adaptation and FEC overhead compensation, followed by a 64B/66B Encoder, and a FEC Encoder/Data Detector.

101.3.2.1 Idle deletion process

In the transmitting PCS, the Idle deletion process is responsible for deleting excess Idle control characters inserted between individual frames to adjust the data rate enforced by the MAC Control (as defined in Clause 103) to the effective data rate supported by the PCS and PMD. The gaps created within the data stream by the operation of the Idle deletion process are used in one of the following ways:

— Some gaps created by the removal of Idle control characters are filled with FEC parity data (FEC overhead compensation sub-process); or
— Other gaps created by the removal of Idle control characters are discarded in order to decrease the effective data rate between the MAC and PHY (data rate adaptation sub-process).

The Idle deletion process deletes a specific number of 72-bit vectors containing Idle control characters from the data stream composed of a series of 72-bit vectors received from the XGMII. The number of deleted 72-bit vectors containing Idle control characters depends on the EPoC PMD data rate, PMD overhead (including, for example, cyclic prefix), and the size of FEC parity data. The Idle deletion process performs the following two functions:

— Create gaps by Idle removal to allow for FEC parity/CRC40.
— Rate adaptation by Idle removal to adjust from the XGMII rate to the PMD rate.

The operation of the EPoC MPCP defined in Clause 103 ensures that a sufficient number of Idle control characters are present in the data stream, so that the minimum IPG between two adjacent frames is preserved once all excess Idle control characters are removed through the operation of the data rate adaptation and the FEC overhead compensation sub-processes.

101.3.2.1.1 Constants

DS_FEC_OSize
TYPE: U5.3 format
The number of 72-bit vectors constituting the overhead (parity and CRC40) portion of a downstream FEC codeword. To normalize the downstream pre-FEC data rate, the Idle deletion process removes *DS_FEC_OSize* vectors per every *DS_PHY_DSize* vectors transferred to the 64B/66B Encoder.
Value: (1800+40)/65

DS_PHY_DSize
TYPE: 16-bit unsigned integer
The number of 72-bit vectors constituting the payload portion of a downstream FEC codeword. To normalize the effective downstream PCS data rate, the Idle deletion process removes DS*_PHY_OSize* vectors per every DS*_PHY_DSize* vectors to compensate for FEC overhead and PMD derating processes.
Value: 220

US_FEC_OSize
TYPE: U5.3 format

The number of 72-bit vectors constituting the parity (overhead) portion of a upstream FEC codeword. To normalize the upstream pre-FEC data rate, the Idle deletion process removes *US_FEC_OSize* vectors per every *US_PHY_DSize* vectors transferred to the 64B/66B Encoder.
Value: (280+40)/65

US_PHY_DSize
TYPE: 16-bit unsigned integer
The number of 72-bit vectors constituting the payload portion of a upstream FEC codeword. To normalize the effective upstream PCS data rate, the Idle deletion process removes *US_PHY_OSize* vectors per every *US_PHY_DSize* vectors to the compensation of FEC overhead and PMD derating process.
Value: 12

XGMII_Rate
TYPE: unsigned integer
The data transfer rate of the XGMII interface.
Value: 10 Gb/s

101.3.2.1.2 Variables

accResidue
TYPE: U1.3 format
The variable *accResidue* tracks the accumulation of *PHY_OSizeFrac*.

BEGIN
TYPE: Boolean
This variable is used when initiating operation of the state diagram. It is set to TRUE following initialization and every reset.

DelayBound
TYPE: 16-bit unsigned integer
This value represents the number of consecutive 65-bit blocks containing Idles used by the Data Detector input and CNU output process to determine end of burst. This value represents the delay sufficient to initiate the transmitter at the CNU and to accommodate timing jitter caused by PMA overhead, such as burst markers, and pilots. This variable is used only by the CNU. By default, the value should be set the same as that for length of the *FIFO_FEC_TX* buffer.

DS_DataRate
See 100.3.2.1.

DS_PHY_OSize
TYPE: 16-bit unsigned integer
To normalize the effective PCS data rate, the Idle deletion process removes *DS_PHY_OSize* vectors per every *DS_PHY_DSize* vectors to compensate for FEC overhead and PMD derating process. *DS_PHY_OSize* is defined in Equation (101–1).

$$DS\_PHY\_OSize = \left\lfloor \frac{XGMII\_Rate - PCS\_DS\_Rate}{PCS\_DS\_Rate} \times (DS\_PHY\_DSize + DS\_FEC\_OSize) + DS\_FEC\_OSize \right\rfloor \quad (101\text{–}1)$$

PCS_DS_Rate:
TYPE: UQ34.3 format
The transmission rate of PCS data, excluding the 64B/65B sync header bit in the 64/65B line encoder, as defined in Equation (101–2).

$$PCS\_DS\_Rate = DS\_DataRate \times \frac{64}{65} \quad (101\text{–}2)$$

PHY_OSizeFrac:

TYPE: U0.3 format

The fractional part of *DS_PHY_OSize* due to the floor operation in Equation (101–1). The *PHY_OSizeFrac* is defined in Equation (101–3).

$$PHY\_OSizeFrac = \frac{XGMII\_Rate - PCS\_DS\_Rate}{PCS\_DS\_Rate} \times (DS\_PHY\_DSize + DS\_FEC\_OSize) + DS\_FEC\_OSize - DS\_PHY\_OSize \quad (101\text{–}3)$$

tx_raw<71:0>

This variable is defined in 49.2.13.2.2.

tx_raw_out<71:0>

72-bit vector sent from the output of the Idle deletion process to the 64B/66B Encoder. This vector contains two XGMII transfers mapped as shown for *tx_raw*<71:0>.

101.3.2.1.3 Counters

countDelete

TYPE: 16-bit unsigned integer

Counts the number of 72-bit vectors that need to be deleted from the received data stream as part of the data rate adaptation and FEC overhead compensation.

countVector

TYPE: 16-bit unsigned integer

Counts the number of 72-bit vectors transmitted after the removal of Idle characters as part of data rate adaptation and FEC overhead compensation.

101.3.2.1.4 Functions

T_TYPE(*tx_raw*<71:0>)

This function is defined in 49.2.13.2.3.

101.3.2.1.5 State diagrams

The CLT PCS shall perform the Idle deletion process as shown in Figure 101–6. The CNU PCS shall perform the Idle deletion process as shown in Figure 101–7.

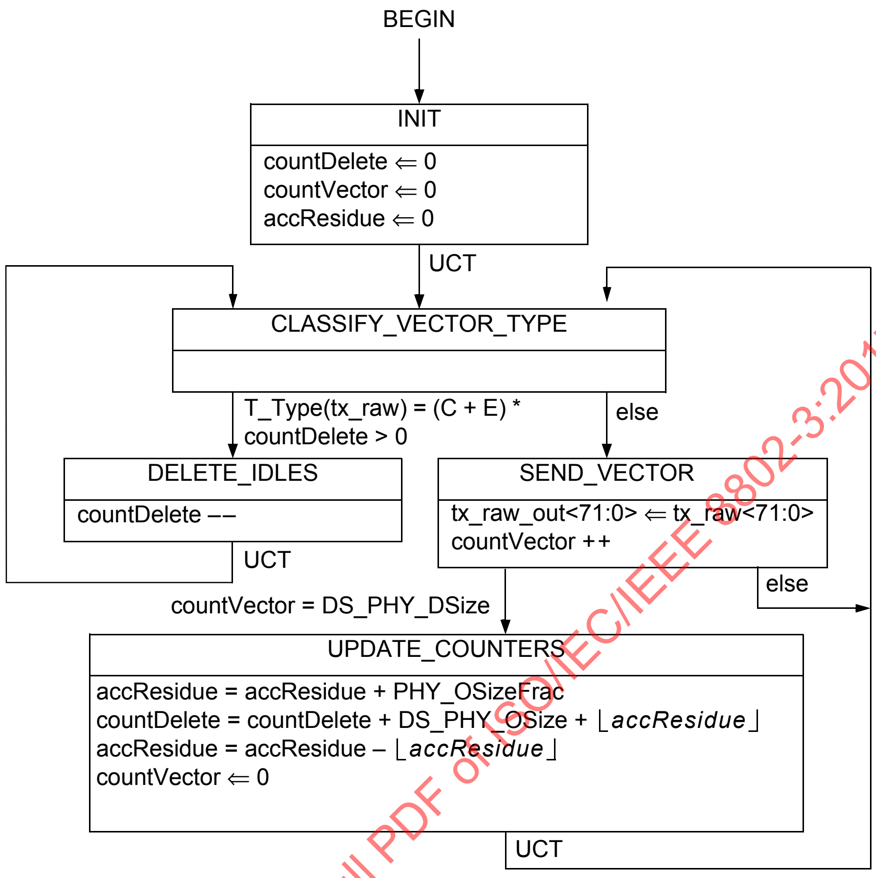


Figure 101–6—CLT Idle deletion process state diagram

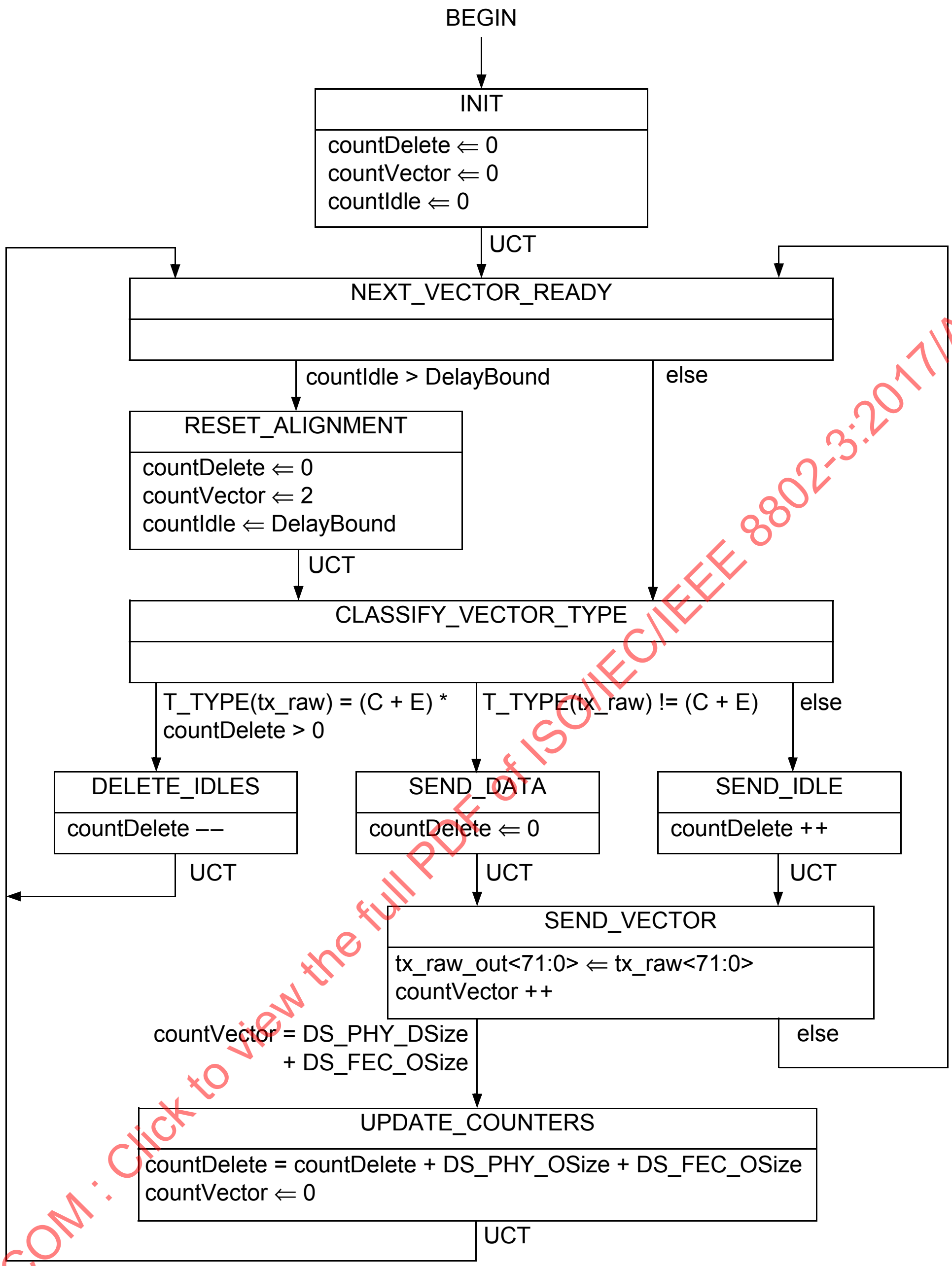


Figure 101–7—CNU Idle deletion process state diagram

101.3.2.2 64B/66B Encoder

The EPoC PHY utilizes a 64B/66B Encoder based on that described in 49.2.5 with several important differences. The EPoC 64B/66B Encoder does not include a scrambler function as described in 49.2.6 and the output is a 65B block with a single synch header bit. The state diagram found in Figure 49-12 is followed after which the sync header bit <0> is removed as illustrated in Figure 101–9.

101.3.2.3 CRC40

The CRC40 field contains a 40-bit cyclic redundancy check value. This value is computed as a function of the contents of the B_Q 65-bit blocks (see Table 101–2), forming the payload portion of the FEC codeword.

The encoding is defined by the CRC40 generating polynomial shown in Equation (101–4):

$$x^{40} + x^{26} + x^{23} + x^{17} + x^{3} + 1 \qquad (101\text{–}4)$$

This CRC40 calculation shall produce the same result as the serial implementation shown in Figure 101–8. At the beginning of each FEC codeword (before the calculation of CRC40 begins), the shift register shall be initialized to the value zero. The content of the shift register is transmitted without inversion.

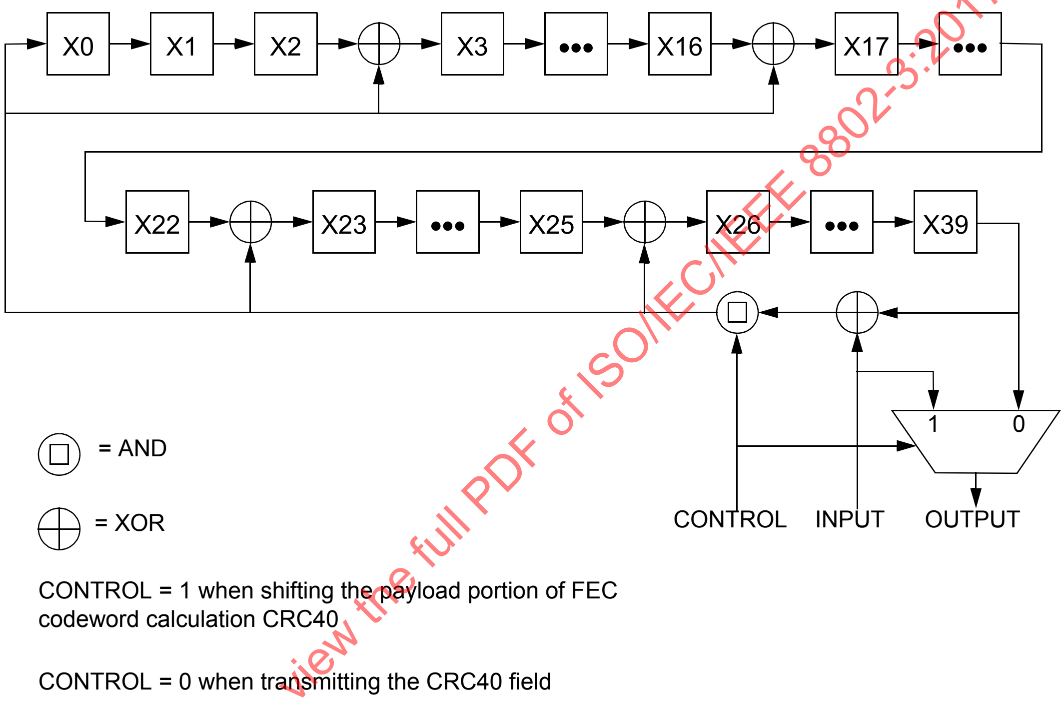


Figure 101–8—CRC40 generation

101.3.2.4 Low Density Parity Check (LDPC) Forward Error Correction (FEC) codes

The 10GPASS-XR PHY encodes the transmitted data using a systematic Low-Density Parity-Check (LDPC) (F_C, F_P) code. A LDPC Encoder encodes F_P information bits $i_0 \ldots i_{F_P - 1}$ into a codeword

$$cFc = (i_0, \ldots, i_{F_P-1}, p_{F_P}, \ldots, p_{F_C-1}) \qquad (101\text{–}5)$$

by adding F_R parity bits $p_{F_P} \ldots p_{F_C-1}$ obtained so that

$$Hc^T = 0$$

where H is an $F_R \times F_C$ binary matrix containing mostly ‘0’ and relatively few ‘1’, called low-density parity-check matrix (see Gallagher [B32]). The detailed description of such parity check matrices is given in 101.3.2.4.1.

The CLT 10GPASS-XR PCS operating on a CCDN shall encode the transmitted data using the LDPC (16200, 14400) code per Table 101–2. The CNU 10GPASS-XR PCS operating on CCDN shall encode the transmitted data using one of the LDPC (F_C, F_P) codes per Table 101–2.

Table 101–2—LDPC codes used in EPoC

Upstream (US) Downstream (DS)	Codeword F_C [bits]	Payload F_P [bits]	Parity F_R [bits]	US filling threshold F_T		Payload		
				bits	65-bit blocks	65-bit blocks B_Q	CRC bits	Padding bits B_P
US/DS	16200	14400	1800	6601	101	220	40	60
US	5940	5040	900	1601	25	76	40	60
US	1120	840	280	1	1	12	40	20

101.3.2.4.1 LDPC matrix definition

The low-density parity check matrix H for LDPC (F_C, F_P) encoder can be divided into blocks of L^2 sub-matrices. Its compact circulant form is represented by an $m \times n$ block matrix:

$$H = \begin{bmatrix} H_{1,1} & H_{1,2} & H_{1,3} & \dots & H_{1,n} \\ H_{2,1} & H_{2,2} & H_{2,3} & \dots & H_{2,n} \\ H_{3,1} & H_{3,2} & H_{3,3} & \dots & H_{3,n} \\ \dots & \dots & \dots & & \dots \\ H_{m,1} & H_{m,2} & H_{m,3} & \dots & H_{m,n} \end{bmatrix}$$

where the submatrix $H_{i,j}$ is an $L \times L$ all-zero submatrix or a cyclic right-shifted identity submatrix. The last $n-m$ submatrix columns represent the parity portion of the matrix. Moreover, $nL = F_C$, $mL = F_P$ and the code rate is $(n - m)/n = (F_C - F_P)/F_C$. The submatrix size L is called the lifting factor.

The submatrix $H_{i,j}$ is represented by a value in {–1, 0,…, L–1}, where a ‘–1' value represents an all-zero sub-matrix, and the remaining values represent an $L \times L$ identity submatrix cyclically right-shifted by the specified value. Such representation of the parity-check matrix is called a base matrix.

Table 101–3 presents a 5×45 base matrix of the low-density parity-check matrix H for LDPC (16200, 14400) code listed in Table 101–2 for downstream and upstream. The lifting factor of the matrix is $L = 360$.

Table 101–3—LDPC (16200, 14400) code matrix

Columns	Rows						Columns	Rows				
	1	2	3	4	5			1	2	3	4	5
1	93	274	134	–1	253		**24**	47	1	345	359	–
2	271	115	355	–	273		**25**	76	159	174	342	–1
3	–1	329	175	184	90		**26**	73	56	269	–1	232
4	83	338	24	70	–1		**27**	150	72	329	224	–1
5	26	124	253	247	–1		**28**	349	126	–1	106	21
6	208	–1	242	14	151		**29**	139	277	214	–1	331
7	245	293	–1	22	311		**30**	331	156	–1	273	313
8	200	–1	187	7	320		**31**	118	32	–1	177	349
9	–1	69	94	285	339		**32**	345	111	–1	245	34
10	175	64	26	54	–1		**33**	27	175	–1	98	97
11	331	342	87	–1	295		**34**	294	–1	218	355	187
12	17	–1	302	352	148		**35**	–1	306	104	178	38
13	86	88	–1	26	48		**36**	145	224	40	176	–1
14	–1	139	191	108	91		**37**	279	–1	197	147	235
15	337	–1	323	10	62		**38**	97	206	73	–1	52
16	–1	137	22	298	100		**39**	106	–1	229	280	170
17	238	212	–1	123	232		**40**	160	29	63	–1	58
18	81	–1	245	139	146		**41**	143	106	–1	–1	–1
19	–1	157	294	117	200		**42**	–1	334	270	–1	–1
20	307	195	240	–1	135		**43**	–1	–1	72	221	–1
21	–1	357	84	336	12		**44**	–1	–1	–1	208	257
22	165	81	76	49	–1		**45**	–1	–1	–1	–1	0
23	–1	194	342	202	179							

Table 101–4 presents a 5 × 33 base matrix of the low-density parity-check matrix H for LDPC (5940, 5040) code listed in Table 101–2 for upstream. The lifting factor of the matrix is L = 180.

Table 101–5 presents a 5 × 20 base matrix of the low-density parity-check matrix H for LDPC (1120, 840) code listed in Table 101–2 for upstream. The lifting factor of the matrix is L = 56.

101.3.2.5 FEC Encoder and Data Detector processes

101.3.2.5.1 Data Detector process

The 10GPASS-XR PCS transmit path includes the Data Detector process. This process contains a delay line (represented by the *FIFO_FEC_TX* buffer) that stores 65-bit blocks received from the output of the

Table 101–4—LDPC (5940, 5040) code matrix

Columns	Rows					Columns	Rows				
	1	2	3	4	5		1	2	3	4	5
1	142	54	63	28	52	**18**	84	171	50	–1	168
2	158	172	11	160	159	**19**	–1	65	46	67	158
3	113	145	112	102	75	**20**	64	141	17	82	–1
4	124	28	114	44	74	**21**	66	–1	175	4	1
5	92	55	61	8	46	**22**	97	42	–1	177	49
6	44	19	123	84	71	**23**	1	83	–1	151	89
7	93	159	72	126	42	**24**	115	7	–1	131	63
8	70	22	55	9	11	**25**	8	–1	92	139	179
9	172	96	114	169	108	**26**	108	39	–1	117	10
10	3	12	20	174	153	**27**	–1	121	41	36	75
11	25	85	53	147	–1	**28**	–1	84	138	18	161
12	44	–1	114	24	72	**29**	11	101	–1	–1	–1
13	141	128	42	145	–1	**30**	–1	171	34	–1	–1
14	160	5	33	–1	163	**31**	–1	–1	74	23	–1
15	50	158	4	26	–1	**32**	–1	–1	–1	8	177
16	45	120	66	–1	9	**33**	–1	–1	–1	–1	19
17	118	51	163	–1	2						

Table 101–5—LDPC (1120, 840) code matrix

Columns	Rows					Columns	Rows				
	1	2	3	4	5		1	2	3	4	5
1	5	0	12	0	36	**11**	3	2	19	53	–1
2	14	35	28	51	6	**12**	–1	23	18	13	11
3	12	1	22	16	3	**13**	34	0	52	–1	22
4	1	26	46	31	51	**14**	7	51	–1	52	23
5	2	0	3	13	4	**15**	46	–1	37	33	43
6	37	10	16	39	19	**16**	10	49	–1	–1	–1
7	45	16	51	27	4	**17**	–1	20	34	–1	–1
8	26	16	2	33	45	**18**	–1	–1	39	38	–1
9	24	34	25	8	48	**19**	–1	–1	–1	7	14
10	0	4	29	27	9	**20**	–1	–1	–1	–1	1

64B/66B Encoder to allow insertion of the FEC parity data into the transmitted data stream. The length of the *FIFO_FEC_TX* buffer is selected in such a way that it is large enough to compensate for the FEC overhead and PHY overhead, as discussed in 101.3.2.3 and 101.3.2.5.2.

101.3.2.5.2 LDPC encode process

The process of padding FEC codewords and appending FEC parity octets in the 10GPASS-XR PCS transmit path is illustrated in Figure 101–9. For the CLT, the FEC Encoder uses a single FEC LDPC codeword size of 16200 bits indicated by "DS" in Table 101–2 represented by constant FEC_DS_CodeWordSize (see 101.3.2.5.2). For the CNU, the FEC Encoder performs an algorithm as described in 101.3.2.5.4 for selecting the use of one or more "long" codewords (upstream size 16200 bits), a "medium" codeword (upstream size 5940), or one or more "short" codewords (upstream size 1120 bits) as detailed in Table 101–2.

The 64B/66B Encoder, as described in 101.3.2.2 and shown in Figure 101–9, delivers a stream of 65-bit blocks to the FEC Encoder and Data Detector. In the CNU only, a 65-bit Burst Time Header is added as the first 65-bit block at the start of a burst (see Figure 101–13).

Next, the FEC Encoder calculates CRC40 (see 101.3.3) over the aggregated B_Q (see Table 101–2) 65-bit blocks, placing the resulting 40 bits of CRC40 code immediately after the B_Q 65-bit blocks, forming the payload portion of the FEC codeword. Finally, based on the codeword size the FEC Encoder appends B_P (see Table 101–2) padding bits (with the binary value of "0") to the payload of the FEC codeword as shown in Figure 101–9.

The resulting F_P bits of data are then passed to the LDPC Encoder operating on a payload length of $F_P - B_P$ bits. The LDPC Encoder generates F_R bits of parity. After encoding, the encoder deletes the B_P bits of padding and constructs the output codeword with a length of $(F_P - B_P) + F_R$ bits.

101.3.2.5.3 LDPC codeword transmission order

Once the process of calculating FEC parity is complete, the payload portion of the FEC codeword and the parity portion of the FEC codeword are then transferred to the transmit PMA Client.

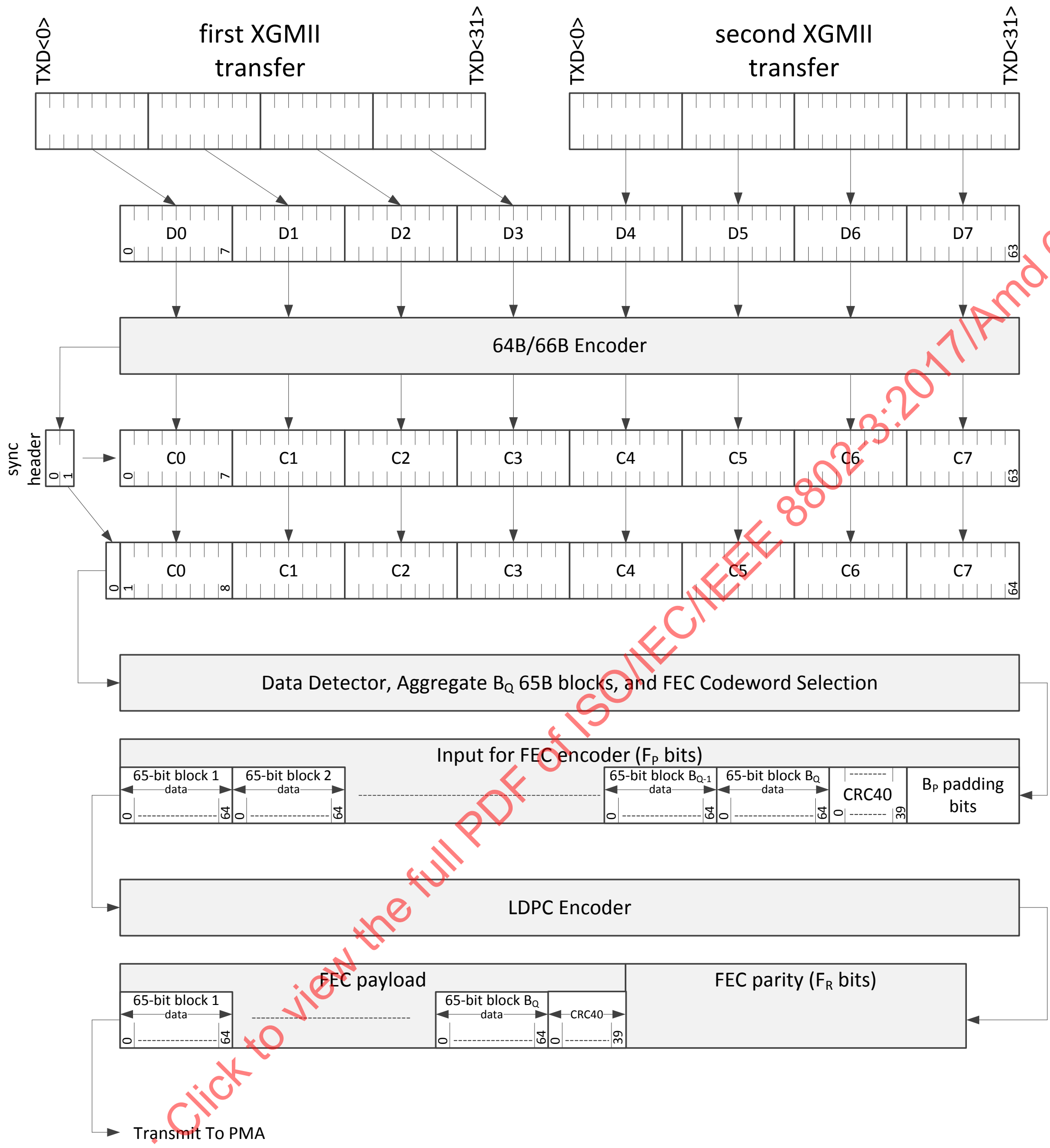


Figure 101–9—10GPASS-XR PCS transmit path processing

Figure 101–10 illustrates the details of the 10GPASS-XR CNU burst structure. In particular, this figure shows the details of the necessary burst elements and the FEC protected portions of the burst transmission, explicitly showing each FEC codeword.

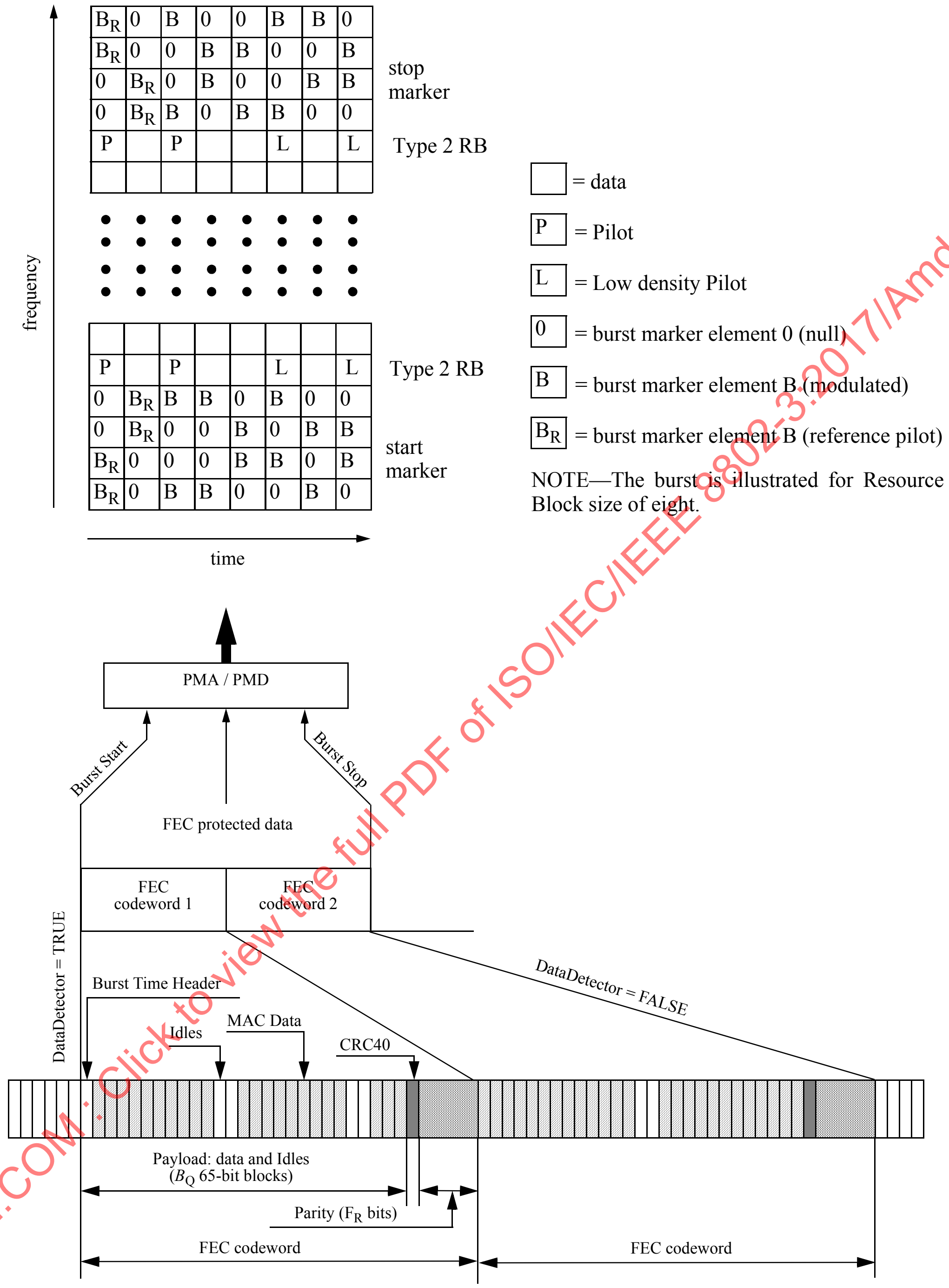


Figure 101–10—Details of burst composition

The CNU burst transmission begins with a start burst marker (see 101.4.4.8), which facilitates the detection of the start of an incoming data burst. When received at the CLT, the start burst marker enables FEC codeword alignment to the incoming data stream, even in the presence of bit errors. The start burst marker is not part of the first FEC codeword but is added by the PMA.

The CNU burst ends with the end burst marker (see 101.4.4.8), which facilitates the detection of the end of the current data burst. When received at the CLT, the end burst marker allows for the rapid reset of the CLT FEC synchronizer, so that it can search for the next burst. The end burst marker is not part of the last FEC codeword but is added by the PMA.

101.3.2.5.4 Upstream FEC encoding

Upstream bursts in EPoC are variable in length and may contain more than one MAC frame. The upstream makes use of three different LDPC codeword sizes as described Table 101–2. Each codeword size has a specific, associated US filling threshold F_T.

Starting with a 16200 (long) codeword:

1) If the number of available 65-bit blocks (Bin) is sufficient to fill a long FEC codeword ($B_Q \geq 220$), create a long FEC codeword. If Bin ≥ 220, is true repeat step 1).
2) If 220 > Bin ≥ 101, create a shortened long FEC codeword.
3) If 101 > Bin ≥ 76, create a medium FEC codeword.
4) If 76 > Bin ≥ 25, create a shortened medium FEC codeword.
5) If 25 > Bin ≥ 12, create a shortened FEC codeword. If Bin ≥ 12, is true repeat step 5).
6) If 12 > Bin ≥ 1, create a shortened short FEC codeword.

101.3.2.5.5 Constants

FEC_DS_CodeWordSize
TYPE: 16-bit integer
The fixed size, in bits, of the downstream FEC codeword.
Value: 16140

SH_CTRL
See 76.3.2.5.2.

SH_DATA
See 76.3.2.5.2.

101.3.2.5.6 Variables

blockCount
TYPE: 16-bit unsigned integer
This variable represents the number of 65-bit blocks input to the FEC Encoder.

B_P
TYPE: 16-bit unsigned integer
VALUE: see Table 101–2
This variable represents the number of padding bits within the payload portion of the FEC codeword.

B_Q
TYPE: 16-bit unsigned integer
VALUE: see Table 101–2
This variable represents the number of 65-bit blocks within the payload portion of the FEC codeword.

burstEnd
TYPE: Boolean
When TRUE this flag signals the end of burst.

burstStart
TYPE: Boolean
When TRUE this flag signals the start of a burst.

CLK
TYPE: Boolean
This variable is TRUE on every negative edge of *TX_CLK* (see 46.3.1) and represents instances of time at which a 66-bit block is passed from the output of the 64B/66B Encoder into the FEC Encoder. This variable is reset to FALSE upon read.

dataPayload<F_P–1:0>
TYPE: Bit array
This array represents the payload portion of the FEC codeword, accounting for the necessary padding. It is initialized to the size of F_P bits and filled with the binary value of "0".

dataParity<F_R–1+B_P:0>
TYPE: Bit array
This array represents the parity portion of the FEC codeword, accounting for the necessary padding. It is initialized to the size of F_R bits and filled with the binary value of "0".

DelayBound
See 101.3.2.1.2.

DS_DataRate
See 100.3.2.1.

FIFO_FEC_TX
TYPE: Array of 65-bit blocks
A FIFO array used to store 65-bit blocks, inserted by the input process and retrieved by the output process in the FEC Encoder (see Figure 101–11, Figure 101–12, and Figure 101–13). The size of FIFO_FEC_TX buffer in the 10GPASS-XR PCS is set to 29 = ceil((1800+40)/65).

firstcodeword
TYPE: Boolean
When TRUE this flag signals the first codeword of a burst.

F_P
TYPE: 16-bit unsigned integer
VALUE: see Table 101–2
This variable represents the number of bits within the payload portion of the FEC codeword.

F_R
TYPE: 16-bit unsigned integer
VALUE: see Table 101–2
This variable represents the number of bits within the parity portion of the FEC codeword.

IdleBlockCount
TYPE: 32-bit signed integer
The number of consecutive non-data 65-bit blocks ending with the most recently received block. The non-data 65-bit blocks are represented by sync header 0 (binary).

lastcodeword
TYPE: Boolean
When TRUE this flag signals the last codeword of a burst.

loc
TYPE: 16-bit unsigned integer
This variable represents the position within the given bit array.

Short2Payload<F_C–1:0>
TYPE: bit array
This bit array is used as a temporary buffer for the second short codeword in the Check_datapayload() function.

Short2blockCount
TYPE: 16-bit unsigned integer
This variable is used as a temporary to hold the *blockCount* of *Short2Payload<>*.

sizeFifo
TYPE: 16-bit unsigned integer
This variable represents the number of 65-bit blocks stored in the FIFO.

Transmitting
TYPE: Boolean
When TRUE this variable indicates the device is transmitting. At the CNU, the default value of *Transmitting* is FALSE. At the CLT, this variable is always set to TRUE except when *PD_Enable* is FALSE (see 102.2.7.3).

tx_coded<65:0>
TYPE: 66-bit block
This 66-bit block contains 64B/66B encoded data from the output of the 64B/66B Encoder. The format for this data block is shown in Figure 49–7. The left-most bit in the figure is *tx_coded<0>* and the right-most bit is *tx_coded<65>*.

tx_coded_out<F_C–1:0>
TYPE: bit array
This bit array contains the output of the FEC Encoder being passed to the Data Detector. The left-most bit is *tx_coded_out<0>* and the right-most bit is *tx_coded_out<F_C–1>*.

txCount
TYPE: 16-bit unsigned integer
This variable is used for counting bits in the Transfer to PMA process.

US_DataRate
See 100.3.2.2.

xfrSize
TYPE: integer
This variable is set as input to the transferToPMA process and indicates the number of bits in the ARRAY_IN.

101.3.2.5.7 Functions

BurstTimeHeader()
The BurstTimeHeader() function returns a 65-bit vector with the following values:
bit <0> = binary 1
bits<1:32> = the current PHY Link timestamp
bits<33:64> = a fixed value of 0xD858E4AB.
This 65-bit vector is transmitted as the first 65-bit block of an upstream burst.

Calculate_CRC40_and_3Parity(paritySize)
This function takes an argument of "LONG", "MEDIUM", or "SHORT" and then processes *dataPayload* and *tx_coded_out* to add CRC40 and appropriate LDPC parity. The *tx_coded_out* array is then passed to transferToPMA() with indicated length and *lastcodeword* status.

```
Function Calculate_CRC40_and_3Parity( paritySize ) {

    IF (paritySize == LONG)
```

```
        parityLength = 1800;
     IF (paritySize == MEDIUM)
        parityLength = 900;
     IF (paritySize == SHORT)
        parityLength = 280;

     dataPayload<loc+39:loc> = calculateCrc(dataPayload<loc-1:0>);
     tx_coded_out<loc+39:loc> = dataPayload<loc+39:loc>;
     loc += 40;
     dataParity<parityLength-1:0> =
        calculateParity(dataPayload<loc-1:0>, loc, paritySize);
     tx_coded_out<loc+parityLength-1:loc> = dataParity<parityLength-1:0>;
     xfrSize += parityLength;
     transferToPMA(tx_coded_out, xfrSize, lastcodeword);

     // Setup for next codeword in burst if more data
     firstcodeword = FALSE;
     loc = 0;
     resetArray(dataPayload);
     resetArray(dataParity);
  }
```

calculateCrc (ARRAY_IN)

This function calculates a CRC40 value for data included in ARRAY_IN (see 101.3.2.3).

calculateParity(ARRAY_IN , Length, paritySize)

This function calculates the LDPC parity (for the code per Table 101–2) for data included in ARRAY_IN up to the specified Length (bits). For any Length less than F_P, any remaining bits in ARRAY_IN after Length are considered padding bits (of length B_P bits) and will not be included in the encoder output producing a shortened codeword; i.e., codeword length will be $F_P - B_P + F_R$. When paritySize is “LONG”, the values for the downstream or upstream codeword size of 16200 are used; for “MEDIUM” the values for the upstream codeword size of 5940 are used; and for “SHORT” the values for the upstream codeword size of 1120 are used.

Check_dataPayload(firstcodeword, lastcodeword)

This function performs the upstream codeword filling algorithm examining accumulated *blockCount* as per 101.3.2.5.4. This function calls Calculate_CRC40_and_3Parity() indicating the appropriate codeword size to use, as appropriate.

```
  Function Check_dataPayload( firstcodeword, lastcodeword ) {

     IF (lastblock == FALSE) {
        IF (blockCount == 220 )
           Calculate_CRC40_and_3Parity(LONG);
     } ELSE {
        IF (blockCount < 200 && blockCount >= 101)
           Calculate_CRC40_and_3Parity(LONG);
        IF (blockCount < 101 && blockCount >= 76)
           Calculate_CRC40_and_3Parity(MEDIUM);
        IF (blockCount < 76 && blockCount >= 25)
           Calculate_CRC40_and_3Parity(MEDIUM);
        IF (blockCount < 24 && blockCount > 12) {
           // dataPayload<> contains two short codewords
           // first is 12 blocks, second is remainder
           Short2blockCount = blockCount - 12;
           Short2Payload<Short2loc:0> = dataPayload<loc:12*65>;
           loc = (12*65) - 1;
           blockCount = 12;
           Calculate_CRC40_and_3Parity(SHORT);
```

```
          dataPayload<Short2loc:0> = Short2Payload<Short2loc:0>;
          tx_coded_out<Short2loc:0> = Short2Payload<Short2loc:0>;
          loc = (Short2blockCount * 65) - 1;
          blockCount = Short2blockCount;
          Calculate_CRC40_and_3Parity(SHORT);
       } ELSE IF ( blockCount >= 1 ) {
          Calculate_CRC40_and_3Parity(SHORT);
       }
    return();
 };
```

resetArray(ARRAY_IN)

This function resets the content of ARRAY_IN, removing all the elements within ARRAY_IN and setting its size to 0.

removeFifoHead(ARRAY_IN)

This function removes the first block in ARRAY_IN and decrements its size by 1.

```
 Function removeFifoHead( ARRAY_IN ){
          ARRAY_IN[0] = ARRAY_IN[1];
          ARRAY_IN[1] = ARRAY_IN[2;]
          ...
          ARRAY_IN[sizeFifo-2] = ARRAY_IN[sizeFifo-1];
          sizeFifo --;
 }
```

transferToPMA(ARRAY_IN, xfrSize, lastcodeword)

This function serially transfers a PCS FEC output codeword that is represented as bits in ARRAY_IN to the PMA using the PMA_UNITDATA.request() service primitive. Rate clocking is provided by the PMA service primitive. In the downstream direction, the PCS continuously provides codewords for transfer. For the first bit of the downstream codeword transfer, *burstStart* is set to TRUE and set to FALSE otherwise; for the last bit, *burstEnd* is set to TRUE, and set to FALSE otherwise. In the upstream direction, the PCS builds an upstream burst that consists of one or more concatenated codewords, where the length of each burst is based on MPCP scheduling. For the first bit of the first codeword of the upstream transfer, *burstStart* is set to TRUE and set to FALSE otherwise; for the last bit of the last codeword of the burst, *burstEnd* is set to TRUE and set to FALSE otherwise. The *burstStart* and *burstEnd* flags are used by the respective PMA symbol mapping functions (see 101.4.3.8 and 101.4.4.5). In the CLT the lastcodeword argument to this function is always TRUE (see Figure 101–12). This function is represented by the following pseudo code:

```
    Function transferToPMA( ARRAY_IN, xfrSize, lastcodeword) {
    burstStart = FALSE;
    burstEnd   = FALSE;
       for ( txCount = 0; txCount < xfrSize; txCount++) {
          if (txCount == 0)
             burstStart = TRUE;
          if ((txCount == (xfrSize-1)) && (lastcodeword == TRUE))
             burstEnd = TRUE;
          PMA_UNITDATA.request(ARRAY_IN[txCount], burstStart, burstEnd)
       }
    }
```

101.3.2.5.8 State diagrams

The CLT and the CNU shall implement the Data Detector input process as depicted in Figure 101–11. The CLT shall implement the Data Detector output process as depicted in Figure 101–12. The CNU shall implement the Data Detector output process as depicted in Figure 101–13.

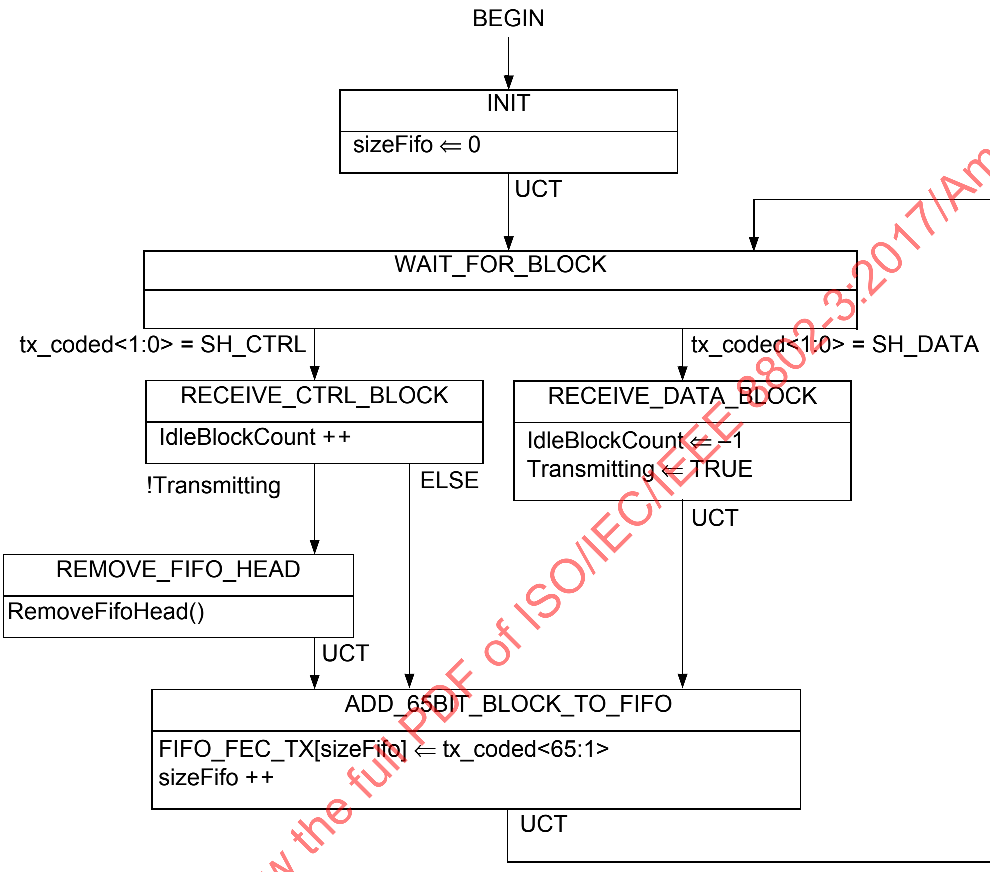


Figure 101–11— FEC Encoder and Data Detector input process state diagram

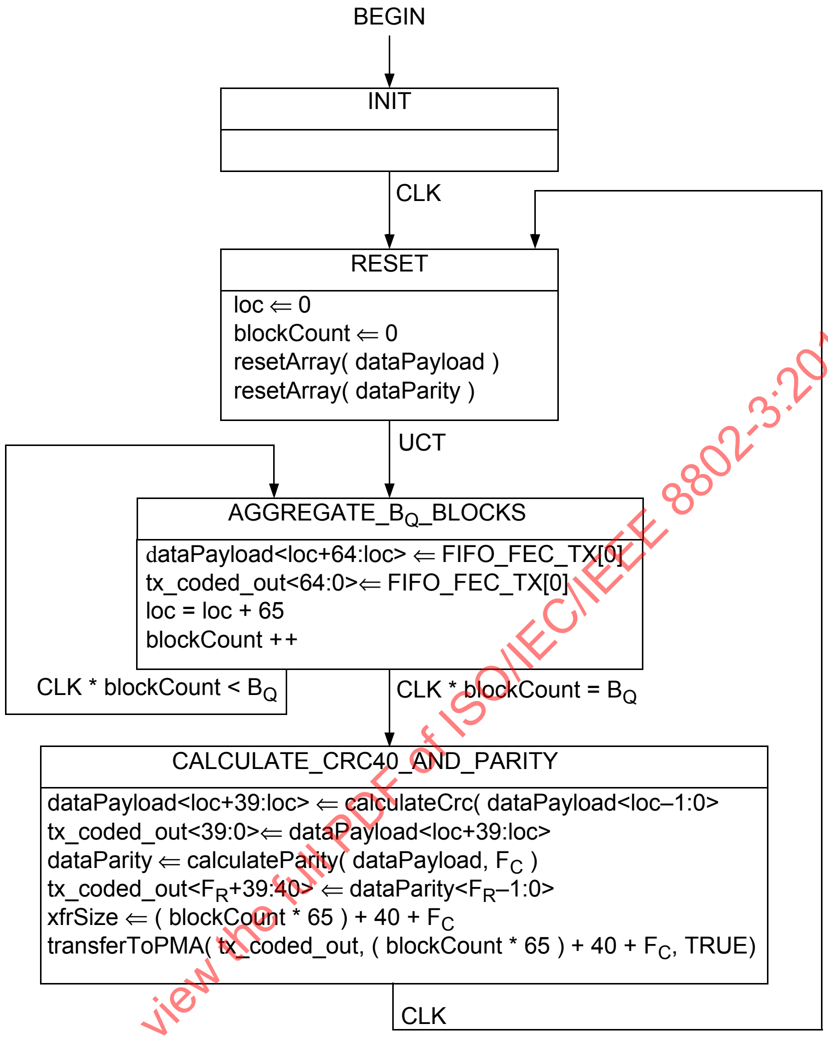


Figure 101–12—CLT FEC Encoder and Data Detector output process state diagram

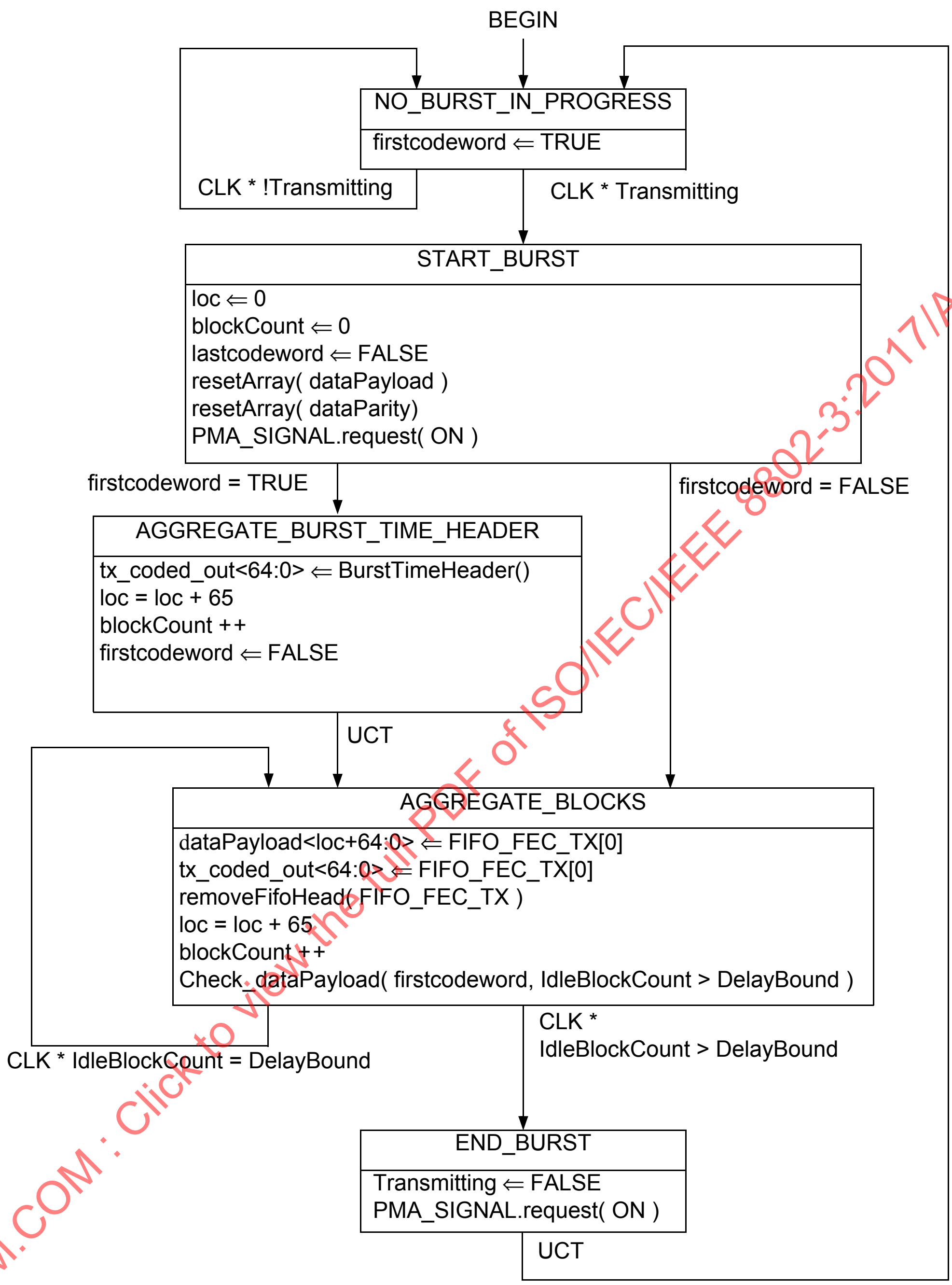


Figure 101–13—CNU FEC Encoder and Data Detector output process state diagram

101.3.3 PCS receive function

In the CLT, the PCS receive function operates in a burst fashion at the data rate of up to 10 Gb/s. In the CNU, the PCS receive function operates in a continuous fashion at the data rate of up to 10 Gb/s. Receive direction functional block diagrams for the CLT and CNU are illustrated in Figure 101–3 and Figure 101–4, respectively.

In the receive direction, the EPoC PCS includes a mandatory FEC Decoder, followed by a 64B/66B Decoder and an Idle control character insertion function performing the function of data rate adaptation and a FEC overhead compensation.

101.3.3.1 FEC Decoder

The 10GPASS-XR PHY decodes the received data using LDPC (F_C, F_P) code. The CLT 10GPASS-XR PCS operating on a CCDN shall decode the received data using one of the LDPC (F_C, F_P) codes per Table 101–2. The CNU 10GPASS-XR PCS operating on CCDN shall decode the received data using LDPC (16200, 14400) code per Table 101–2.

101.3.3.1.1 Upstream FEC decoding

The CLT receives an upstream burst with a length of R bits from a CNU via the PMA Client.

Start with B_Q = 220, CRC = 40, and F_R = 1800 for long codewords:

1) If $R \geq B_Q * 65 + 40 + F_R$ bits, decode a long codeword.
   Repeat and decode using long codewords if remaining bits $\geq B_Q * 65 + 40 + F_R$ bits.
   End processing burst if remaining bits ≤ 0.
2) If remaining bits $< (B_Q = 220) * 65 + 40 + (F_R = 1800)$ and $\geq (B_Q = 101) * 65 + 40 + (F_R = 1800)$, decode a shortened long codeword.
   End processing burst if remaining bits ≤ 0.
3) If remaining bits $\geq (B_Q = 76) * 65 + 40 + (F_R = 900)$, decode a medium codeword.
   End processing burst if remaining bits ≤ 0.
4) If remaining bits $< (B_Q = 76) * 65 + 40 + (F_R = 900)$ and $\geq (B_Q = 25) * 65) + 40 + (F_R = 900)$, decode a shortened medium codeword.
   End processing burst if remaining bits ≤ 0.
5) If remaining bits $\geq (B_Q = 12) * 65 + 40 + (F_R = 280)$, decode a short codeword.
   Repeat and decode using short codewords if remaining bits $\geq (B_Q = 12) * 65 + 40 + (F_R = 280)$ bits.
   End processing burst if remaining bits ≤ 0.
6) If remaining bits $\geq 65 + 40 + 280$, decode a shortened short codeword.
7) If remaining bits, declare receiver burst error.

All codeword decoding follows the same procedures as the downstream with the following differences:

— The appropriate values from Table 101–2 are used for the corresponding codeword size being decoded.
— The *burstStart* indication in the PMA_UNITDATA.indication() corresponds to the first bit in the concatenated burst received from a CNU.
— The *burstEnd* indication in the PMA_UNITDATA.indication() corresponds to the last bit of the concatenated burst received from a CNU.
— The nominal data rate of the PMA_UNITDATA_request() is *US_DataRate* calculated by the CLT (see 100.3.2.2).

101.3.3.1.2 LDPC decoding process within CNU (downstream)

The process of decoding FEC codewords in the 10GPASS-XR CNU receiver is illustrated in Figure 101–14.

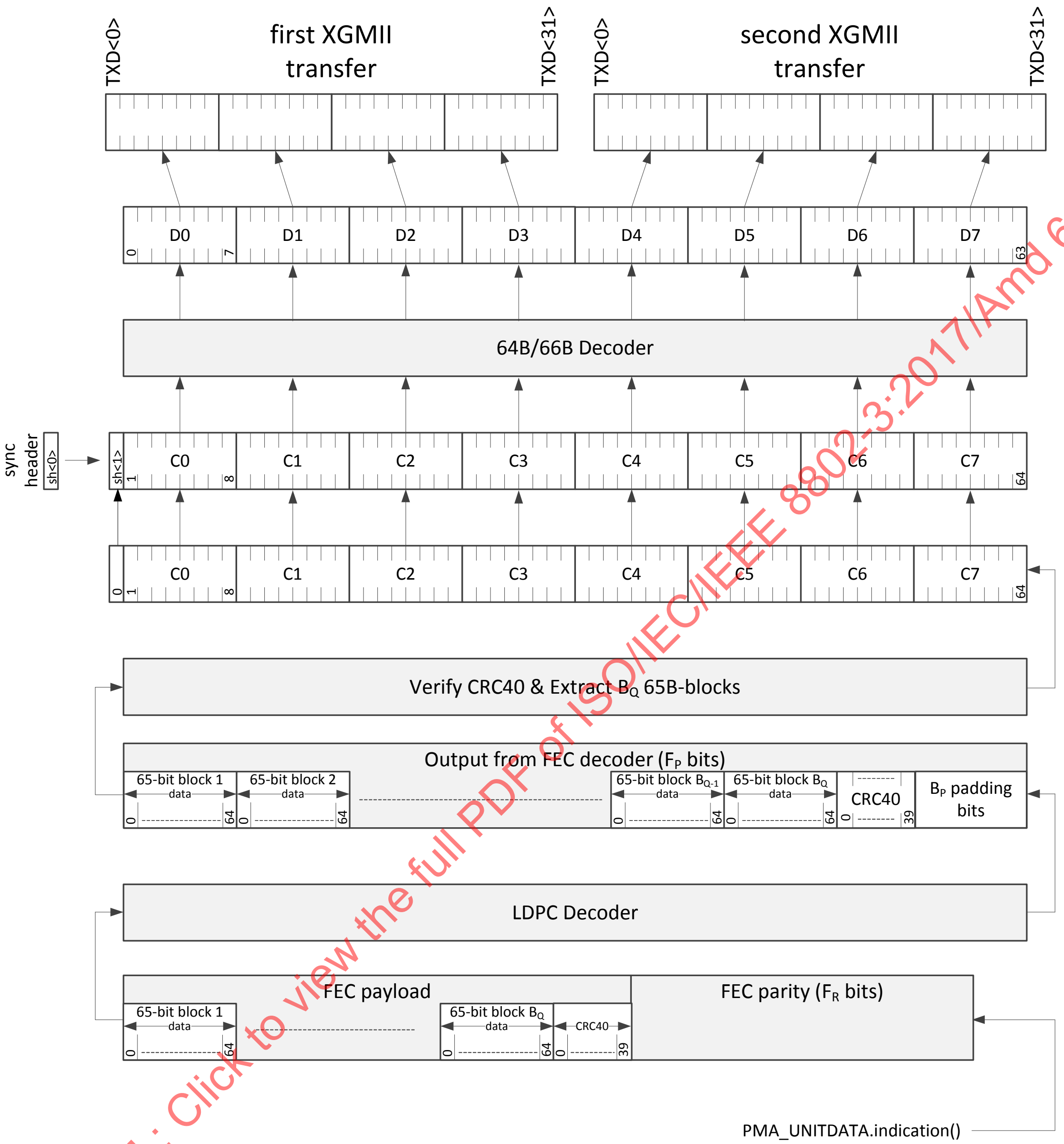


Figure 101–14—PCS receive path processing

Once the alignment to the FEC codeword is found, the 10GPASS-XR CNU receiver aggregates a total of FEC_DS_CodeWordSize bits received from the descrambler as input to the FEC Decoder. The output of the FEC Decoder contains the full FEC Payload consisting of 65-bit blocks number 1 to B_Q, the CRC40 data, and B_P padding bits with all bits set to the binary value of "0".

The FEC Decoder produces the FEC payload portion of the codeword with the size of F_P (in bits), where bits $<F_P - B_P - 1>$ ... $<F_P - 1>$ contain padding (with the binary value of "0"). Next, the CRC40 is calculated over the remaining 65-bit blocks 1 through B_Q and then compared with the value of CRC40 retrieved from the received FEC codeword. If both CRC40 codes match, the decoded FEC codeword is treated as error-free. Otherwise, the decoded FEC codeword is treated as errored.

Finally, the FEC Decoder prepends each of the B_Q 65-bit blocks with bit <0> of the sync header containing the binary inverse of the value carried in bit <1> of the sync header, producing 66-bit blocks. This also guarantees that properly decoded blocks meet the requirements of 49.2.4.3.

The FEC Decoder maintains error monitors to detect FEC codeword successes and failures. See 101.3.3.1.4 for details.

Each resulting 66-bit block is then fed into the 64B/66B Decoder, removing the sync header information (bit <0> and bit <1>), which is used to generate control signaling for the XGMII. Finally, the resulting 64-bit block is then separated into two 32-bit portions, which are transmitted across the XGMII on two consecutive transfers, with the proper control signaling retrieved from the sync header information retrieved in the 64B/66B Decoder.

101.3.3.1.3 LDPC decoding process within CLT upstream

In the Verify CRC40 and Extract B_Q 65B Blocks function of the upstream receiver, the CLT will remove the first 65-bit block of a burst containing the Burst Time Header, the remainder of the 65-bit blocks will be passed to the 64B/66B Decoder. The 32-bit PHY Link timestamp value will be extracted. The use of this timestamp in the upstream receiver processing is implementation specific and beyond the scope of this standard. This timestamp is provided as a mechanism to minimize any jitter introduced by OFDMA framing and the 1D to 2D insertion and extraction mechanisms. For example, an implementation may implement a timestamp-based burst play out buffer prior to passing any frames contained within a burst to the XGMII.

101.3.3.1.4 Codeword error monitor

The FEC Decoder shall provide a user-configurable option (variable *CRC40ErrCtrl*) to indicate an uncorrectable FEC codeword to higher layers. If *CRC40ErrCtrl* is TRUE and the calculated value of CRC40 does not match the value of CRC40 retrieved from the received FEC codeword, the FEC Decoder replaces bit <0> and <1> in the sync headers in the first 64B/66B block and every eighth 64B/66B block, (1st, 9th, 17th, 25th, etc.) as well as the last 64B/66B block from the errored FEC codeword with the binary value of “11”. The state table for replacing the sync header bits is shown in Table 101–6. For EPoC, the BER monitor state machine as defined in Clause 49 is disabled.

Table 101–6—Sync header decoding state table

		CRC40ErrCtrl	
		FALSE	**TRUE**
CRC40	matches	Pass SH as received	Pass SH as received
	does not match	Pass SH as received	Replace SH with “11”

101.3.3.1.5 Constants

IDLE

TYPE: 66-bit vector
This constant represents /I/ character with 64B/66B encoding, as defined in 49.2.4.7.

XGMII_Rate

See 101.3.2.1.1.

101.3.3.1.6 Variables

blockCount
: See 101.3.2.5.5.

B_P
: See 101.3.2.5.5.

B_Q
: See 101.3.2.5.5.

CLK
: See 101.3.2.5.5.

CRC40ErrCtrl
: TYPE: Boolean
: This variable controls the processing of codewords that fail the CRC40 checksum test. See 101.3.3.1.4.

dataInSize
: TYPE: 16-bit unsigned integer
: VALUE: $(B_Q + 1) \times 65 + 40 + B_P$
: This variable represents the size of the *dataIn* array in bits, containing the combination of the payload portion of the FEC codeword ($(B_Q + 1) \times 65$), the CRC40 (40), and the parity portion of the FEC codeword (B_P).

dataCrcA<39:0>
: TYPE: Bit array
: This array represents the CRC40 recovered from the payload portion of the FEC codeword prior to the FEC decoding process. This array is initialized to the size of 40 bits and filled with the binary value of “0”.

dataCrcB<39:0>
: TYPE: Bit array
: This array represents the CRC40 calculated over B_Q 65-bit blocks in the payload portion of the FEC codeword after the FEC decoding process. This array is initialized to the size of 40 bits and filled with the binary value of “0”.

dataIn<dataInSize–1:0>
: TYPE: Bit array
: This array represents the combination of the payload portion of the FEC codeword, the parity portion of the FEC codeword, CRC40, and all the necessary padding. It is initialized to the size of *dataInSize* bits and filled with the binary value of “0”.

dataOut<F_P–1:0>
: TYPE: Bit array
: This array represents the combination of the payload portion of the FEC codeword, CRC40, and all the necessary padding. It is initialized to the size of F_P bits and filled with the binary value of “0”.

FecCodeWordCount
: TYPE: 32-bit unsigned integer
: This variable is incremented for every received FEC codeword. After reaching 0xFF-FF-FF-FF, this variable is set to 0x00-00-00-00.

FecCodeWordFail
: TYPE: 32-bit unsigned integer
: This variable is incremented for every received FEC codeword for which the decoding process failed. After reaching 0xFF-FF-FF-FF, this variable is set to 0x00-00-00-00.

FecCodeWordSuccess

TYPE: 32-bit unsigned integer

This variable is incremented for every received FEC codeword for which the decoding process completes successfully. After reaching 0xFF-FF-FF-FF, this variable is set to 0x00-00-00-00.

FIFO_FEC_RX

TYPE: Array of 66-bit blocks

A FIFO array used to store tx_coded<65:0> blocks, inserted by the input process in the FEC Decoder, while encoded data is then sent to 64B/66B Decoder for processing and transmission towards the XGMII.

loc

See 101.3.2.5.5.

PMA_CLK

TYPE: Boolean

This variable is to TRUE on every negative edge of a clock that is synchronized to the PMA_UNITDATA.indication data rate of *DS_DataRate* (see 101.4.2.1). This variable is set to FALSE upon read. This variable is set to FALSE upon read.

rx_coded_in<64:0>

TYPE: 65-bit block

This 65-bit block contains the input into the FEC Decoder being passed from PMA. The left-most bit is *rx_coded_in<0>* and the right-most bit is *rx_coded_in<64>*.

rx_coded_in<F_C–1:0>

TYPE: bit array

This array contains the input into the FEC Decoder being passed from PMA. The left-most bit is *rx_coded_in<0>* and the right-most bit is *rx_coded_out*<F_C–1>.

rxCount

TYPE: 16-bit unsigned integer

This variable is used for counting bits in the Transfer from PMA process.

sizeFifoRx

TYPE: 16-bit unsigned integer

This variable represents the number of 65-bit blocks stored in the FIFO.

syncFec

TYPE: Boolean

This variable indicates whether the FEC codeword alignment was found (value equal to TRUE) or not (value equal to FALSE).

tx_coded<65:0>

See 101.3.2.5.5.

101.3.3.1.7 Functions

calculateCrc (ARRAY_IN)

See 101.3.2.5.5.

decodeFec(ARRAY_IN, Length)

This function performs FEC decoding (for the codeword per Table 101–2) for data included in ARRAY_IN, comprising the combination of the FEC payload portion, CRC40, and FEC Parity (F_R). Since the FEC Parity and CRC are of constant size, if Length < F_C, the FEC payload will be shortened by F_C – Length bits (considered as padding bits B_P). The output of the decoder will be of length F_P bits composed of the received FEC payload, the received CRC40, and the added B_P padding bits. The padding bits will be set to a binary value of 0.

resetArray(ARRAY_IN)
: See 101.3.2.5.5.

transferFromPMA(ARRAY_OUT)
: This function invokes the Transfer From PMA process to transfer a downstream burst (codeword) from the PMA to the FEC Decoder.

101.3.3.1.8 State diagrams

The CLT PCS shall implement the transfer from PMA process as shown in Figure 101–15.

The CNU PCS shall implement the LDPC decoding process input process, and LDPC decoding output process as shown in Figure 101–16 and Figure 101–17, respectively.

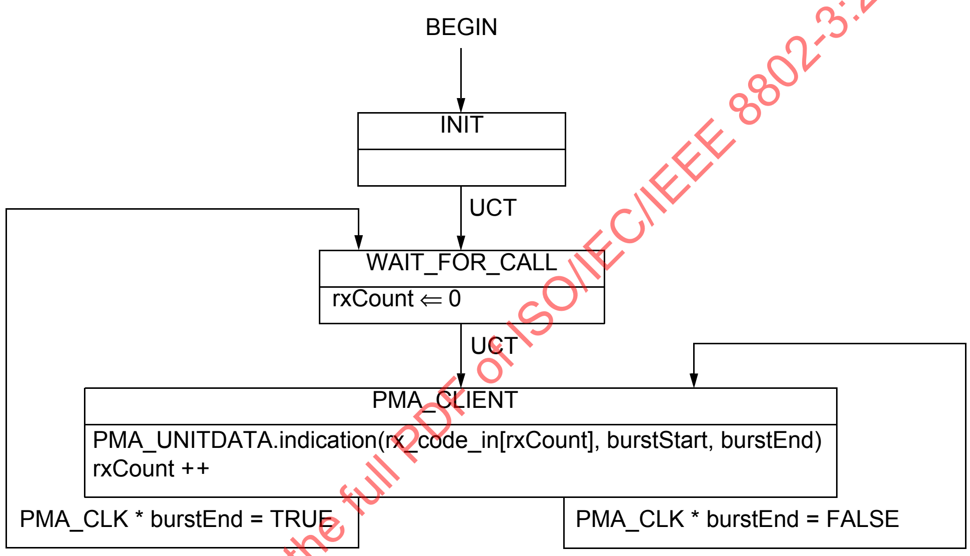


Figure 101–15—Upstream CLT transfer from PMA process state diagram

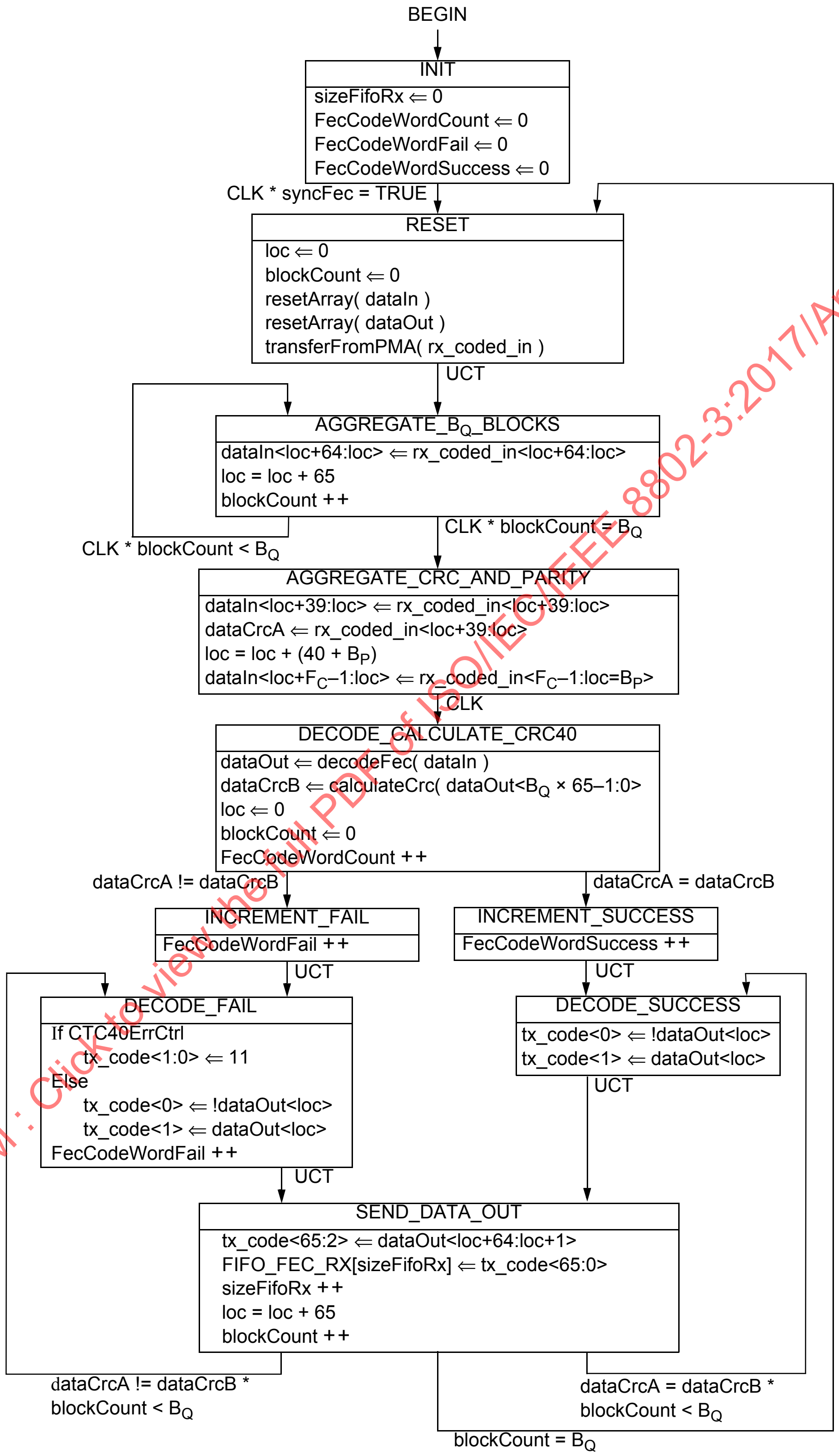


Figure 101–16—CNU FEC decoding input process state diagram

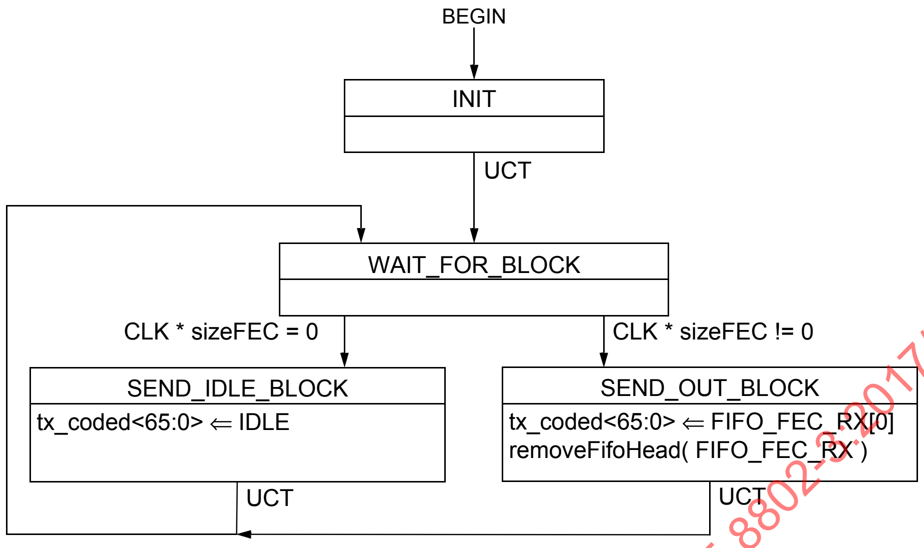


Figure 101–17—FEC Decoder, output process state diagram (CNU)

101.3.3.2 64B/66B Decoder

The EPoC PHY utilizes a 64B/66B Decoder based on that described in 49.2.11 with several important differences. The EPoC 64B/66B Decoder does not include a descrambler function as described in 49.2.10 and the input is a 65B block with a single sync header bit. The state diagram found in Figure 49-17 is followed after the addition of sync header bit <0> as illustrated in Figure 101–14.

101.3.3.3 Idle control character insertion process

In the receiving PCS, the Idle control character insertion process inserts Idle control characters into the data stream with gaps as received from the FEC Decoder and 64B/66B Decoder, adjusting the effective PCS and PMD data rate to the data rate expected by the MAC Control (as defined in Clause 103). Effectively, the Idle control character insertion process fills in the gaps created after the removal of FEC parity data, as well as compensates for the derating of the EPoC PMD relative to the EPoC MAC.

The Idle control character insertion process (see Figure 101–18) is composed of the following:

a) A receive process, receiving 72-bit vectors from the 64B/66B Decoder and writing them into the Idle Insertion FIFO (called FIFO_II); and
b) A transmit process, reading 72-bit vectors from FIFO_II and transferring them to the XGMII.

The receive process receives 72-bit vectors from the 64B/66B Decoder at a slower data rate than the nominal XGMII data rate for the following two reasons:

1) The FEC parity data is removed within the FEC Decoder, leaving behind gaps in the data stream; and
2) The data rate supported by EPoC PCS and PMD is lower than the data rate expected by MAC Control Client, requiring data rate adaptation between the PCS and MAC.

The transmit process outputs 72-bit vectors at the nominal XGMII data rate.

To match the difference in data rates between the receive process and the transmit process, the Idle control character insertion process inserts additional 72-bit vectors containing Idle control characters. The additional blocks are inserted between frames and not necessarily at the same locations where FEC parity data was removed within the FEC Decoder.

101.3.3.3.1 Constants

IDLE_VECTOR
TYPE: 72-bit binary array
This constant represents a 72-bit vector containing Idle control characters.

LBLOCK_R
This constant is defined in 49.2.13.2.1.

101.3.3.3.2 Variables

BEGIN
TYPE: Boolean
This variable is used when initiating operation of the state diagram. It is set to TRUE following initialization and every reset.

FIFO_II
TYPE: Array of 72-bit vectors
The FIFO_II buffer is used to perform data rate adaptation between XGMII data rate and the EPoC PMD data rate. Upon initialization, all elements of this array are filled with instances of IDLE_VECTOR. The FIFO_II buffer has the size of *FIFO_II_SIZE* (see 101.3.3.3.1).

FIFO_II_SIZE
TYPE: 16-bit unsigned integer
This variable represents the size of Idle Insertion FIFO buffer. The size of this buffer is selected in such a way that it is able to accommodate the number of 66-bit vectors sufficient to fill the gap introduced by removing the FEC parity data for a maximum size MAC frame, and compensate for the maximum supported difference between the MAC rate and PMD rate. *FIFO_II_SIZE* is dependent on the line rate the PHY is operating at and may need to be adjusted whenever the profile is changed.

RX_CLK
TYPE: Boolean
This variable represents the *RX_CLK* signal defined in 46.3.2.1.

rx_raw_in<71:0>
TYPE: 72-bit binary array
This variable represents a 72-bit vector received from the output of the 64B/66B Decoder. *RXD*<0> through *RXD*<31> for the second transfer are placed in *rx_raw*<40> through *rx_raw*<71>, respectively.

rx_raw_out<71:0>
TYPE: 72-bit binary array
This variable represents a 72-bit vector passed from the Idle control character insertion process to XGMII. The vector is mapped to two consecutive XGMII transfers as follows:
Bits *rx_raw*<3:0> are mapped to *RXC*<3:0> for the first transfer.
Bits *rx_raw*<7:4> are mapped to *RXC*<3:0> for the second transfer.
Bits *rx_raw*<39:8> are mapped to *RXD*<31:0> for the first transfer.
Bits *rx_raw*<71:40> are mapped to *RXD*<31:0> for the second transfer.

countVector
TYPE: 16-bit unsigned integer

This variable represents the number of 72-bit vectors stored in the *FIFO_II* at the given moment of time.

101.3.3.3.3 Functions

T_TYPE(*rx_raw*<71:0>)
This function is defined in 49.2.13.2.3.

101.3.3.3.4 Messages

DECODER_UNITDATA.indicate(*rx_raw*_in<71:0>)
A signal sent by the EPoC PCS Receive process, conveying the next received 72-bit vector.

DUDI
Alias for DECODER_UNITDATA.indicate(*rx_raw*_in<71:0>).

101.3.3.3.5 State diagrams

The CLT and CNU PCS shall perform the Idle control character insertion process as shown in Figure 101–18.

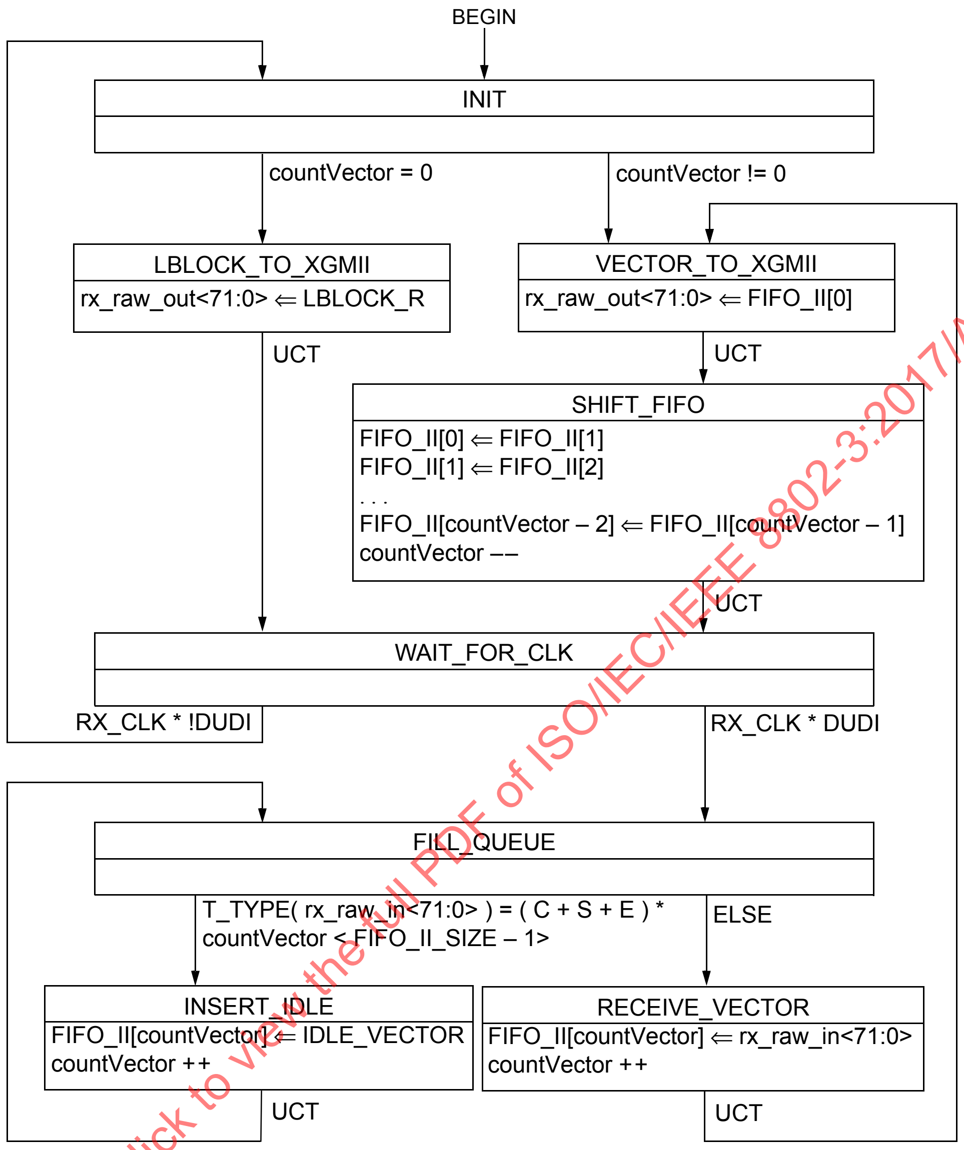


Figure 101–18—Idle control character insertion process state diagram

101.4 10GPASS-XR PMA

101.4.1 Overview

This subclause defines the Physical Media Attachment (PMA) for 10GPASS-XR, supporting operation over the point-to-multipoint coaxial cable distribution networks. The 10GPASS-XR PMA is specified to support the operation of up to 10 Gb/s in the downstream direction and up to 1.6 Gb/s in the upstream direction, where the upstream and downstream data rates are configured independently.

Figure 101–5 shows the relationship between the 10GPASS-XR PMA sublayer and the ISO/IEC OSI reference model. Figure 101–1 illustrates the CLT transmitter functional block diagram, including the PMA, while Figure 101–2 illustrates the CNU transmitter functional block diagram. Figure 101–3 and Figure 101–4 illustrate the functional block diagram of the receive path in the CLT and CNU, respectively in the 10GPASS-XR PMA.

The transmit PMA sublayer translates a serial data stream into a stream of I/Q value pair and channel number using the following functions: data scrambler, symbol mapper, interleaver (CLT only), Pilot Insertion, Inverse Discrete Fourier Transform (IDFT), and Cyclic Prefix insertion. The receive PMA sublayer translates a stream of I/Q value pair and channel number into a serial data stream using the following functions: Fast Fourier Transform (FFT), equalization, Pilot processing, de-interleaver (CNU only), symbol de-mapper, and data descrambler.

101.4.2 PMA Service Interface

The EPoC PMA provides a Service Interface to the 10GPASS-XR PCS sublayer, i.e., the PMA client. These services are described in an abstract manner and do not imply any particular implementation. The PMA Service Interface shall support the exchange of data between the PMA and the PMA client.

The PMA inputs serial data from the PCS and, after processing, passes serial data to the PMD and vice versa. It also generates an additional status indication for use by its client.

The following primitives are defined:
PMA_UNITDATA.request(tx_data_bit<bit>, *burstStart*, *burstEnd*)
PMA_UNITDATA.indication(rx_data_bit<bit>, *burstStart*, *burstEnd*)

101.4.2.1 PMA_UNITDATA.request

This primitive defines the transfer of data (in the form of data bits) from the PMA client to the PMA and notifies the PMA of the start and the end of the data burst.

PMA_UNITDATA.request is generated by the PMA client's transmit process.

101.4.2.1.1 Semantics of the service primitive

PMA_UNITDATA.request(tx_data_bit<bit>, *burstStart*, *burstEnd*)

The data conveyed by PMA_UNITDATA.request is a single data bit which has been prepared for transmission by the PMA client. The Boolean variable *burstStart* is set to TRUE when the data bit is the first bit at the start of transmission burst, and is set to FALSE otherwise. The Boolean variable *burstEnd* is set to TRUE when the data bit is the last bit of a transmission burst, and is set to FALSE otherwise. In the downstream direction, the CLT transmission burst is composed of a single FEC codeword; whereas, in the CNU upstream, the burst may include one or more concatenated FEC codewords (see 101.3.2.5.3).

101.4.2.1.2 When generated

The PMA client continuously sends data bits to the PMA at a nominal rate of *DS_DataRate* in the downstream direction. In the upstream direction, the nominal rate is *US_DataRate* during a burst. Refer to 100.3.2.2.

NOTE 1—*DS_DataRate* is calculated by the PMA after the downstream PHY has been configured. It is based on the sum of the available data bits per subcarrier over the timespan of a downstream OFDM frame consisting of 128 modulation symbols. *DS_DataRate* is a constant during the span of the PHY configuration. If re-configured, *DS_DataRate* is re-calculated.

NOTE 2—*US_DataRate* is calculated by the PMA after the upstream PHY has been configured. It is based on the sum of the available data bits per Resource Element over the timespan of the upstream superframe consisting of 256 symbols plus 6 Probe Period symbols. *US_DataRate* is a constant during the span of the PHY configuration. If reconfigured, *US_DataRate* is recalculated.

101.4.2.1.3 Effect of receipt

Upon receipt of this primitive, the PMA Symbol Mapper transfers the data bit into the OFDM frame.

In the CLT and upon the start of a downstream OFDM frame and when *burstStart* is TRUE, the PMA Symbol Mapper updates the FEC Codeword Pointer (FCP) in the downstream PHY Link. See 101.4.3.8.

In the CNU, both *burstStart* and *burstEnd* parameters are used by the upstream Symbol Mapper for placing start and end burst markers, respectively, into the appropriate Resource Elements. See 101.4.4.8.

101.4.2.2 PMA_UNITDATA.indication

This primitive defines the transfer of data in the form of bits from the PMA to its client. PMA_UNITDATA.indication is used by the client's receive path process.

101.4.2.2.1 Semantics of the service primitive

PMA_UNITDATA.indication(rx_data_bit<bit>, *burstStart*, *burstEnd*)

The data conveyed by PMA_UNITDATA.indication is single data bit that has been prepared by the PMA receive process to the PMA client. The Boolean variable *burstStart* is set to TRUE when the data bit is the first bit at the start of received burst, and is set to FALSE otherwise. The Boolean variable *burstEnd* is set to TRUE when the data bit is the last bit of a received burst, and is set to FALSE otherwise.

101.4.2.2.2 When generated

The PMA sends one rx_data_bit <bit> to the PMA client corresponding to the receipt of each bit of received from the receiver Symbol De-Mapper.

In the CNU, the PMA continuously sends data bits to the PMA client at a nominal rate of *DS_DataRate* in the downstream direction. In the upstream direction, the nominal rate is *US_DataRate* during a burst. Refer to 100.3.2.1 and 100.3.2.2.

101.4.2.2.3 Effect of receipt

The effect of receipt of this primitive by the client is specified in 101.3.3.

101.4.3 Downstream PMA transmit function

101.4.3.1 Overview

The downstream PMA transmit functional diagram is shown in Figure 101–2. The PMA supports five 190 MHz wide OFDM channels; each containing 3800 active subcarriers. Each OFDM channel is associated with the following processing functions: Time and Frequency Interleaver (see 101.4.3.9), Pilot Insertion (see 101.4.3.10), IDFT (see 101.4.3.11), and cyclic prefix and Windowing (see 101.4.3.12). The outputs of each OFDM channel are digitally combined. All OFDM channels follow the same frame timing and use the same OFDM Clock (see 100.4.4), cyclic prefix size, and window size.

OFDM channel 1 shall always be enabled but is muted during RxMER testing (see 100.4.2). Optional OFDM channels 2, 3, 4, and 5 are enabled when configured for operation via the *DS_ChCnt* variable. When enabled, each OFDM channel is configured for placement in the downstream RF frequency band of the coax cable distribution network (see Figure 100–1). The encompassed spectrum of any OFDM channel does not overlap with that of any other OFDM channel. The tight time skew requirements (see Table 101–7) permit the active edge subcarrier of one OFDM channel to be placed immediately adjacent to that of the adjacent OFDM channel without any guard band. CLTs shall declare the number of downstream OFDM channels it supports via the *DS_OFDM_ChAbility* variable.

The Symbol Mapper distributes PCS data over all active subcarriers that are configured to carry data (subcarriers that are not configured as excluded are active subcarriers). See 101.4.3.8.

The PHY Link is processed by the OFDM channel 1 IDFT and cyclic prefix and Windowing functions.

101.4.3.2 Time and frequency synchronization

This subclause specifies the timing and frequency synchronization requirements for CLT transmitters and CNU receivers.

The purpose of this subclause is to help ensure that the CLT transmitter can provide proper timing and frequency references for EPoC downstream OFDM operation and that the CNU receiver can acquire the system timing and subcarrier from the downstream for proper EPoC operation.

The CLT downstream OFDM symbol and subcarrier frequency and timing relationship is defined in 101.4.3.3.

Tolerances for the downstream Subcarrier Clock frequency are specified in this subclause (Table 101–7). Downstream Subcarrier Clock frequency and downstream signal generation are detailed in 101.4.3.3. The Subcarrier Clock frequency tolerance performance is coupled to the phase noise requirements of Table 100–4 and the downstream OFDM Clock requirements as follows:

— Each cycle of the downstream Subcarrier Clock is 4096 cycles (50 kHz subcarrier spacing) of the downstream OFDM Clock frequency (which is nominally 204.8 MHz).
— The downstream Subcarrier Clock waveform is locked to the 10.24 MHz Master Clock frequency (see Table 100–3, 101.4.3.3, and Equation (101–6)).
— The downstream OFDM Clock jitter requirements in Table 101–7 shall apply equivalently to the downstream Subcarrier Clock and its harmonics.

NOTE—The requirements on the OFDM Clock are effectively measured on observables in the downstream waveform, which include the downstream Subcarrier Clock frequency (manifested in the subcarrier spacing) and downstream subcarrier frequencies.

CLT transmitters and CNU receivers shall conform to the requirements given in Table 101–7.

Table 101–7—Downstream time and frequency synchronization

Item	Requirement
OFDM Clock jitter	1) < [–21 + 20×$\log_{10}$ (f_{DS} /204.8)] dBc (i.e., < 0.07 ns RMS) 10 Hz to 100 Hz 2) < [–21 + 20×$\log_{10}$ (f_{DS} /204.8)] dBc (i.e., < 0.07 ns RMS) 100 Hz to 1 kHz where f_{DS} is the frequency of the measured downstream OFDM Clock in MHz.[a]
Inter-OFDM channel time skew	156.25 ns
CNU Timing Acquisition Accuracy	Better than 1 OFDM Clock period (1/204.8 MHz).
Acquisition time	< 60 seconds

[a] The CLT uses a value of f_{DS} that is an integral multiple or divisor of the downstream OFDM Clock frequency. For example, an f_{DS} = 409.6 MHz clock may be measured if there is no explicit 204.8 MHz clock available.

The CLT shall lock the 204.8 MHz downstream OFDM Clock and downstream OFDM RF transmissions to the CLT 10.24 MHz Master Clock (Table 100–3).

Inter-OFDM channel time skew is defined as the maximum transmission time skew between any two OFDM channels.

The CNU timing acquisition accuracy for the downstream clock timing is defined with respect to downstream PHY Link frame. The CNU shall adjust its 10.24 MHz Master Clock to synchronize its own clock timing with PHY Link frame for proper operation. The CNU acquires downstream clock timing from the downstream signal (pilots, preambles, or mixed pilots, preambles, and data).

Downstream OFDM channel acquisition time for a CNU is defined as the time required for a single CNU with no previous network frequency plan knowledge to achieve downstream signal acquisition (frequency and time lock, see Table 101–7).

In addition to meeting the clock jitter requirements given previously, the CLT is required to meet the phase noise specifications defined in Table 100–4. In the event of a conflict between the clock jitter and the phase noise requirement, the CLT shall meet the more stringent requirement.

101.4.3.3 Subcarrier clocking

The synchronization of the Subcarrier Clock and subcarrier frequency are defined and characterized by the following rules:

- Each OFDM symbol is defined with an FFT duration (equal to Subcarrier Clock period) of 20 µs. For each OFDM symbol, the Subcarrier Clock period (µs) may vary from nominal with limits defined in Table 101–7.
- The number of OFDM Clock periods (1/204.8 MHz) of each subcarrier generated by the CLT during one period of the Subcarrier Clock is an integer number. The CLT Subcarrier Clock shall be synchronous with the 10.24 MHz Master Clock defined by the following:

$$SC_f = ((2 \times 10)/4096) \times MC_f \quad (101\text{–}6)$$

where
SC_f is the Subcarrier Clock frequency
MC_f is the 10.24 MHz Master Clock frequency (see Table 100–3)

- The limitation on the variation from nominal of the Subcarrier Clock frequency at the output connector is defined in 101.4.3.2.
- Each OFDM symbol has a cyclic prefix that is an integer multiple of 1/128th, of the Subcarrier Clock period.
- Each OFDM symbol duration is the sum of one Subcarrier Clock period and the cyclic prefix duration.
- The carrier frequency (i.e., the center frequency of the N-th subcarrier) is an integer multiple of the subcarrier spacing and may contain phase noise with limits defined in Table 100–4. The number of cycles for each subcarrier generated by the CLT during an OFDM symbol duration (Sym_T) shall be as given in Equation (101–7).

$$Sym_T = K + K \times L/128 \quad (101\text{–}7)$$

where
K is an integer equal to the nominal RF frequency of the subcarrier (Hz) divided by the nominal subcarrier spacing (Hz)
L is an integer related to the cyclic prefix as shown in Equation (101–8)

$$L = 128 \times (DSNcp \times 10^{-6}) \times 50000 \quad (101\text{–}8)$$

101.4.3.4 Subcarrier configuration and bit loading

Each subcarrier in an OFDM channel is configured using the *DS_ModTypeSC(n)* variables (where $0 \le n \le 4095$) in conjunction with *DS_OFDM_ID*. The OFDM channel being configured is determined by *DS_OFDM_ID*. The *DS_ModTypeSC(n)* variables configure each subcarrier to be nulled, to be a continuous pilot, to have a specific bit loading (such as 512-QAM or 1024-QAM), or to be excluded. Subcarrier configuration in an EPoC OFDM channel of 192 MHz shall conform to the rules outlined in Table 101–8.

All CNUs and the CLT in an EPoC network share the same downstream subcarrier configuration and bit loading including nulled subcarriers, continuous pilots, bit loaded subcarriers, and excluded subcarriers.

An EPoC PHY shall declare which of the optional modulation types listed in Table 100–2 it supports via the *DS_ModAbility* and *US_ModAbility* variables.

Table 101–8—Downstream subcarrier configuration rules

Parameter	Limit	Unit
Minimum number of active subcarriers in a contiguous group	40	subcarriers
Minimum OFDM channel guard band	1	MHz
Maximum excluded spectrum in the encompassed spectrum	20	%

101.4.3.4.1 Nulled subcarriers

Nulled subcarriers do not carry MAC or PHY Link data but may be used as pilots. Nulled subcarriers are BPSK modulated using the pseudo-random sequence generated by the 13-bit linear feedback shift register, illustrated in Figure 101–28 except when being used as a scattered pilot in the downstream direction (see 101.4.3.6.1).

101.4.3.4.2 Continuous pilots

In the downstream direction continuous pilots are used to help delineate the downstream PHY Link (see 101.4.3.6.2).

101.4.3.4.3 Bit loaded subcarriers

When a subcarrier is used to carry MAC data it uses the modulation type of QPSK or 2^n-QAM, where the integer n is $4 \le n \le 12$, assigned via the *DS_ModTypeSC(n)* variable except when used as a downstream scattered Pilot (see 101.4.3.6.1).

There is at least one contiguous 22 MHz or greater band of active subcarriers with an assigned non-zero bit loading in any single 192 MHz OFDM channel. This 22 MHz band may include subcarriers intended as Pilots and PHY Link subcarriers. A 1 MHz guard band of excluded subcarriers above and below this 22 MHz creates a minimum width OFDM channel of 22 MHz encompassed spectrum.

101.4.3.4.4 Excluded subcarriers

An EPoC PHY shall not transmit energy into a subcarrier that has been excluded from the OFDM channel (i.e., excluded subcarriers have zero amplitude). Typically there is a band edge Exclusion Band at both the top and bottom of the OFDM channel and there may be up to 14 exclusion bands internal to a single 192 MHz OFDM channel.

101.4.3.4.5 PHY Link managed variables

DS_ModAbility

TYPE: 5-bit binary

This bit mapped variable is used to declare which optional modulation types the PHY supports in the downstream direction for the MAC data path. When a bit read as TRUE it indicates that the PHY supports that modulation type.

Bit	Modulation type
0	8-QAM
1	16-QAM
2	32-QAM
3	8192-QAM
4	16384-QAM

DS_ModTypeSC(n)

TYPE: 4-bit binary

This set of variables determines the modulation parameters for each of the 4096 downstream OFDM subcarriers ($0 < n < 4095$). Each variable controls one of the 4096 subcarriers that are transmitted over an OFDM channel, with *DS_ModTypeSC(0)* controlling subcarrier zero, *DS_ModTypeSC(1)* controlling subcarrier 1, etc. The assignment of bits to each modulation type is shown below:

bit 3 2 1 0
1 1 1 1 = Excluded subcarrier
1 1 1 0 = 16384-QAM
1 1 0 1 = 8192-QAM
1 1 0 0 = 4096-QAM
1 0 1 1 = 2048-QAM
1 0 1 0 = 1024-QAM
1 0 0 1 = 512-QAM
1 0 0 0 = 256-QAM
0 1 1 1 = 128-QAM
0 1 1 0 = 64-QAM
0 1 0 1 = 32-QAM
0 1 0 0 = 16-QAM
0 0 1 1 = 8-QAM
0 0 1 0 = QPSK
0 0 0 1 = reserved (used by PHY for continuous pilots only, if set via MDIO to this value the PHY treats the subcarrier as null)
0 0 0 0 = null (carries no data but used for Wideband Probing)

DS_OFDM_ChAbility

TYPE: 3-bit integer

This variable indicates the number of OFDM channels the PHY is able to support in the downstream direction. The value of these bits is between 1 and 5 inclusive.

DS_OFDM_ID

TYPE: 3-bit integer

This variable is a pointer to one of the five possible OFDM channels in the downstream EPoC network. Thus when *DS_OFDM_ID* is set to a value of one variables *DS_ModTypeSC(n)* reflect the OFDM descriptor for OFDM channel one. When *DS_OFDM_ID* is set to a value of two variables *DS_ModTypeSC(n)* reflect the OFDM descriptor for OFDM channel two, etc.

101.4.3.5 Framing

The downstream OFDM frame is synchronized to the downstream PHY Link frame and the downstream Timestamp (see 102.2). Each downstream OFDM frame is composed of 128 OFDM symbols as illustrated in Figure 101–19 and Figure 102–1. The first 8 symbols of the downstream OFDM frame coincide with the 8 downstream symbols of the downstream PHY Link preamble. The Timestamp marks the first subcarrier of the first symbol after the Preamble (see Figure 102–11).

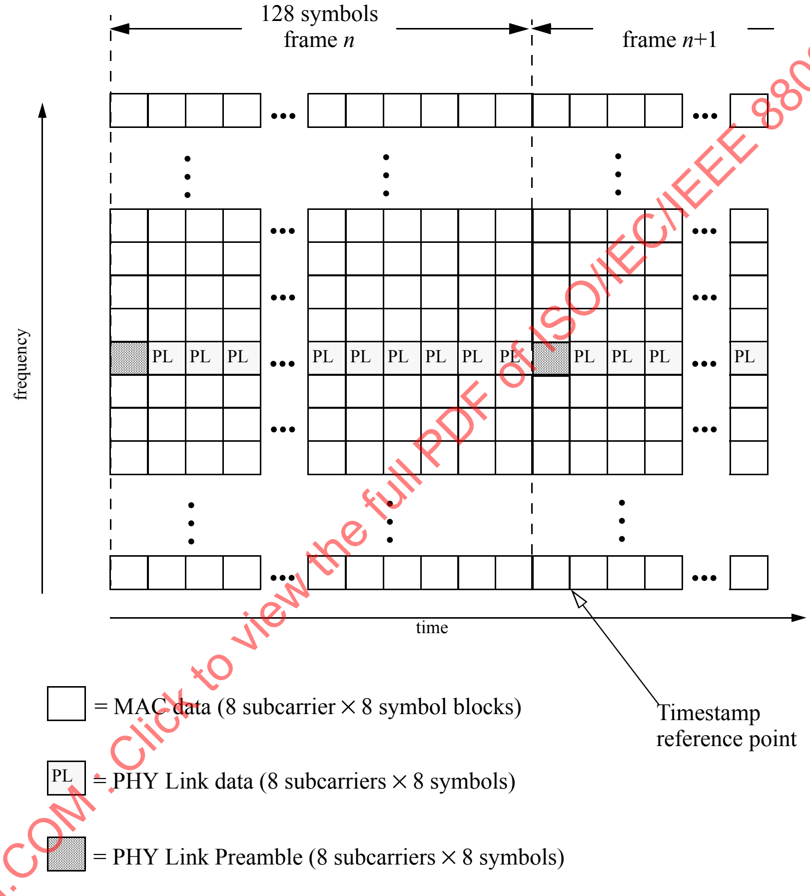


Figure 101–19—Downstream OFDM frame structure

101.4.3.6 Pilot map

Downstream pilots are composed of subcarriers modulated with a predefined data sequence known to all CNUs. The pilot data sequence is conveyed via the Pilot Insertion function (see 101.4.3.10 and Figure 101–1). Pilot Insertion follows time and frequency interleaving, before IDFT processing.

There are two types of downstream pilots: continuous and scattered. Scattered pilots occur at different frequency locations in different symbols in a repeating cyclic pattern. Continuous pilots occur at fixed frequencies in every symbol.

101.4.3.6.1 Scattered pilots

The scattered pilot pattern is synchronized to the PHY Link as illustrated in Figure 101–20. The first OFDM symbol after the PHY Link preamble has a scattered pilot in the subcarrier just after the highest frequency subcarrier of the PHY Link.

The remainder of the scattered pilot pattern is placed so that in each symbol scattered pilots occur every 128 subcarriers. From symbol to symbol, scattered pilots are shifted by one subcarrier position in the direction of the increasing frequency. This will result in scattered pilots placed in the exclusion band and in the 400 kHz PHY Link band, such scattered pilots are not transmitted.

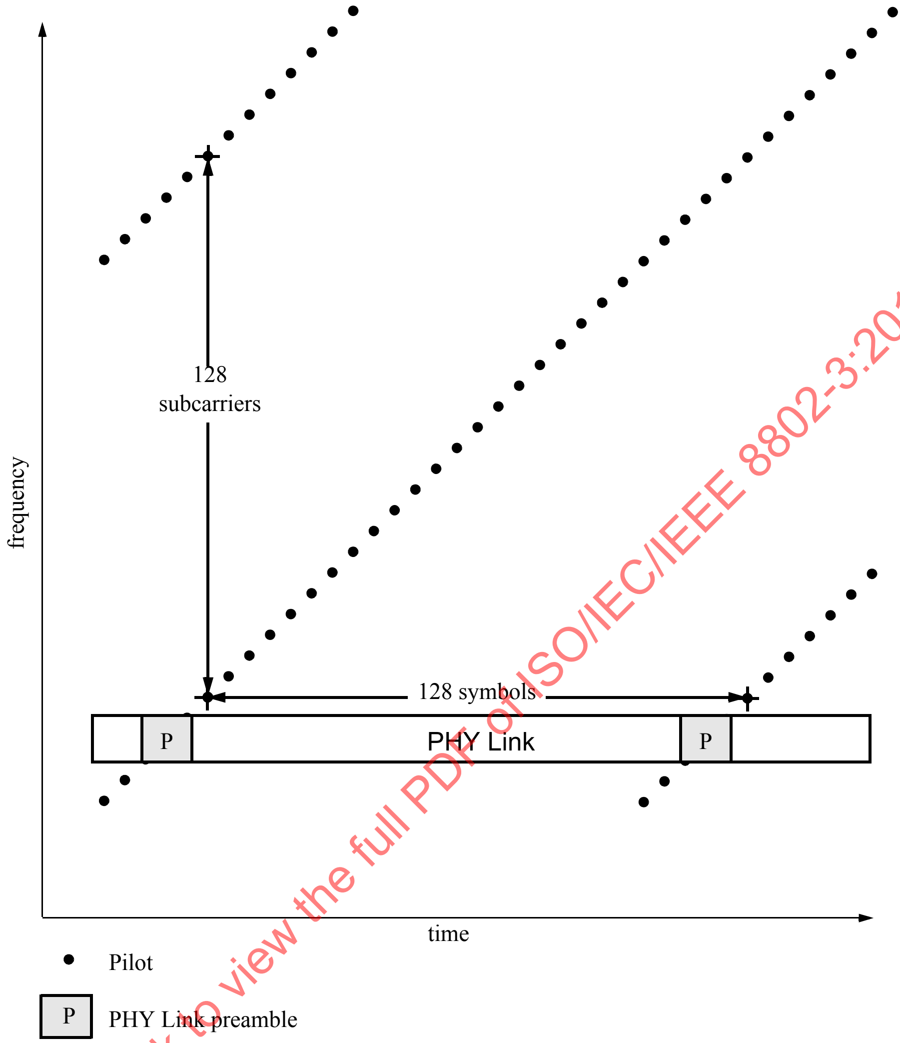


Figure 101–20—Downstream scattered pilot pattern

Mathematically, the scattered pilot pattern shall be defined as follows:

Let a subcarrier just after the PHY Link preamble be referred to as $x(m,n)$,

where

m is the frequency index
n is the time index (i.e., the OFDM symbol number)

The scattered pilots in the 128 symbols following (and including symbol n) are given by:

Symbol n:$x(n, m\pm128i)$, for all non-negative integers i
Symbol $(n+1)$:$x(n+1, m\pm128i + 1)$, for all non-negative integers i
Symbol $(n+2)$:$x(n+2, m\pm128i + 2)$, for all non-negative integers i
...
Symbol $(n+127)$:$x(n+127, m\pm128i + 127)$, for all non-negative integers i

Each of the above locations is a scattered pilot, provided that it does not fall on a continuous pilot, on the PHY Link, on an exclusion zone or on an excluded subcarrier. If the scattered pilot coincides with a continuous pilot it is treated as a continuous pilot and not as a scattered pilot.

This pattern repeats every 128 symbols. That is, symbol ($128+n$) has the same scattered pilot pattern as symbol n.

101.4.3.6.2 Continuous pilots

Continuous pilots occur at the same frequency location in all symbols and are used for receiver synchronization. Placement of continuous pilots is determined in one of the following two ways:

1) Predefined continuous pilot placement around the PHY Link (see Figure 102–7), or
2) Continuous pilot placement defined via PHY Link instructions.

Note that continuous and scattered pilots can overlap; the amount of overlap, in terms of number of carriers, changes from symbol to symbol. Overlapping pilots are treated as continuous pilots.

101.4.3.6.3 Predefined continuous pilots around the PHY Link

As discussed in 102.2, the PHY Link is placed at the center of a 6 MHz spectral region. Four pairs of predefined continuous pilots shall be placed symmetrically around the PHY Link as shown in Figure 102–7 at the distances indicated in Table 101–9. The spacing between each pilot pair and the PHY Link are different to prevent all pilots from being impacted at the same time by echo or interference.

The locations of the continuous pilots are defined with reference to the edges of the PHY Link band. Hence, once the PHY Link has been detected, these continuous pilots also become known to the receiver.

Table 101–9 provides the values of d_1, d_2, d_3, and d_4, measured in number of subcarriers from the PHY Link edge. That is, d_x is the absolute value of the difference between the index of the continuous pilot and the index of the PHY Link subcarrier at the PHY Link edge nearest to the continuous pilot. The index of a subcarrier is the integer k of the IDFT definition given in 101.4.3.11. For example, let the lowest frequency subcarrier of the PHY Link have the IDFT index k equal to 972. Then according to Table 101–9 the continuous pilot nearest to this lowest frequency PHY Link subcarrier will have the IDFT index k of (972 – 15) = 957. The index k of the highest frequency PHY Link subcarrier of this OFDM channel is 979. Hence continuous pilot that is nearest upper frequency edge of the PHY Link has an index k of 994.

For each distance (d_x) defined in Table 101–9, the CLT places two pilots: one d_x subcarriers above and one d_x subcarriers below the edge of the PHY Link band.

Table 101–9—Subcarrier distances for placement of predefined pilots

	d_1	d_2	d_3	d_4
PHY Link 8 subcarriers	15	24	35	47

101.4.3.6.4 Continuous pilot placement defined by PHY Link message

The CLT defines a set of continuous pilots distributed as uniformly as possible (see paragraphs that follow) over the entire OFDM spectrum in addition to the predefined continuous pilots described in 101.4.3.6.3.

The CLT ensures that there are no isolated active OFDM spectral regions that are not covered by continuous pilots.

The CLT provides the continuous pilot placement definition via the 10GPASS-XR downstream profile descriptor variables *DS_ModTypeSC(n)* using the PHY Link EPoC message block format contained in 102.2.3.3.

The CLT shall place continuous pilots (excluding the eight continuous pilots around the PHY Link) per the following eight steps after calculating a value for N_{PC} using Equation (101–9). This calculation occurs as the first step of activating a downstream profile (see 102.2.3.1.1).

The CLT obtains the value of N_{PC} using Equation (101–9):

$$N_{PC} = min\left(max\left(8, \left\lceil CntPltSF \times \left(\frac{F_{max} - F_{min}}{190 \times 10^6}\right)\right\rceil\right), 120\right) \quad (101\text{–}9)$$

where

F_{max} refers to frequency in Hz of the highest frequency active subcarrier of the OFDM channel
F_{min} refers to frequency in Hz of the lowest frequency active subcarrier of the OFDM channel
CntPltSF is the continuous pilot scaling factor

The number of continuous pilots is between 16 and 128. This range includes the eight continuous pilots around the PHY Link channel.

The value of *CntPltSF* in Equation (101–9) is kept as a parameter that can be adjusted by the CLT.

NOTE—The typical value proposed for *CntPltSF* is 48.

Step 1:

Merge all the subcarriers between F_{max} and F_{min} eliminating the following:

1) Exclusion bands
2) 6 MHz band containing the PHY Link

Let the merged frequency band be defined as the frequency range [0, $F_{mergedmax}$].

Step 2:

Define a set of N_{PC} frequencies using the following equation:

$$F_i = \frac{F_{mergedmax}}{2N_{PC}} + \frac{i \times F_{mergedmax}}{N_{PC}}, \text{ for } i = 0, 1, \ldots, N_{PC} - 1 \quad (101\text{–}10)$$

This yields a set of uniformly spaced N_{PC} frequencies:

$$\left\{\frac{F_{mergedmax}}{2N_{PC}}, \frac{3F_{mergedmax}}{2N_{PC}}, \ldots, F_{mergedmax} - \frac{F_{mergedmax}}{2N_{PC}}\right\} \quad (101\text{–}11)$$

Step 3:

Map the set of frequencies given above to the nearest subcarrier locations in the merged spectrum. This will give a set of N_{PC} approximately uniformly spaced subcarriers in the merged domain.

Step 4:

De-merge the merged spectrum through the inverse of the operations through which the merged spectrum was obtained in step 1.

Step 5:

If any continuous pilot is within 1 MHz of a band edge, move this inwards (but avoiding subcarrier locations impacted by interferences like CSO/CTB) so that every continuous pilot is at least 1 MHz away from a band edge. This is to prevent continuous pilots from being impacted by external interferences. If the width of the spectral region does not allow the continuous pilot to be moved 1 MHz from the edge then the continuous pilot has to be placed at the center of the spectral region.

Step 6:

Identify any spectral regions containing active subcarriers (separated from other parts of the spectrum by exclusion bands on each side) that do not have any continuous pilots. Introduce an additional continuous pilot at the center of every such isolated active spectral region.

In the unlikely event that the inclusion of these extra pilots results in the total number of continuous pilots defined by PHY Link exceeding 120, return to step 1 and re-do the calculations after decrementing the value of N_{PC} by one.

Step 7:

Test for periodicity in the continuous pilot pattern and disturb periodicity, if any, through the perturbation of continuous pilot locations using a suitable algorithm. A simple procedure would be to introduce a random perturbation of up to ±5 subcarrier locations around each continuous pilot location, but avoiding subcarrier locations impacted by interferences like CSO/CTB.

Step 8:

The CLT transmits this continuous pilot pattern to the CNUs in the system and communicates the placement using the PHY Link.

101.4.3.6.5 PHY Link managed variables

CntPltSF

TYPE: 7-bit unsigned integer
This variable is used to determine the number of continuous pilots in the downstream OFDM channels.
$120 \geq CntPltSF \geq 48$.

101.4.3.7 Scrambler

The PHY shall scramble the output of the LDPC FEC encoding process using a linear feedback shift register mechanism as illustrated in Figure 101–21.

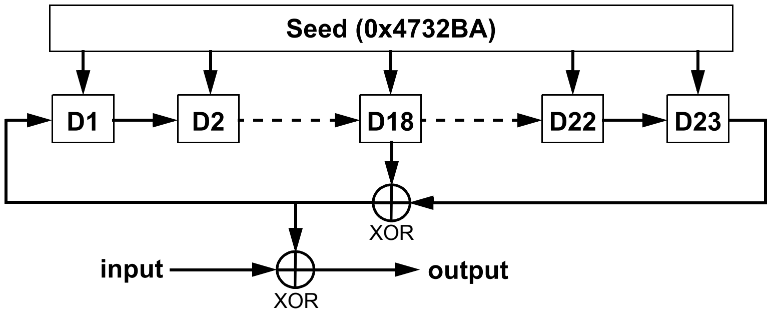


Figure 101–21—Scrambler

The scrambler is defined by the following polynomial.

$$x^{23} + x^{18} + 1$$

The scrambler is initialized to the hexadecimal value of 0x4732BA. The CLT shall initialize the scrambler at the first codeword of the downstream OFDM frame. The CNU shall initialize the scrambler with the hexadecimal value at the beginning of each grant.

101.4.3.8 Symbol mapper

101.4.3.8.1 Introduction

The Symbol Mapping function performs the following:

1) Initializes (resets) the scrambler function (see 101.4.3.7) and sets an *FCPbitCnt* to 1 (see 101.4.3.8.4), and initializes the mapping function with the lowest numbered active subcarrier.
2) Continually accepts a tx_unit (bit) from the Scrambler via the PMA_UNITDATA.request as well as monitors the Boolean state of *burstStart* and *burstEnd* (see 101.3.2.5.6) and the start of OFDM frame indication from the frame timing function. Also, the *FCPbitCnt* is incremented for each bit processed.
3) Per OFDM symbol, allocates scrambled tx_unit bits to all active OFDM data-carrying subcarriers (over all active channels) in ascending order based on a mapping configuration that anticipates frequency interleaving, staggered pilot placement and PHY Link signals per channel. While processing tx_unit bits, upon a start of frame indication, the bit counter is reset to one and the scrambler is reset before mapping the current bit to a subcarrier. Upon the next transition of *burstStart* = TRUE, the FCP update function calculates the next FCP value and updates the current PHY Link message (see 101.4.3.8.4).
4) Converts tx_unit bits to an array of QAM constellation points using a two-dimensional array with an I and Q “bin” value for each subcarrier and passes these values to the Interleaver.
5) When the last active subcarrier of the current symbol is completed, counter k is reset to 1 and processing of the next OFDM symbol begins.

The transmitter uses the number of bits per subcarrier as defined in Table 100–3 when bit mapping subcarrier (MAC) data to QAM constellations. Permissible modulation Types are listed in Table 100–2. QAM constellation mappings are described in 101.4.5.

101.4.3.8.2 Transmitter bit loading for symbol mapping

The excluded versus non-excluded (active) status, PHY Link use, continuous pilot placement, and bit loading pattern (profile) information for each subcarrier is provided by the Subcarrier Configuration and Bit Loading Function. This information is configured by management.

The notation $S^{(E)}$ is used here to define the non-empty set of excluded subcarriers.

The notation $S^{(C)}$ is used here to define the set of continuous pilots (see 101.4.3.6.2).

The notation $S^{(P)}$ is used here to define the set of PHY Link subcarriers (see 101.4.3.6.3).

For bit loading, continuous pilots and the PHY Link are treated in the same manner as excluded subcarriers; hence, the set of subcarriers that includes the PHY Link, continuous pilots and excluded subcarriers is defined as:

$$S^{(PCE)} = S^{(P)} \cup S^{(C)} \cup S^{(E)} \tag{101–12}$$

The subcarriers in the set $S^{(PCE)}$ do not carry MAC data (PHY Link carries signaling information).

Bit loading information includes the option for nulled subcarriers (i.e., subcarriers that are not use for data transport) and are BPSK modulated, as described in 101.4.5.2.

Scattered pilots do not occur at the same frequency in every symbol; in some cases scattered pilots will overlap with continuous pilots. If a scattered pilot overlaps with a continuous pilot, then that pilot is no longer considered to be a scattered pilot. It is treated as a continuous pilot.

Because the locations of scattered pilots change from one OFDM symbol to another, the number of overlapping continuous and scattered pilots changes from symbol to symbol. Since overlapping pilots are treated as continuous pilots, the number of scattered pilots changes from symbol to symbol.

The following notation is used here:

N:The total number of subcarriers in the OFDM symbol (4096 per OFDM channel)
N_C:The number of continuous pilots in an OFDM symbol
N_S:The number of scattered pilots in an OFDM symbol
N_E:The number of excluded subcarriers in an OFDM symbol
N_P:The number of PHY Link subcarriers in an OFDM symbol
N_D:The number of data subcarriers in an OFDM symbol
N_I:The number of scattered pilots and data subcarriers in the OFDM symbol

The values of N, N_C, N_E, and N_P do not change from symbol to symbol for a given OFDM template; the values of N_S and N_D change from symbol to symbol.

The following equations holds for all symbols:

$$N = N_C + N_S + N_E + N_P + N_D \tag{101–13}$$

$$N_I = N_S + N_D \tag{101–14}$$

Interleaving and de-interleaving are applied to the set of data subcarriers and scattered pilots of size N_I.

101.4.3.8.3 Bit loading

The bit loading pattern defines the QAM constellations assigned to each of the 4096 (N) subcarriers per OFDM channel of the OFDM transmission. Let the bit loading pattern per OFDM channel for configuration i be defined as $A_i(k)$, where:

k is the subcarrier index that goes from 0 to 4095

$A_i(k) \in \{0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14\}$. A value of 0 indicates that the subcarrier k is nulled. Other values indicate that the modulation of subcarrier k is QAM with order shown in Equation (101–15). See variable *DS_ModTypeSC(n)* defined in 101.4.3.4.5.

$$QAM\ order = 2^{A_i(k)} \quad (101\text{–}15)$$

The function $A_i(k)$ and subsequent bit loading functions are defined per OFDM channel as the interleaver function is replicated with identical operation per OFDM channel. As up to five OFDM channels are accommodated (refer to Table 101–12) with a labeling of 1 to 5 (L), the bit loading processing ordering is $L = \{1, 2, 3, 4, 5\}$. OFDM channel 1 is always present and contains active data subcarriers.

Downstream RF spectrum availability as well as device implementation will determine OFDM channel presence and actual subcarrier use. The symbol mapping function therefore shall process all active subcarriers per symbol across all OFDM channels.

Let the sequence

$\{A_i(k), k = 0, 1, \ldots, (N-1), k \notin S^{(PCE)}\}$ be arranged as N_I consecutive values of another sequence:

$B_i(k), k = 0, 1, \ldots, (N_I - 1)$.

Given the locations of the excluded subcarriers, continuous pilots and the PHY Link in the OFDM configuration, it is possible to obtain the bit-loading pattern $B_i(k)$ that is applicable only to spectral locations without excluded subcarriers, continuous pilots, and PHY Link subcarriers. However, note that $B_i(k)$ does contain the spectral locations occupied by scattered pilots; these locations change from symbol to symbol.

The bit loading pattern is defined in the domain in which subcarriers are transmitted on the media, however bit loading is processed prior to interleaving. As such there is a permutation mapping of subcarriers, defined by the interleaving function, between the domain in which bit loading is applied to subcarriers and the domain in which subcarriers are transmitted.

The total number of subcarriers that pass through the interleaver and de-interleaver is given in Equation (101–14) and does not change from symbol to symbol. The frequency interleaver introduces a one-to-one permutation mapping P on the N_I subcarriers.

NOTE—The corresponding permutation mapping applied at the receiver de-interleaver is P^{-1}.

The bit loading pattern at the input to the interleaver. This is given by:

$$C_i(k) = P^{-1}(B_i(k)) \quad (101\text{–}16)$$

The sequence $C_i(k)$ is obtained by sending $\{B_i(k), k = 0, 1, \ldots, N-1\}$ through the frequency de-interleaver.

Note that $C_i(k)$ gives the bit-loading pattern for N_I subcarriers per OFDM channel. Scattered pilots are avoided in the bit-loading process and identified by a two-dimensional binary pattern $D(k, j)$ per OFDM channel. The scattered pilot pattern has a periodicity of 128 in the time dimension, this binary pattern also has periodicity 128 in the column dimension j.

$D(k, j)$ is defined for $k = 0, 1, ..., (N_I - 1)$ and for $j = 0, 1, ..., 127$.

The binary pattern $D(k, j)$ begins with the transmitted scattered pilot pattern defined in 101.4.3.6.1.

The CLT executes the following steps to obtain the pattern $D(k, j)$:

1) Define a two-dimensional binary array $P(k, j)$ per OFDM channel in the subcarrier transmitted domain that contains a one for each scattered pilot location and zero otherwise:
   $P(k, j)$, for $k = 0, 1, ..., 4095$ and for $j = 0, 1, ..., 127$
   The first column of this binary sequence corresponds to the first OFDM symbol following the preamble of the PHY Link.
2) Exclude the rows corresponding to excluded subcarriers, continuous pilots, and PHY Link from the two-dimensional array $P(k, j)$ to give an array $Q(k, j)$. The number of rows of the resulting array is N_I and the number of columns is 128.
3) Pass this two-dimensional binary array $Q(k, j)$ through the frequency de-interleaver and then the time de-interleaver, with each column treated as an OFDM symbol. After the 128 columns of the pattern have been input into the interleaver, re-insert the first *DS_TmIntrlv* columns, where *DS_TmIntrlv* is the depth of the time interleaver. This is equivalent to periodically extending $Q(k, j)$ along the dimension j and passing (128 + *DS_TmIntrlv*) columns of this extended sequence through the frequency de-interleaver and the time de-interleaver.
4) Discard the first *DS_TmIntrlv* symbols coming out of the time de-interleaver and collect the remaining 128 columns into an array to give the binary two-dimensional array $D(k, j)$ of size ($N_I \times 128$).

For bit loading the CLT accesses the appropriate column j of the binary pattern bit $D(k, j)$ together with the appropriate bit loading profile $C_i(k, j)$. If the value of the bit $D(k, j)$ is 1, the CLT skips this subcarrier k and moves to the next subcarrier. This subcarrier is included as a placeholder for a scattered pilot that will be inserted in this subcarrier location after interleaving. After each symbol the column index j has to be incremented modulo 128.

The CLT uses this binary two-dimensional array $D(k, j)$ of size ($N_I \times 128$) in order to do bit-loading of OFDM subcarriers, as described earlier in this subclause.

The corresponding operation in the CNU is de-mapping the QAM subcarriers to get log-likelihood ratios corresponding to the transmitted bits. This operation, described below, is much simpler than the mapping operation in the transmitter.

The scattered pilots and data subcarriers of every received symbol are subjected to frequency and time de-interleaving. The scattered pilots have to be tagged so that these can be discarded at the output of the time and frequency de-interleavers. This gives N_I subcarriers for every OFDM symbol. The CNU accesses theses N_I de-interleaved subcarriers together with the bit-loading pattern $C_i(k)$ to implement the de-mapping of the QAM subcarriers into log-likelihood ratios. If the subcarrier k happens to be a scattered pilot, then this subcarrier, as well as the corresponding value $C_i(k)$, is skipped and the CNU moves to the next subcarrier (k +1).

101.4.3.8.4 FCP calculation

The FCP calculation is supplied by the Symbol Mapper via a function call UpdateFCP. The Symbol Mapper resets the bit counter, FCPbitCnt, to zero at the start of each downstream OFDM frame and increments it for every bit processed in the frame. On the first transition of *burstStart* to TRUE from the PMA_UNITDATA.request after the start of a new frame the Symbol Mapper calls the UpdateFCP function with the counter value. The UpdateFCP function calculates the next (new) FCP value based on the supplied value, the *DS_Frame_Data_Load* (see 100.3.2.1) and *FEC_DS_CodeWordSize* (see 101.3.2.5.2) per

Equation (101–17). The UpdateFCP function shall complete and pass the new FCP value to the PHY Link with sufficient time for insertion in the PHY Link frame currently being processed.

$$FCP = (FCPbitCnt + DS\_Frame\_Data\_Load) \bmod FEC\_DS\_CodeWordSize \quad (101\text{–}17)$$

where

FCPbitCnt is a counter reset to zero at the beginning of each downstream OFDM frame and is incremented for each bit that is transfered from the PMA service interface.

The downstream FEC Encoder is not aligned with the downstream OFDM frame, thus FEC codewords may straddle downstream OFDM frame boundaries. The CNU may use the FCP value in the received PHY Link messages to help locate the downstream FEC codewords. The FCP value indicates the starting bit position of the first full codeword in the next downstream OFDM frame. See 102.2.3.5.

101.4.3.9 Time and frequency interleaver

101.4.3.9.1 Overview

The CLT first applies a time interleaver to all N_I subcarriers of each OFDM symbol [see Equation (101–14)] across a group of *DS_TmIntrlv* OFDM symbols. The CLT then subjects each OFDM symbol containing these N_I time interleaved subcarriers to frequency interleaving. There is a single Time and Frequency interleaving function per OFDM channel for the MAC data path.

101.4.3.9.2 Time interleaving

The CLT shall time interleave after OFDM symbols have been mapped to QAM constellations and before they are frequency interleaved as described in this subclause.

The time interleaver is a convolutional interleaver that operates at the OFDM subcarrier level. If the depth of the interleaver is *DS_TmIntrlv*, then there are *DS_TmIntrlv* branches, as shown in Figure 101–22.

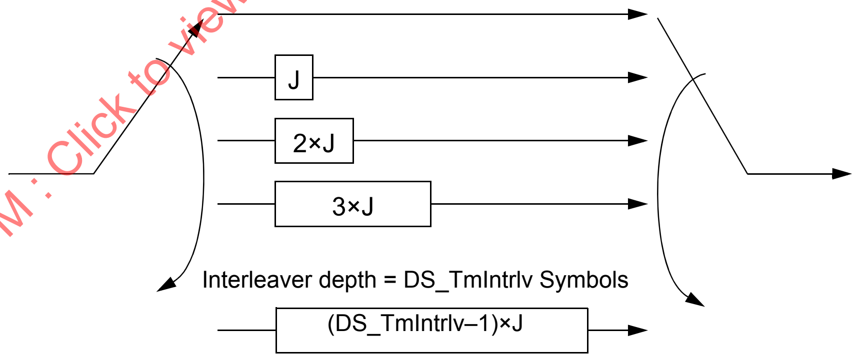


Figure 101–22—Time interleaver structure

The CLT shall support values of *DS_TmIntrlv* from 1 to 32 (see 101.4.3.9.5).

Each branch is a delay line; the input and output will always be connected to the same delay line. This delay line will be clocked to insert a new subcarrier's data into the delay line and to extract a subcarrier's data from the delay line. Next, the commutator switches the input and the output to the next delay line in the direction shown by the arrows in Figure 101–22. After the delay line with the largest delay, the commutator will move to the delay line with zero delay.

The lowest frequency subcarrier of an OFDM symbol always goes through the branch with zero delay. Then the commutator switch at input and the corresponding commutator switch at output are rotated by one position for every new subcarrier.

The value of J is given by the following equation:

$$J = \left\lceil \frac{N_{\mathrm{I}}}{DS\_\mathrm{TmIntrlv}} \right\rceil \qquad (101\text{–}18)$$

Where, N_{I} [see Equation (101–14)] is the number of data subcarriers and scattered pilots in an OFDM symbol.

If N_{I} is not divisible by *DS_TmIntrlv*, all of the branches are not filled. Therefore, "dummy subcarriers" are added to the symbol to make the number of subcarriers equal to a multiple of *DS_TmIntrlv*. The number of dummy subcarriers is given by:

$$J \times DS\_TmIntrlv - N_{\mathrm{I}} \qquad (101\text{–}19)$$

The dummy subcarriers are added for definition purposes only; at the output of the interleaver these dummy subcarriers are discarded.

101.4.3.9.3 Frequency interleaving

The CLT shall perform frequency interleaving after time interleaving; subcarriers containing continuous pilots, excluded subcarriers, or PHY Link data are not frequency interleaved.

The frequency interleaver works on individual OFDM symbols. Each symbol to be interleaved consists of N_{I} subcarriers indexed from 0 to $N_{\mathrm{I}} - 1$ in ascending frequency order. These N_{I} subcarriers are made up of N_{D} data subcarriers and N_{S} scattered pilot placeholders. Although N_{D} and N_{S} are not the same for every symbol, the value of N_{I} is a constant for all OFDM symbols in the downstream OFDM frame for a given system configuration.

Conceptually, frequency interleaving of each individual OFDM symbol is performed using memory arranged in a 2D store comprising 2^L rows and K columns where L and K are chosen depending on the size of the FFT used for creating the OFDM symbols. If the number of data subcarriers and scattered pilots in the OFDM symbol is N_{I}, then the number of columns, K, is given by the following equation:

$$K = \left\lceil \frac{N_{\mathrm{I}}}{2^L} \right\rceil \qquad (101\text{–}20)$$

If N_I is not an integer multiple of 2^L, then the last column will only be partially filled during the frequency interleaving process. The number of data subcarriers in the last column, C, is given by:

$$C = N_{\mathrm{I}} - 2^L(K-1) \qquad (101\text{–}21)$$

The frequency interleaver follows the following process; note that rows are numbered 0 to 2^L–1, and columns are numbered from 0 to *K–1*:

1) Write successive consecutive subcarriers into the 2D store in the row given by the *L*-bit CRC (cyclic redundancy check) value of each *L*-bit row address (Figure 101–25).
2) Rotate the subcarriers in each row written by the same *L*-bit CRC value of the row address modulo the number of columns in that row (either modulo *K* for a row below *C* or modulo *K*–1 for row *C* and higher) using a right circular shift (Figure 101–23a).
3) Rotate the subcarriers in each column by the *L*-bit CRC value of [*K*–1 minus the column address] using a downward circular shift (Figure 101–23b). Note that the last column *K*–1 with a CRC value of 0 is not rotated.
4) Read the subcarriers out of the 2D store column-wise from row 0, column 0 to row *C*–1, column *K*–1.

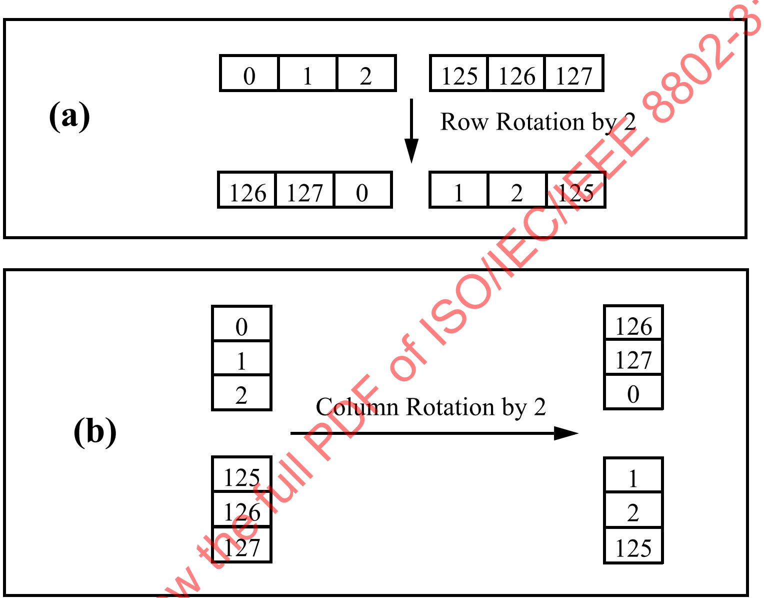


Figure 101–23—Rotation of subcarriers: a) Horizontal rows, b) Vertical columns

Assume that the input subcarriers of the OFDM symbol are initially arranged into the 2D store in sequential order column-wise from row 0, column 0 to row *C*–1, column *K*–1. The above procedure relocates each sequential input subcarrier number in row *r*, column *c* into a permuted output subcarrier number in the 2D store in that position in row *r*, column *c* as *sc(r,c)* given by Equation (101–22):

$$sc(r,c) = sc_0[(r - CRC(K-1-c))mod2^L] + (c - (r - CRC(K-1-c)mod2^L))modM \quad (101\text{–}22)$$

where $M = K$, for $(r - CRC(K - 1 - c))mod2^L < C$

otherwise $M = K–1$

$sc(r,c) \in [0,1,\ldots,N_I - 1]$ and $sc_0[n]$ is defined as an array of 2^L elements where each element contains the cumulative number of subcarriers previously written into the 2D store prior to writing into the permuted output row *n*. Note that if the last column contains fewer subcarriers than 2^L, the cumulative value in $sc_0[n]$

takes into account those previously written permuted output rows that were shorter by one subcarrier (i.e., those prior row addresses that were greater than or equal to C, the number of subcarriers in the last column).

The structure of the two-dimensional store is shown in Figure 101–24.

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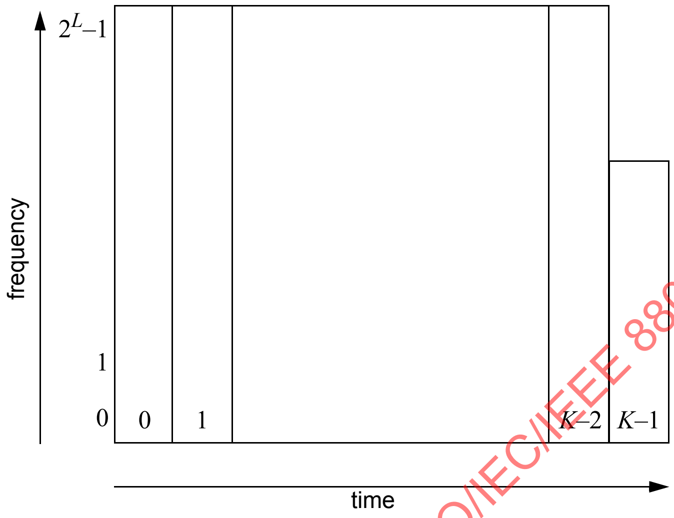


Figure 101–24—Two-dimensional store block structure

The m-stage linear feedback shift register for calculating the CRC of each row address is defined using a generator polynomial of degree $m = L$ in the finite (Galois) field GF[2]:

$$G(X) = g_m X^m + g_{m-1} X^{m-1} + g_{m-2} X^{m-2} + \ldots + g_2 X^2 + g_1 X^1 + g_0 \quad (101\text{–}23)$$

where the coefficients g_m corresponding to the feedback taps of the linear feedback shift register are chosen such that the resulting generator polynomial is primitive (i.e., if the polynomial is prime and cannot be factored, and if it is a factor that evenly divides X^N+1, where $N = 2^m–1$). This guarantees that each L-bit address for the 2^L rows is unique and the CRC values span the entire set of 2^L, L-bit addresses.

The linear feedback shift register implementing the generator polynomial is shown in Figure 101–25.

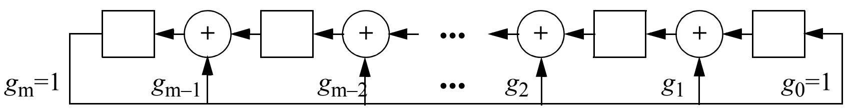


Figure 101–25—Row address linear feedback shift register

Calculation of the CRC c_{m-1}, c_{m-2}, …, c_1, c_0 for each row address b_{m-1}, b_{m-2}, …, b_1, b_0 using this linear feedback shift register structure is shown in Figure 101–26.

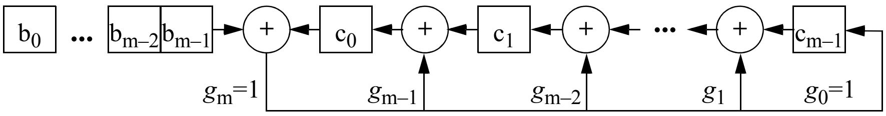


Figure 101–26—CRC calculation using a linear feedback shift register

The specific generator polynomial for the calculation of the CRC with $m = L = 6$ is given by:

$$G(X) = X^6 + X^1 + 1 \qquad (101–24)$$

The corresponding linear feedback shift register is shown in Figure 101–27.

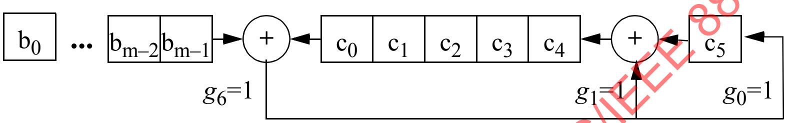


Figure 101–27—CRC calculation for $G(X) = X^6 + X^1 + 1$ with a linear feedback shift register

De-interleaving is accomplished by reversing the interleaving process described above. Each symbol to be de-interleaved consists of N_I subcarriers indexed from 0 to $N_I - 1$ in ascending frequency order. Assume that the input subcarriers of the interleaved OFDM symbol are arranged into the 2D store in sequential order column-wise from row 0, column 0 to row 2^L, column C.

The frequency de-interleaver performs the following process to reverse the interleaving process; note that rows are numbered from 0 to 2^L-1, and columns are numbered from 0 to $K-1$:

1) Write the subcarriers into the 2D store column-wise from column 0, row 0 to column $K-1$, row C.
2) Rotate the subcarriers in each column by the L-bit CRC value of [$K-1$ minus the column address] using an upward circular shift (reverse of Figure 101–25b). Note that the last column $K-1$ with a CRC value of 0 in not rotated.
3) Rotate the subcarriers in each row written by the same L-bit CRC value of the row address modulo the number of columns in that row (either modulo K for a row below C or modulo $K-1$ for row C and higher) using a left circular shift (reverse of Figure 101–25a).
4) Read the subcarriers out of the 2D store row-wise in the row order given by the L-bit CRC value of each L-bit row address skipping the last column at or beyond row C.

101.4.3.9.4 Interleaving impact on continuous pilots, scattered pilots, PHY Link and excluded spectral region

The CLT interleaves the subcarriers that are tagged to act as placeholders for scattered pilots. The actual BPSK modulation to these placeholder subcarriers is applied after interleaving as described in 101.4.3.9.2 and 101.4.3.9.3.

The CLT retains a reference pattern for inserting scattered pilot placeholders prior to interleaving. Since the scattered pilot pattern repeats every 128 symbols, this pattern is a ($N_I \times 128$) two-dimensional bit pattern. A value of one in this bit-pattern indicates the location of a scattered pilot. The CLT inserts data subcarriers where this reference pattern has a zero and scattered pilot placeholders where this pattern has a one.

This reference pattern may be derived from the following procedure:

1) In the time-frequency plane, create a two-dimensional bit-pattern of zeros and ones from the transmitted "diagonal" scattered pilot patterns described in 101.4.3.6.1. This pattern has a periodicity of 128 symbols and has a value of one for a scattered pilot location and zero otherwise. Let the time axis be horizontal and the frequency axis vertical.
2) Delete all horizontal lines containing continuous pilots, excluded subcarriers, and PHY Link from the above mentioned two-dimensional bit pattern; note that some scattered pilots could coincide with continuous pilots. These locations are treated as continuous pilot locations.
3) Send the resulting bit-pattern through the frequency de-interleaver and the time de-interleaver in succession. This will give another two-dimensional bit pattern that has a periodicity of 128 symbols. The appropriate 128-symbol segment of this bit-pattern is chosen as the reference bit pattern referred to above.

The synchronization of the scattered pilot pattern to the PHY Link preamble, as described in Figure 101–20 uniquely defines the 128-symbol segment that is used as the reference pattern.

Note that the number of OFDM subcarriers that are interleaved does not change from symbol to symbol. The insertion of continuous pilots, PHY Link, and excluded regions happens after both time and frequency interleaving. Interleaving is independent of individual subcarrier modulation and the modulation pattern of these data subcarriers may change from symbol to symbol.

101.4.3.9.5 PHY Link managed variables

DS_TmIntrlv

TYPE: 5-bit integer

This variable indicates the number of time interleaved OFDM symbols in the downstream direction. The value is between 1 and 32.

101.4.3.10 Pilot insertion

Continuous and scattered pilots shall be BPSK modulated using the pseudo-random sequence generated by the 13-bit linear feedback shift register, illustrated in Figure 101–28 with polynomial $(x^{13}+x^{12}+x^{11}+x^{8}+1)$ and described next.

This linear feedback shift register is initialized to all ones at the k=0 index of the discrete Fourier transform defining the OFDM signal (refer to 101.4.3.11). It is then clocked after every subcarrier of the IDFT. If the subcarrier is a pilot (scattered or continuous), then the BPSK modulation for that subcarrier is taken from the linear feedback shift register output.

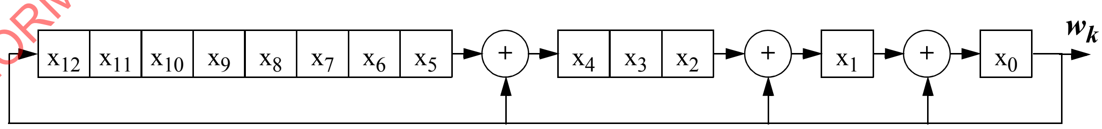


Figure 101–28—13-Bit Linear Feedback Shift Register for the pilot modulation Pseudo-Random Sequence

Let the output of the linear feedback shift register be w_k then BPSK modulation used for the pilot is:

w_k = 0: BPSK constellation point = 1 + j0

w_k = 1: BPSK constellation point = –1 + j0

101.4.3.10.1 Pilot boosting

All active subcarriers, with the exception of pilots, are transmitted with the same average power. The CLT shall multiply the real and imaginary components of continuous and scattered pilots by a real-valued number such that the amplitude of the continuous and scattered pilots is twice the root-mean-square value of the amplitude of other subcarriers of the OFDM symbol. That is, continuous and scattered pilots are boosted by approximately 6 dB with reference to other subcarriers.

101.4.3.11 Inverse Discrete Fourier Transform (IDFT)

The CLT OFDM and CNU OFDMA signals are assembled in the frequency domain using 4096 subcarriers per OFDM/OFDMA channel. The signal is composed of: MAC data subcarriers, scattered pilots, continuous pilots, PHY Link subcarriers, zero-bit-value subcarriers, and excluded subcarriers (zero valued into the IDFT).These OFDM/OFDMA signals are described in IDFT Equation (101–25).

$$x(i) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(k) \exp\left(j \frac{2\pi i \left(k - \frac{N}{2}\right)}{N}\right), \text{ for } i = 0, 1, \ldots, (N-1) \quad (101\text{–}25)$$

where
- N equals 4096
- $X(0)$ is the lowest frequency component
- $X(N–1)$ is the highest frequency component
- k is the spectral index of the subcarrier

The resulting time domain discrete signal, *x(i)*, is a baseband complex-valued signal, sampled at 204.8 million samples per second resulting in a subcarrier spacing of 50 kHz.

Once the CNU detects the downstream PHY Link and receives the *DS_FreqCh(1)* variable (see Table 101–1), the CNU knows the location of $k = 0$.

The encompassed spectrum of a 192 MHz OFDM channel is 190 MHz (3800 active subcarriers, see Table 100–3 and Table 100–11). These 3800 maximum active subcarriers of a CLT or CNU OFDM transmitter channel shall occupy the range $148 \le k \le 3947$, where k is the spectral index of the subcarrier in Equation (101–25).

101.4.3.11.1 PHY Link managed variables

DS_FreqCh(n)
See 100.3.2.3.

101.4.3.12 Cyclic prefix and windowing

CLT and CNU cyclic prefix (CP) and windowing processing begins with the N-point output of the IDFT:

$\{x(0), x(1), \ldots, x(N-1)\}$

The variable *DSNcp* represents the provisioned duration, in OFDM Clock periods, of the downstream cyclic prefix parameter (see Table 101–10) for the CLT. The *DSNcp* samples at the end of this *N*-point IDFT are copied and prepended to the beginning of the IDFT output to give a sequence of length $(N + DSNcp)$:

$$\{x(N - DSNcp), x(N - DSNcp + 1), \ldots, x(N - 1), x(0), x(1), \ldots, x(N - 1)\}$$

The variable *DSNrp* represents the provisioned duration, in OFDM Clock periods, of the downstream windowing parameter (see Table 101–11 for the CLT. The *DSNrp* samples at the start of the *N*-point IDFT are copied and appended to the end of the IDFT output to give a sequence of length $(N + DSNcp + DSNrp)$:

$$\{x(N - DSNcp), x(N - DSNcp + 1), \ldots, x(N - 1), x(0), x(1), \ldots, x(N - 1), x(0), x(1), \ldots, x(DSNrp - 1)\}$$

Let this extended sequence of length $(N + DSNcp + DSNrp)$ be defined as:

$$\{y(i),\ i=0, 1, \ldots, (N + DSNcp + DSNrp - 1)\} \qquad (101\text{–}26)$$

DSNrp samples at both ends of this extended sequence are subject to tapering. This tapering is achieved using a raised-cosine window function; a window is defined to be applied to this entire extended sequence. This window has a flat top and raised-cosine tapering at the edges, as shown in Figure 101–29.

The window function *w(i)* is symmetric at the center; therefore, only the right half of the window is defined in the following equation:

$$w\left(i + \frac{N + DSNcp + DSNrp}{2}\right) = 1.0 \qquad (101\text{–}27)$$

$$\text{for } i = 0, 1, \ldots, \frac{(N + DSNcp + DSNrp)}{2} - 1$$

$$w\left(i + \frac{N + DSNcp + DSNrp}{2}\right) = \frac{1}{2}\left(1 - \sin\left(\frac{\pi}{\alpha(N + DSNcp)}\left(i - \frac{N + DSNcp}{2} + \frac{1}{2}\right)\right)\right) \qquad (101\text{–}28)$$

$$\text{for } i = \left(\left(\frac{N + DSNcp - DSNrp}{2}\right), \ldots, \left(\frac{N + DSNcp + DSNrp}{2} - 1\right)\right)$$

Here,

$$\alpha = \frac{DSNrp}{N + DSNcp} \qquad (101\text{–}29)$$

defines the window function for $(N + DSNcp + DSNrp)/2$ samples. The complete window function of length $(N + DSNcp + DSNrp)$ is defined using the symmetry property as:

$$w\left(\frac{N + DSNcp + DSNrp}{2} - i - 1\right) = w\left(\frac{N + DSNcp + DSNrp}{2} + 1\right), \qquad (101\text{–}30)$$

$$\text{for } i = 0, 1, \ldots, \frac{(N + DSNcp + DSNrp)}{2} - 1$$

This yields a window function (or sequence): $\{w(i), i=0, 1, \ldots, (N + DSNcp + DSNrp - 1)\}$. The length of this sequence is an even-valued integer.

The previous window function is applied to the sequence $\{y(i)\}$:

$$z(i) = y(i)\, w(i), \quad for\ i = 0, 1, \ldots, (N + DSNcp + DSNrp - 1) \tag{101–31}$$

Each successive set of N samples at the output of the IDFT yields a sequence $z(i)$ of length $(N + DSNcp + DSNrp)$. Each of these sequences is overlapped at each edge by *DSNrp* samples with the preceding and following sequences, as shown in the last stage of Figure 101–29. Overlapping regions are added together.

To define this "overlap and add" function mathematically, consider two successive sequences $z_1(i)$ and $z_2(i)$. The overlap and addition operations of these sequences are defined using the following equation:

$$z_1(N + DSNcp + i) + z_2(i), \quad for\ i=0, 1, \ldots, DSNrp - 1 \tag{101–32}$$

That is, the last *DSNrp* samples of sequence $z_1(i)$ are overlapped and added to the first *DSNrp* samples of sequence $z_2(i)$.

The length of the extended OFDM symbol is $(N + DSNcp + DSNrp)$ samples. Of this, $(DSNrp/2)$ samples are within the preceding symbol, and $(DSNrp/2)$ samples are within the following symbol. This yields a symbol period of $(N + DSNcp)$ samples.

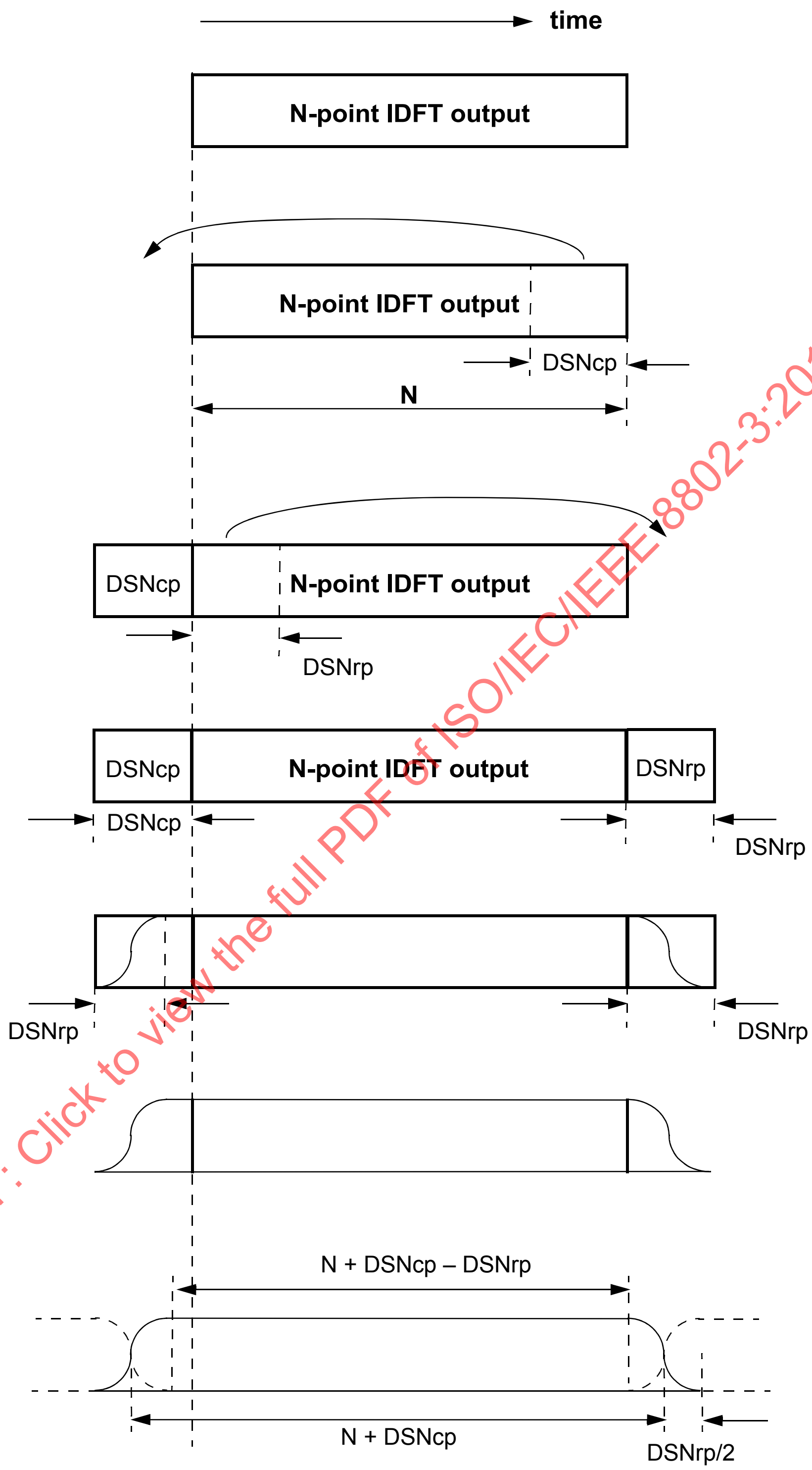
The process of cyclic prefix and windowing is illustrated in Figure 101–29. In the downstream direction the CLT shall use one of the permissible values for *DSNcp* and *DSNrp* given in Table 101–10 and Table 101–11, respectively, selected such that $DSNrp < DSNcp$.

Table 101–10—Size of cyclic prefix (*DSNcp*), downstream direction

DSNcp **[OFDM Clock period (1/204.8 MHz)]**	**[µs]**
256	1.25
512	2.5
768	3.75

Table 101–11—Size of OFDM Window (*DSNrp*), downstream direction

DSNrp **[OFDM Clock period (1/204.8 MHz)]**	**[µs]**
0	0
64	0.3125
128	0.625
192	0.9375
256	1.25



NOTE—Cyclic prefix and Windowing in the upstream direction is created in a similar fashion using US-Ncp and USNrp.

Figure 101–29—Cyclic prefix and windowing algorithm

101.4.3.12.1 PHY Link managed variables

DSNcp

TYPE: 4-bit binary

This variable controls the size of the cyclic prefix in the downstream direction per the following enumeration:

bit 3 2 1 0
1 x x x = reserved
0 1 x x = reserved
0 0 1 1 = 768 OFDM Clock periods (1/204.8 MHz)
0 0 1 0 = 512 OFDM Clock periods (1/204.8 MHz)
0 0 0 1 = 256 OFDM Clock periods (1/204.8 MHz)
0 0 0 0 = reserved

DSNrp

TYPE: 3-bit binary

This variable controls the size of the windowing function in the downstream direction per the following enumeration:

bit 2 1 0
1 1 x = reserved
1 0 1 = 256 OFDM Clock periods (1/204.8 MHz)
1 0 0 = 192 OFDM Clock periods (1/204.8 MHz)
0 1 1 = 128 OFDM Clock periods (1/204.8 MHz)
0 1 0 = 64 OFDM Clock periods (1/204.8 MHz)
0 0 1 = reserved
0 0 0 = 0 samples (windowing disabled)

101.4.3.13 OFDM channel requirements

The 10GPASS-PX-D PHY shall comply with the OFDM channel operational requirements in Table 101–12.

Table 101–12—Multiple OFDM channel requirements

Item	Requirement
OFDM channel 1 configuration	OFDM channel 1 is always be enabled. OFDM channel 1 processes subcarriers for data as well as the PHY Link.
OFDM channel 2, 3, 4, 5 configuration	OFDM channels 2, 3, 4, or 5 may be enabled or disabled for operation. OFDM channels are enabled in ascending order: e.g., enable OFDM channel 2 before enabling OFDM channel 3, enable OFDM channel 3 before enabling OFDM channel 4, enable OFDM channel 4 before enabling OFDM channel 5.
OFDM channel frequency placement	An OFDM channel may be configured for operation in any portion of the downstream Frequency Band as per Table 100–3.
OFDM channel subcarrier indexing relation to RF frequency	OFDM channel 1: 0 to 4095 OFDM channel 2: 4096 to 8191 OFDM channel 3: 8192 to 12287 OFDM channel 4: 12288 to 16383 OFDM channel 5: 16384 to 20479

Table 101–12—Multiple OFDM channel requirements *(continued)*

Item	Requirement
OFDM channel subcarrier frequency ordering	RF frequency correlates to subcarrier index; i.e., the lower the subcarrier index, the lower the RF frequency.
Minimum encompassed Spectrum	The minimum encompassed spectrum of any enabled OFDM channel is 22 MHz as per Table 100–3.
Encompassed spectrum overlap	The encompassed spectrum of any enabled OFDM channel does not overlap with that of any other enabled OFDM channel.
Adjacent OFDM channel placement	The CLT transmitter permits placement of the edge subcarrier of an OFDM channel's encompassed spectrum immediately adjacent to the edge subcarrier of another OFDM channel's encompassed spectrum without any frequency guard band.

101.4.4 Upstream PMA transmit function

101.4.4.1 Overview

101.4.4.2 Time and frequency synchronization

CNU upstream frequency and transmission timing is based on downstream channel tracking, and in the case of timing, also on receiving and applying timing adjustments commanded by the CLT using the PHY Link Channel.

This subclause describes the CNU upstream transmission performance requirements for frequency and timing that are based on tracking the downstream input to the CNU, and receiving and operating on commands from the CLT.

101.4.4.2.1 OFDM channel frequency accuracy

The CNU shall lock the frequency of the upstream Subcarrier Clock (50 kHz) and lock each upstream subcarrier frequency to the 10.24 MHz Master Clock derived from the downstream OFDM signal.

All upstream subcarrier frequency specifications assume a downstream input to the CNU per 101.4.3.2 and 101.4.3.3 and a downstream received signal per 100.3.6.3 but with a CNR of at least 32 dB and received signal level of at least –15 dBmV for 6 MHz averaged for OFDM downstream.

The frequency of the upstream Subcarrier Clock shall be accurate within 0.4 ppm. Each subcarrier frequency shall be accurate to within 30 Hz. Both of these requirements are relative to the 10.24 MHz Master Clock reference, and both for five sigma of the upstream OFDMA transmissions, for subcarrier frequencies up to 204.8 MHz.

101.4.4.2.2 OFDM channel timing accuracy

For OFDMA upstream the ranging time offset is described in 102.4.1.6. The CNU shall implement the OFDMA timing adjustment to within ± 10 ns.

101.4.4.2.3 Modulation timing jitter

CNU OFDM Clock timing error relative to the CLT 10.24 MHz Master Clock as measured at the CLT shall be within ± 10 ns in each burst measured within any 35 second measurement period. This applies to the worst-case jitter and frequency drift specified for the CLT 10.24 MHz Master Clock and the CLT downstream OFDM Clock. The mean error is the result of the adjustment applied by the CNU as specified in 101.4.4.3.6.

101.4.4.3 Frame timing

The frame timing function is reset by the PHY Link during link auto-negotiation. The framing timing state machine (see Figure 101–31) implements the RB Superframe structure per 101.4.4.3.1.

101.4.4.3.1 RB Superframe configuration and burst transmission

The upstream Superframe shall be composed of the Probe Period followed by 256 OFDMA symbols. Each Probe Period is six OFDMA symbols in duration. An RB Frame is one Resource Block column (i.e., one column of Resource Blocks over the entire upstream spectrum). Each Resource Block is composed of one subcarrier and has a duration of either 8 or 16 symbols and is set using the *RBsize* variable. Changing the Resource Block duration results in a network restart. The superframe structure is illustrated in Figure 101–30.

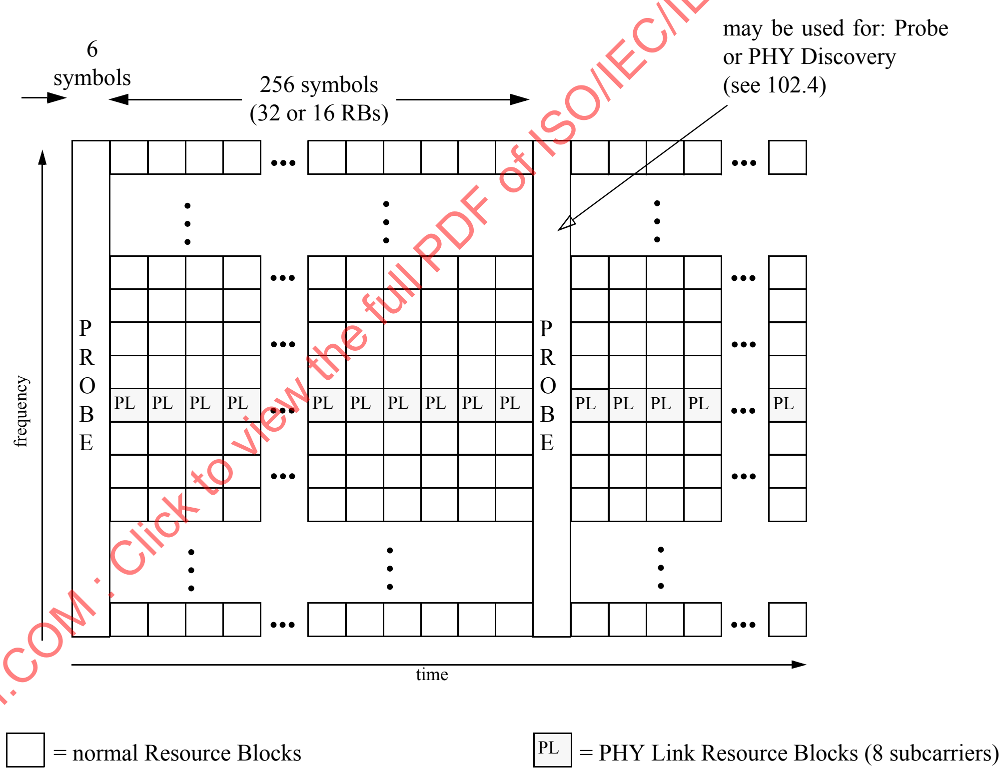


Figure 101–30—Upstream superframe structure

101.4.4.3.2 OFDMA transmission burst start

A CNU OFDMA transmission shall start with four contiguous subcarriers that include the start burst marker (see 101.4.4.8). No MAC data is transmitted during the burst marker.

101.4.4.3.3 OFDMA transmission internal to a burst

In general Resource Blocks internal to a burst may be of Type 0, Type 1 or Type 2 as determined by the provisioned Pilot pattern (see 101.4.4.6). An OFDMA transmission may straddle excluded subcarriers, unused subcarriers, and the Probe Period. An example of this would be if the transmission burst start and stop markers straddle an exclusion band or if the burst start marker occurs in one RB Frame and the stop marker occurs in a subsequent RB Frame. In such cases, where the OFDMA transmission crosses a band edge (anywhere an excluded subcarrier is adjacent to an active subcarrier), the active subcarrier immediately adjacent to the band edge shall be of Type 2.

101.4.4.3.4 OFDMA transmission burst end

An OFDMA transmission shall end with four contiguous subcarriers that include the stop burst marker (see 101.4.4.8). No MAC data is transmitted during the burst marker.

101.4.4.3.5 Variables

RBsize
: TYPE: Boolean
: This variable determines the size of the upstream Resource Blocks. When *RBsize* is TRUE then Resource Block size is 16 symbols, When *RBsize* is FALSE then Resource Block size is 8 symbols.

RBlen(*RBsize*)
: TYPE: integer
: This integer represents the number of symbols for the configured Resource Block size. See Table 101–1.
: Value: 8 when *RBsize* is FALSE, 16 when *RBsize* is TRUE.

SCLK
: TYPE: Boolean
: This clear on read variable is TRUE on every negative edge of a clock that is synchronized to the period of the Extended OFDM symbol time composed of the 20 µs useful symbol time plus the cyclic prefix time *USNcp*.

RBSF_reset
: TYPE: Boolean
: This variable is used to reset the frame timing state diagram (see Figure 101–31). A transition from FALSE to TRUE causes the state diagram to reset to the beginning of the RB_SUPERFRAME_RESET when *SCLK* goes TRUE. Upon being read this variable is reset to FALSE. The variable is set to TRUE on any reset or any Link-down condition (as defined in Table 102–14).

Probe_start
: TYPE: Boolean
: This variable transitions from the value of FALSE to TRUE for the first symbol of the Probe region. At the end of the first symbol of the probe region, the value transitions to FALSE until the first symbol of the next RB Superframe.

RB_Frame_start
: TYPE: Boolean
: This variable transitions from the value of FALSE to TRUE for the first symbol of each RB Frame in the RB Superframe as related to *RBsize*. The value is FALSE for all probe region symbols and for symbol 2 through *RBlen*(*RBsize)* for each RB Frame.

SYMcount
TYPE: unsigned integer
This is variable is used for counting the symbols of the RB Superframe.

RBmod
TYPE: unsigned integer
This variable is used to set the symbols per RB Frame upon reset.

101.4.4.3.6 State diagram

The CLT PMA shall implement the frame timing process as shown in Figure 101–31.

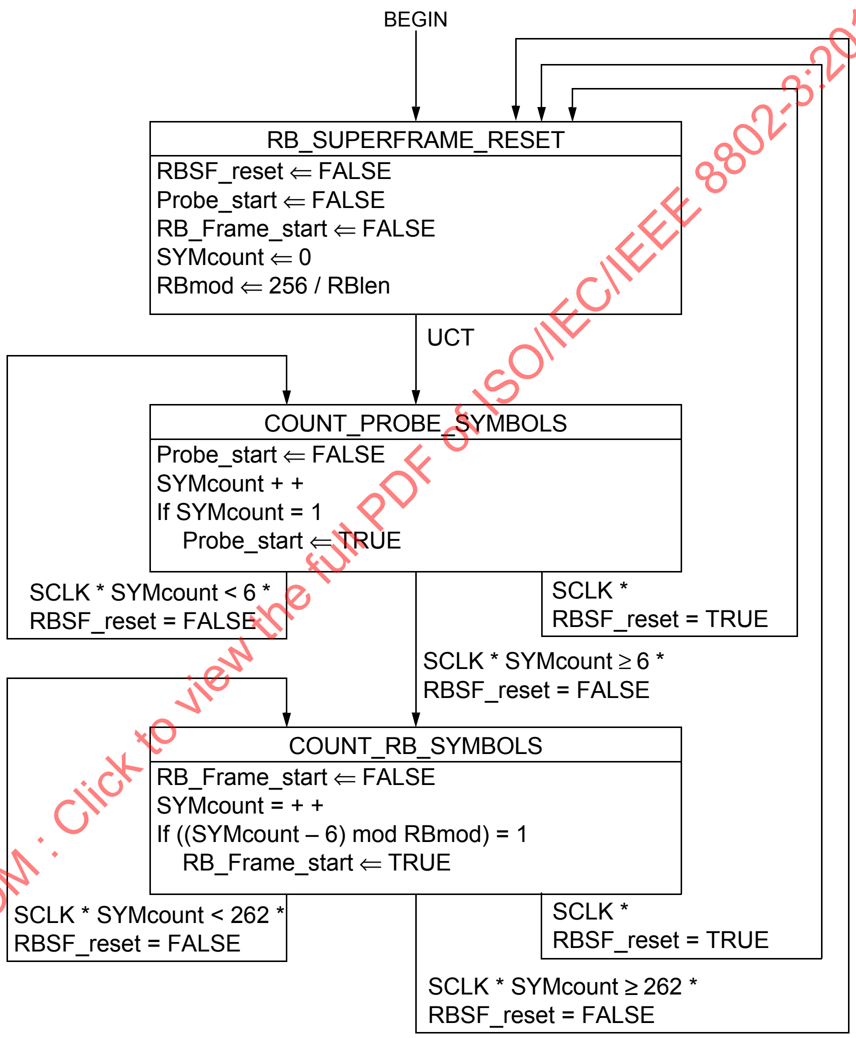


Figure 101–31—Framing timing state diagram

101.4.4.4 Subcarrier configuration and bit loading

Each subcarrier in the OFDMA channel is configured using the *US_ModTypeSC(n)* (where $0 \leq n \leq 4095$) or *TypeN_Repeat/TypeN_Start* ($N = 1$ or 2) variables. These variables allow the PHY to configure each subcarrier to be nulled, to have a specific bit loading (such as 512-QAM or 1024-QAM), or to be excluded and to define the pilot pattern to be used in upstream transmissions. Subcarrier configuration in an EPoC OFDM channel of 192 MHz at the CNU shall conform to the rules outlined in Table 101–13.

All devices in an EPoC network share the same upstream subcarrier configuration and bit loading including nulled subcarriers, pilot pattern, bit loaded subcarriers, and excluded subcarriers.

Table 101–13—Upstream subcarrier configuration rules

Parameter	Limit	Unit
Minimum number of combined active and nulled subcarriers for Probe	180	Subcarriers
Minimum OFDMA channel guard band	1	MHz
Max OFDMA channel encompassed spectrum	190	MHz

101.4.4.4.1 Nulled subcarriers

Nulled subcarriers do not carry MAC or PHY Link data but may be used as probes. Nulled subcarriers are not modulated except when being used as a Probe Symbol in the upstream direction (see 102.4.2).

101.4.4.4.2 Bit loaded subcarriers

When a subcarrier is used to carry MAC data it uses the modulation type of QPSK or 2^n-QAM, where $4 \leq n \leq 16$, assigned via the *US_ModTypeSC(n)* variables except when used as an upstream pilot (see 101.4.4.6), Probe, PHY Discovery Response (see 102.4.1), or burst marker (see 101.4.4.8).

There is at least one contiguous 10 MHz or greater band of active subcarriers in the upstream 192 MHz OFDM channel (see Table 100–1). This may include subcarriers intended as Pilots and PHY Link subcarriers. A 1 MHz guard band of excluded subcarriers above and below this 10 MHz creates a minimum width OFDM channel of 10 MHz encompassed spectrum.

101.4.4.4.3 Excluded subcarriers

CNUs shall not transmit energy into a subcarrier that has been excluded from the OFDM channel (i.e, excluded subcarriers have zero amplitude). There is a band edge Exclusion Band at both the top and bottom of the OFDM channel.

101.4.4.4.4 PHY Link managed variables

US_ModAbility

TYPE: 2-bit binary

This bit mapped variable is used to declare which modulation types the PHY supports in the upstream direction for the MAC data path. When a bit read as TRUE it indicates that the PHY supports that modulation type.

Bit	Modulation type
0	2048-QAM
1	4096-QAM

US_ModTypeSC(n)

TYPE: 4-bit binary

This set of provisioned variables determine the modulation parameters for each of the 4096 upstream OFDM subcarriers. 0 < *n* < 4095. Each variable controls one of the 4096 subcarriers that are transmitted over the OFDMA channel, with *US_ModTypeSC(0)* controlling subcarrier zero, *US_ModTypeSC(1)* controlling subcarrier 1, etc. The assignment of bits to each modulation type is shown below:

bit 3 2 1 0
1 1 1 1 = Excluded subcarrier
1 1 1 0 = reserved
1 1 0 1 = reserved
1 1 0 0 = 4096-QAM
1 0 1 1 = 2048-QAM
1 0 1 0 = 1024-QAM
1 0 0 1 = 512-QAM
1 0 0 0 = 256-QAM
0 1 1 1 = 128-QAM
0 1 1 0 = 64-QAM
0 1 0 1 = 32-QAM
0 1 0 0 = 16-QAM
0 0 1 1 = 8-QAM
0 0 1 0 = QPSK
0 0 0 1 = BPSK (Used for continuous pilots only)
0 0 0 0 = null (carries no data)

101.4.4.5 Upstream symbol mapper

The upstream symbol mapper consists of an idle loop process and a fill process. The idle loop process is initialized when the upstream profile is configured and set to align with the start of the RB Superframe. An RB Superframe is composed of a Probe Period (first six OFDMA symbols) followed by 32 (*RBsize* value FALSE) or 16 (*RBsize* value TRUE) RB Frames (see 101.4.3.5). The main task of the idle loop is to walk through all data bits in all data carrying Resource Elements (in each RB Frame) at the clock rate established by *US_DataRate* (see 100.3.2.2). The fill process, upon an assertion of the start of a burst from the PMA Client, starts filling at the Resource Block, Resource Element, and fill bit that is at the current walk point. This includes placing the start burst marker elements, filling bits in data Resource Elements and low density pilots as specified, creating the QAM map for the fill word bits, sensing the end of burst, padding to the end of the current Resource Block, encoding and placing the end burst marker elements and then terminating. Both processes are continuous loops. During the idle walk and fill processes, two-dimensional arrays (Resource Block size by total subcarriers) termed RB Frames are allocated and passed to the staging process when complete. RB Frames initially consist of null values that correspond to excluded subcarriers. Non-null values are inserted by the fill process when mapping burst markers and filling data Resource Elements, and when later processed by the Pilot Insert process fill "P" type pilots patterns (see 101.4.4.6). Null Resource Blocks are equivalent to excluded subcarriers and produce no energy on the corresponding OFDMA subcarrier after the IDFT process.

101.4.4.5.1 Variables

BITPOS

TYPE: integer

This is an integer used by the fill process to indicate the current bit position being filled in *FillWord*.

END

TYPE: enumerated type

This variable that ends the end state processing of the fill process, where:
FALSE indicates a *burstStart* = TRUE has not been received from received PMA_UNITDATA.request() primitive,
PAD indicates *burstStart* = TRUE has been received and the fill process is padding bits to the end of the current RB,
TRUE indicates that the fill process has reached the end of the last RB while padding.

FillWord<16:1>
TYPE: bit array
This an array that stages the bits to fill a Resource Element prior to mapping to QAM symbols.

FIRST
TYPE: Boolean
This is used within the fill process to indicate status of placing the first bit passed in the function call. If TRUE, the passed first bit is used, otherwise the bit from the processed PMA_UNITDATA.request() is used.

FRB
TYPE: integer
This variable is used to determine the current Resource Block being processed in the fill process. The range of values is from 0 to 4095.

FRE
TYPE: integer
This variable is used to determine the current Resource Element being processed in the fill process. The range of values is from –1 to 16.

ICLK
TYPE: Boolean
This clear on read variable is set to TRUE on each positive transition of a clock running at the *US_DataRate* (see 100.3.2.2).

IDLEBITS
TYPE: integer
This variable is used by the idle loop to increment through the bit loading of the current data carrying Resource Element.

IRB
TYPE: integer
This variable is used to determine the current Resource Block being processed in the idle process. The range of values is from –1 to 4095.

IRE
TYPE: integer
This variable is used to determine the current Resource Element being processed in the idle process. The range of values is from 0 to *RBlen*.

LBIT
TYPE: integer
This variable records the last bit filled in the current data Resource Element (QAM symbol) before mapping. The value can be from 1 to 15, where 1 represents the LSB. The value is set to the bit loading for the data Resource Element and then decremented during the symbol mapper fill process for mapping data burst bits to the current data Resource Element. This value is reset for each new data Resource Element being filled. The value is incremented while filling bits and stops incrementing upon receiving an end of burst indication. This value is not incremented or reset when placing padding bits.

LRE
TYPE: integer

This variable records the last filled data Resource Element in the current Resource Block. The value can be from 1 to 16, where 1 represents the first Resource Element in the Resource Block (in time) and up to 8 or 16 (*RBlen*) representing the last Resource Element in the Resource Block (later in time). The value is reset for each new Resource Block being filled. The value is incremented to the current data Resource Element being filled and stops incrementing upon receiving an end of burst indication. This value is not incremented or reset when placing padding bits.

PILOT_MAP<4096>

TYPE: array of enumerated values
This array defines the pilot pattern use for Type 1 and Type 2 pilot patterns as defined in the upstream profile descriptor (see 101.4.4.6). The pilot pattern is fixed for the RB Superframe configuration and remains constant. The enumerated type values are as follows:
"EX": no Type 0, Type 1, or Type 2 pattern is configured for this subcarrier (i.e., nulled subcarriers and excluded)
"T0": this Resource Block, if used for data, contains a Type 0 pattern (see 101.4.4.6)
"T1": this Resource Block, if used for data, contains a Type 1 pattern (see 101.4.4.6)
"T2": this Resource Block, if used for data, contains a Type 2 pattern (see 101.4.4.6)
"PHYLINK": this Resource Block is reserved for use by the PHY Link
All other enumerated type values are reserved. For any used Resource Element containing data and not containing either a start or end burst marker, this value is used to set the *RB_Type* array element value for further processing by the pilot insertion and staging functions.

RB_Frame<4096, *RBlen*>

TYPE: Array of *I_value* and *Q_value* bin value pair.
This two-dimensional array holds the I and Q QAM symbol bin values that are passed from the symbol mapper to the staging function, then to the IDFT for transmission by the CNU. When first allocated, *RB_Frame* contains null values ("0") in all I and Q values. I and Q bin values are signed 16-bit integers. Index 4095:0 represents the total number of possible subcarriers in the upstream corresponding OFDMA channel, *RBlen* represents the number of Resource Elements in Resource Block. Subcarrier 0, RB number 1 (*RB_Frame*<0,1>) is reserved for special use in coordinating symbol mapper idle and fill processing: I_value of "0" indicates the *RB_Frame* has not transferred to the staging process, *I_value* of "1" indicates the *RB_Frame* has been passed to the staging process, *Q_value* is always "0".

RB_Type<4096>

TYPE: array of enumerated values
This array defines the use of each Resource Block, the values and descriptions are as follows:
"EX": the Resource Block is excluded (no energy output from IDFT), all Resource Elements contain null I and Q value pairs.
"T0": Resource Block in use, Type 0 pilot pattern (see 101.4.4.6)
"T1": Resource Block in use, Type 1 pilot pattern (see 101.4.4.6)
"T2": Resource Block in use, Type 2 pilot pattern (see 101.4.4.6)
"SM": Resource Block in use, contains a start marker pattern
"EM": Resource Block in use, contains an end marker pattern
All other enumerated type values are reserved. The use of this array indicates the availability and type of each used Resource Block to pilot insertion. A null (unused) Resource Block array element produces no energy output from the IDFT for the corresponding OFDMA subcarrier. (This is also true for excluded subcarriers).

RBlen(*RBsize*)

See 101.4.4.3.5.

101.4.4.5.2 Functions

Allocate_RB_Frame(*RB_Frame*, *RB_Type*)
This function allocates a new *RB_Frame* array with all *I_value* and *Q_value* bin pairs set to null "0" and a new *RB_Type* array with all enumerations set to "EX".

BITLOAD(*resource_element*, *Resource Block*)
This function returns the current bit loading capacity of the current data carrying Resource Element or low density pilot. Bit loading is based on the setting of *US_ModTypeSC(n)* for this Resource Block (subcarrier) as well as Resource Elements containing low density pilots in Type 2 Resource Blocks (see 101.4.4.6).

Initialize_Pilot_Map()
This function initializes the *PILOT_MAP<>* array based on the descriptor information for indicating Type 0, Type 1, and Type 2 patterns. See 101.4.4.6.

Map_End_Marker (*RB_number*, *Last_Bit*, *Last_RE*)
This function starts at the current *RB_number*. This function then constructs the end burst marker by encoding the *Last_Bit* and *Last_RE* information. See 101.4.4.8.3 for end marker encoding. The value of *Last_Bit* directly indicates fill position in the current Resource Element. A values of *Last_RE* ranges from "0" which indicates the first Resource Element of the Resource Block up to *RBlen* – 1.This function then places end burst marker elements in the Resource Block according to the *RBlen* of the Superframe. This function continues to increment Resource Blocks (subcarriers) and places the remaining end burst marker elements in the next usable Resource Block as indicated in *US_ModTypeSC(n)* setting in the upstream profile descriptor. For each Resource Block used for an end burst marker element, the corresponding entry in the *RB_Type* array is set to "EM". Excluded subcarriers and null subcarriers are skipped. The next usable Resource Block is defined as an *US_ModTypeSC(n)* value from binary 0001 (BPSK) to binary 1110 (16384-QAM) and not being used by the PHY Link.
If at any time this function increments beyond the last usable Resource Block in the current *RB_Frame<>* (highest usable subcarrier configured in the profile descriptor), it examines the *I_value* of *RB_Frame*<0,1>. If "0", this function sets the value to "1" and passes the *RB_Frame<>* array and *RB_Type* array to the staging function and allocates a new *RB_Frame<>* array and *RB_Type* array use the Allocate_RB_Frame() function. If *I_value* of *RB_Frame*<0,1> is "1", the function skips passing to staging and allocations, assumes a new *RB_Frame<>* has been allocated, and increments to the first data carrying Resource Block and Resource Element in the new *RB_Frame<>*.

Map_Start_Marker (*RB_number*)
This function begins by placing the first Resource Block of a start burst marker in the current Resource Block *RB_number*, according to the *RBlen* of the Superframe (see 101.4.4.8). This function continues to increment Resource Blocks (subcarriers) and placing the remaining start burst marker elements in the next usable Resource Block(s) as indicated in *US_ModTypeSC(n)* setting in the upstream profile descriptor [defined as a *US_ModTypeSC(n)* value from binary 0001 (BPSK) to binary 1110 (16384-QAM) and not being used by the PHY Link]. Excluded subcarriers and null subcarriers are skipped. After placing the last start burst marker Resource Block, this function returns the value in *RB_number*.
For each Resource Block used for a start burst marker element, the corresponding entry in the *RB_Type<RB_number>* array is set to "SM". The next usable Resource Block is defined as a *US_ModTypeSC(n)* value from binary 0001 (BPSK) to binary 1110 (16384-QAM) and not being used by the PHY Link.
If at any time this function increments beyond the last usable Resource Block in the current *RB_Frame* (highest usable subcarrier configured in the profile descriptor), it examines the I_value of *RB_Frame*<0,1>. If "0", this function sets the value to "1" and passes the *RB_Frame* array and *RB_Type* array to the staging function and allocates a new *RB_Frame* array and *RB_Type* array use the Allocate_RB_Frame() function. If I_value of

RB_Frame<0,1> is "1", skips passing to staging and allocations, assume a new *RB_Frame* has been allocated, and increments to the first data carrying Resource Block and Resource Element in the new *RB_Frame*.

Map_to_QAM(*resource_block*, *resource_element* , *FillWord*, *FILLBITS*)

This function maps the bits in *FillWord*<> into the *I* and *Q* bin value pairs for the current Resource Element in the current *resource_block* (subcarrier) in *RB_Frame*<> (see 101.4.4.3). *Fillbits* represents the bitloading of the current data Resource Element or low density pilot, where *FillWord*<*Fillbits*> represents the MSB and *FillWord*<1> represents the LSB for the mapping.

If *RB_Type*<*resource_block*> is "EX", this function overrides the value and sets *RB_Type*<*resource_block*) to *PILOT_MAP*<*resource_block*> to indicate this Resource Block is in use and contains non-null values.

Next_RE(re*source_element*, *resource_block*)

This function increments to the next usable data carrying Resource Element starting from the passed resource_element number in the passed resource_block (subcarrier). This includes data carrying Resource Elements and low density pilots, pilot Resource Elements are skipped. See 101.4.4.6. The Resource Element is returned and may have a value from 1 to *RBlen*. If *resource_element* has a value of –1, this function increments to the next Resource Block and begins with the first useable Resource Element.

This function first increments to the next usable Resource Element in the current Resource Block. If necessary, this function increments to the next data carrying Resource Block (e.g., Type 0, 1, or 2). The Resource Block number (subcarrier) is from 0 to 4095.

When advancing to the next Resource Block and *FILL_STATE* = FILL, the value from *Pilot_Map*<*Resource Block*> sets the value of *RB_Type*<*Resource Block*>.

If at any time this function increments beyond the last usable Resource Block in the current *RB_Frame* (highest usable subcarrier configured in the profile descriptor), It examines the I_value of *RB_Frame*<0,1>. If "0", this function sets the value to "1" and passes the *RB_Frame* array and *RB_Type* array to the staging function and allocates a new *RB_Frame* array and *RB_Type* array using the allocate_RB_Frame() function. If I_value of *RB_Frame*<0,1> is "1", it skips passing to staging and allocations, and assumes a new *RB_Frame* has already been allocated, and increments to the first data carrying Resource Block and Resource Element in the new RB Frame.

Upon return, the updated Resource Element index is returned via *resource_element*, and the current Resource Block (subcarrier) index returned via *resource_block*.

Reset_Scrambler()

The upstream symbol mapper utilizes a separate instantiation of the scrambler as described in 101.4.3.7 with the same seed value of 0x4732BA. This function initializes the bit scrambler with the seed value.

Scramble(*bit*)

This function provides a bit scrambler, local to the upstream data symbol mapper function. The passed *bit* is used as input to the scrambler, the output is used as the return value. See 101.4.3.7.

101.4.4.5.3 State diagrams

The CNU PMA shall perform the symbol mapper idle process as shown in Figure 101–32.

The CNU PMA shall perform the symbol mapper fill process as shown in Figure 101–33.

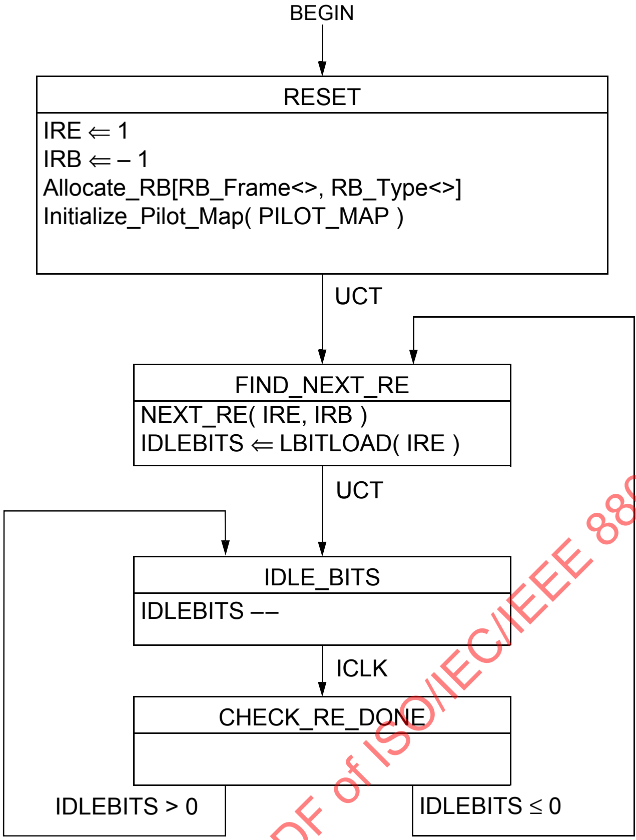


Figure 101–32—Upstream symbol mapper idle loop state diagram

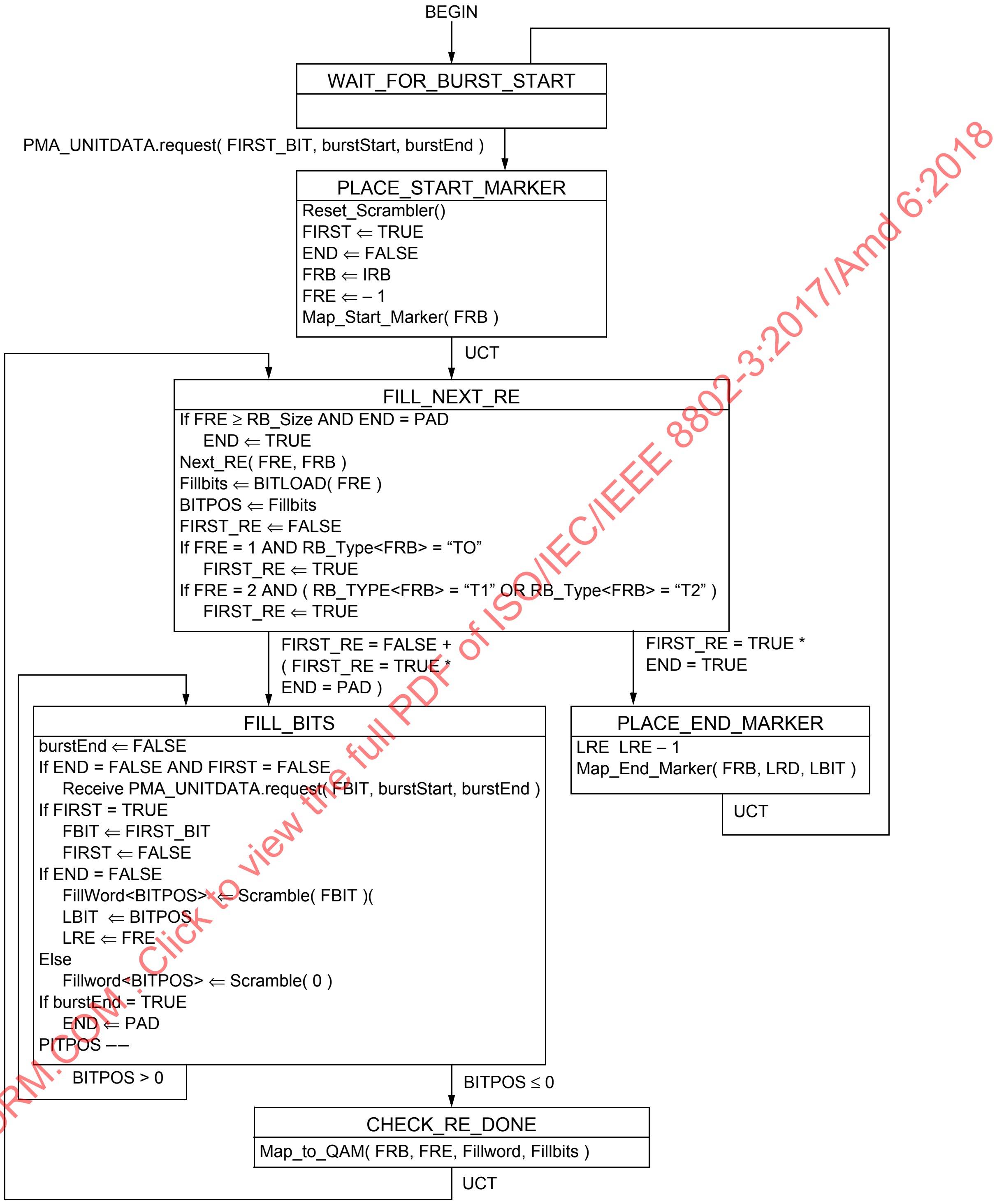


Figure 101–33—Upstream symbol mapper fill process state diagram

101.4.4.5.4 Minimum gap time and burst marker overhead

The CLT ensures a minimum gap time between bursts from any CNU equal to the transmission time of one Resource Block expressed in units of *time_quantum*.

Let *Highestbitload* be the highest bit loading among all active subcarriers in any data carrying symbol (non-probe symbol) in an upstream RB frame, the number of *time_quantum* per Resource Block is calculated as per Equation (101–33):

$$RB\_time\_quanta = \lceil RBlen \times (Highestbitload)/(US\_DataRate)/(time\_quantum) \rceil \quad (101\text{–}33)$$

Start and end burst marker overhead is a multiple of *RB_time_quanta*. For *RBlen* of 8, total burst marker overhead is eight (8) times *RB_time_quanta*. For *RBlen* of 16, total burst marker overhead is four (4) times *RB_time_quanta*. See 101.4.4.8 for burst marker Resource Block use.

101.4.4.6 Pilot patterns

A Resource Block may be any one of three types as illustrated in Figure 101–34. Type 0 Resource Blocks contain only data Resource Elements modulated per the *ModTypeSC(n)* variable where *n* is the subcarrier index of the Resource Block. Type 1 Resource Blocks contain two pilots in the first and third Resource Element transmitted. Type 2 Resource Blocks contain a Low Density Pilot, in the last and third from last Resource Elements transmitted, in addition to the two pilots of the Type 1 Resource Block. The Low Density Pilot Resource Element is modulated using the higher modulation order of either BPSK or 4 bits lower than the bit loading specified in the *ModTypeSC(n)* variable for that subcarrier. Each RB type is configured via the variables *Type1_Start*, *Type1_Repeat*, *Type2_Start*, and *Type2_Repeat* as described next. The configuration of these variables determines the upstream transmission pilot pattern that all CNUs in the network use. However the pattern is defined over the entire 4095 subcarrier range with subcarrier 0 being the first subcarrier and subcarrier 4095 being the last subcarrier in the range. Excluded subcarrier settings override the pilot pattern definition, and Type 2 pilot definitions override Type 1 definitions. See 101.4.4.3.1 for additional rules on Pilot Type usage in burst transmissions.

The *TypeN_Start* variable determines on which subcarrier the repeating pattern for Type N pilot starts and the *TypeN_Repeat* variable determines the number of subcarriers between Type N pilots in the repeating pattern is encoded as shown in Table 101–14. *US_ModTypeSC(n)* excluded subcarriers override the repetitive pilot pattern and the Type 2 Pilot pattern overrides the Type 1 Pilot pattern.

Table 101–14—TypeN_Repeat[a] encoding

TypeN_Repeat value	Number of SC between TypeN Pilots
000	TypeN Pilot pattern disabled
001	0
010	1
011	3
100	7
101	15
11x	reserved

[a] $N = 1$ or 2

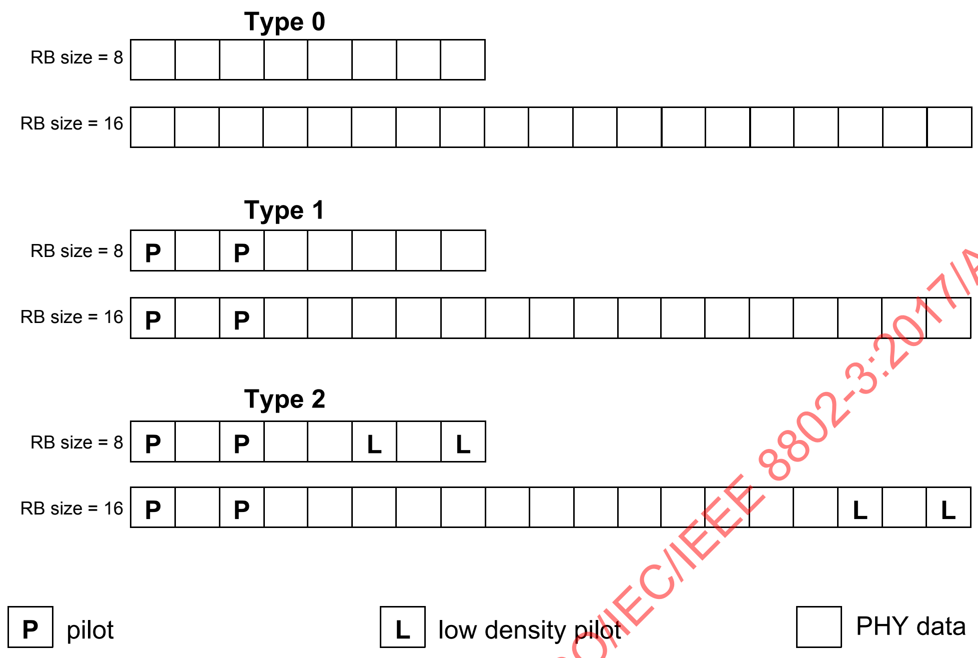


Figure 101–34—Resource Block types

101.4.4.6.1 variables

Type1_Repeat
TYPE: 3-bit unsigned integer
This variable indicates the number of subcarriers, from 0 to 7, between repeating Type 1 Pilots.

Type1_Start
TYPE: 4-bit unsigned integer
This variable indicates the number, between 0 and 15, of the first subcarrier designated as a Type 1 Pilot.

Type2_Repeat
TYPE: 3-bit unsigned integer
This variable indicates the number of subcarriers, from 0 to 7, between repeating Type 2 Pilots.

Type2_Start
TYPE: 4-bit unsigned integer
This variable indicates the number, between 0 and 15, of the first subcarrier designated as a Type 2 Pilot.

101.4.4.7 Staging and pilot insertion

101.4.4.7.1 Staging

The Staging function accepts an *RB_Frame* and *RB_Type* array from the Symbol Mapper when transferred from the Symbol Mapper. Staging then accumulates (copies) a PHY Link RB Frame (8 subcarriers by

Resource Block size 8 or 16) if available for this *RB_Frame*. If a PHY Link RB Frame was copied, the *RB_Type* entries for the corresponding subcarriers are set to “T2” (see *RB_Type* array in 101.4.4.5.1).

Pilot insertion then proceeds as per the procedure in 101.4.4.7.2. Upon a positive transition of *RB_Frame_start* (value FALSE to value TRUE) as set by frame timing, the *RB_Frame* and *RB_Type* arrays are transferred to the IDFT process.

101.4.4.7.2 Pilot insertion

Upstream pilot insertion is performed using a BPSK mapped bit sequence generated by a pseudo-random sequence (PRBS) generator defined by the polynomial $x^{12}+x^9+x^8+x^5+1$ (illustrated in Figure 102–27). Pilots are inserted after the RB Frame is processed by the symbol mapper (see 101.4.3.8) and before the RB Frame is passed to the IDFT function.

The method for pilot insertion shall be as follows:

1) The PRBS generator is initialized with the seed value 0xBFF at the beginning of each RB Frame for the subcarrier with index *k*=0 of the IDFT Equation (101–25) (see 101.4.3.11).
2) the PRBS generator is clocked once for every subcarrier of the IDFT.
3) Pilots are inserted (mapped) into the “P” positions of PHY Link subcarriers in each subcarrier where a CNU is transmitting a PHY Link message (see 102.3.4) and in each Resource Block to be transmitted containing a data burst designated as Type 1 or Type 2 Resource Block (see 101.4.4.6).
4) “P” pilots are BPSK modulated with the output of the feedback shift register, with a value of 0 mapping to (1 + j0) and a value of 1 mapping to (–1 + j0).
5) The same BPSK value is used for each “P” location in a subcarrier.

When an RB Frame has been processed by this function, the RB Frame is passed to the IDFT function for further processing.

101.4.4.8 Burst markers

101.4.4.8.1 Introduction

Burst markers are used to indicate the start or end of a burst received via the PMA service interface. A burst marker is a predefined sequence of two types of burst marker elements: B’s and 0’s, where B’s represent differential QPSK (D-QPSK) modulated symbols (see 101.4.4.8.3), and 0’s represent nulls (i.e., no energy being transmitted). Each burst marker element is transmitted in one Resource Element. B burst marker elements are boosted by 3 dB. The first modulated B marker element on a subcarrier is encoded as a reference pilot. There are separate burst marker patterns for 8 and 16 symbol Resource Blocks.

Burst markers are placed by the upstream Symbol Mapper function (see 101.4.4.5).

101.4.4.8.2 Burst marker start and stop sequences

For the 8 symbol Resource Block, the start and stop burst marker sequences are defined in Figure 101–35. For the 16 symbol Resource Block, the start and stop marker sequences are defined in Figure 101–36.

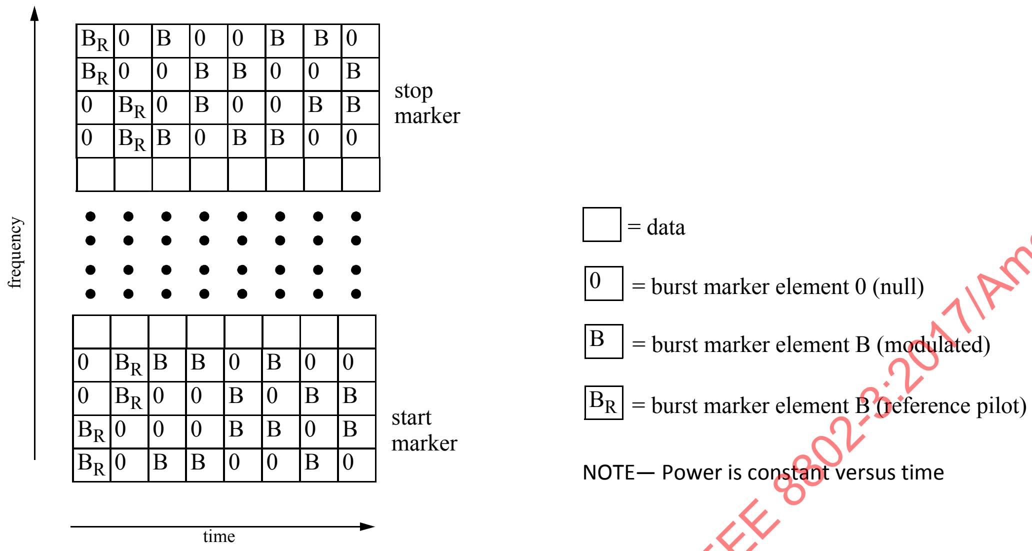


Figure 101–35—Burst marker in 8 symbol Resource Block

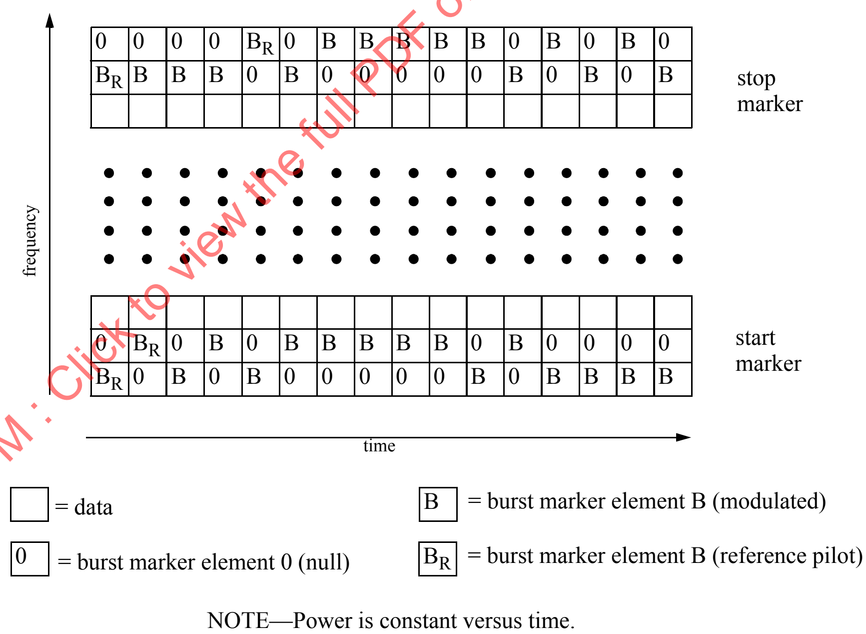


Figure 101–36—Burst marker example in 16 symbol Resource Block

101.4.4.8.3 Burst marker B element encoding

The first modulated D-QPSK symbol for each subcarrier of a start and end burst marker is a reference pilot and is modulated with value (11). This is indicated by the position of the B_R burst marker element in Figure 101–35, Figure 101–36, Figure 101–37, and Figure 101–38.

The remaining B burst marker elements are D-QPSK modulated with information value pairs and parity encoding value pairs. The parity encoding is a Reed-Solomon coding over GF(2^4) with $t = 2$. The Reed-Solomon code of RS(15,11) is shortened to length 6 of 7 depending on the Resource Block length. The RS generator is shown in equation Equation (101–34) where the primitive element alpha (a) is 0x2.

$$g(x) = (x + a^0)(x + a^1)(x + a^2)(x + a^3) \tag{101–34}$$

The RS primitive polynomial is shown in equation Equation (101–35).

$$p(x) = x^4 + x + 1 \tag{101–35}$$

For Resource Block size of 8, two information code symbols designated I2 and I1 contain 8 information bits and are encoded and shortened to a length of 6:

(0 0 0 0 0 0 0 0 0 I2 I1 P4 P3 P2 P1)

For Resource Block size of 16, three information code symbols designated I3, I2, and I1 contain 12 information bits and are encoded and shortened to a length of 7:

(0 0 0 0 0 0 0 0 I3 I2 I1 P4 P3 P2 P1)

Each information code symbol is represented by a pair of D-QPSK symbols. The high order pair is designated as $I_{\#H}$ and the low order pair by $I_{\#L}$, for # = 1, 2, or 3. For each parity code symbol high order pair is designated as $P_{\#H}$ and the low order pair by $P_{\#L}$, for # = 1, 2, 3, or 4.

For start burst markers and Resource Block size 8, the two information code symbols I2 and I1 are each set to 0xF (i.e., 0xFF, all ones in all information symbols) with the D-QPSK modulated symbol pair placement as per Figure 101–37.

For start burst markers and Resource Block size 16, the three information code symbols I3, I2, and I1 are each set to 0xF (i.e., 0xFFF, all ones in all information symbols) with the D-QPSK modulated symbol pair placement as per Figure 101–38.

The start burst marker setting of 0xFF and 0xFFF in RB Frames of size 8 and 16, respectively designates that the first bit of data for the burst starts in the MSB bit of the first usable data Resource Element in the Resource Block immediately following the start burst marker. All other values and designations are reserved.

For stop burst markers and Resource Block size 8, the two information code symbols are set as follows: L_2 encodes the last Resource Block value as designated by the symbol mapper (see 101.4.4.5) as per Table 101–15 and L_1 encodes the last fill bit position value as designated by the symbol mapper (see 101.4.4.5) as per Table 101–16 with the D-QPSK modulated symbol pair placement as per Figure 101–37.

For stop burst markers and Resource Block size 16, the three information code symbols are set as follows: L_3 encodes a pad value of 0x00 (i.e., not null), L_2 encodes the last Resource Block value as designated by the symbol mapper (see 101.4.4.5) as per Table 101–15, and L_1 encodes the last fill bit position value as designated by the symbol mapper (see 101.4.4.5) as per Table 101–16 with the D-QPSK modulated symbol pair placement as per Figure 101–38.

Table 101–15—Last Resource Element position encoding

Last Resource Element Position in Last Resource Block	MSB Pointer Bits $(I_{2H})I_{(2L)}$ $(0_{MSB}\ 0)_H\ (0_{MSB}\ 0)_L$
0	$(00)_H(00)_L$
1	$(00)_H(01)_L$
2	$(00)_H(10)_L$
3	$(01)_H(11)_L$
4	$(01)_H(00)_L$
5	$(01)_H(01)_L$
6	$(01)_H(10)_L$
7	$(01)_H(11)_L$
8	$(10)_H(00)_L$
9	$(10)_H(01)_L$
10	$(10)_H(10)_L$
11	$(10)_H(11)_L$
12	$(11)_H(00)_L$
13	$(11)_H(01)_L$
14	$(11)_H(10)_L$
15	$(11)_H(11)_L$

.

Table 101–16—Last bit position encoding

Last Fill Bit Position in Last Resource Element	MSB Pointer Bits $(I_{1H})I_{(1L)}$ $(0_{MSB}\ 0)_H\ (0_{MSB}\ 0)_L$
0	$(00)_H(00)_L$
1	$(00)_H(01)_L$
2	$(00)_H(10)_L$
3	$(01)_H(11)_L$
4	$(01)_H(00)_L$

Table 101–16—Last bit position encoding *(continued)*

Last Fill Bit Position in Last Resource Element	MSB Pointer Bits $(I_{1H})I(_{1L})$ $(0_{MSB}\ 0)_H\ (0_{MSB}\ 0)_L$
5	$(01)_H(01)_L$
6	$(01)_H(10)_L$
7	$(01)_H(11)_L$
8	$(10)_H(00)_L$
9	$(10)_H(01)_L$
10	$(10)_H(10)_L$
11	$(10)_H(11)_L$
12	$(11)_H(00)_L$
13	$(11)_H(01)_L$
14	$(11)_H(10)_L$
15	$(11)_H(11)_L$

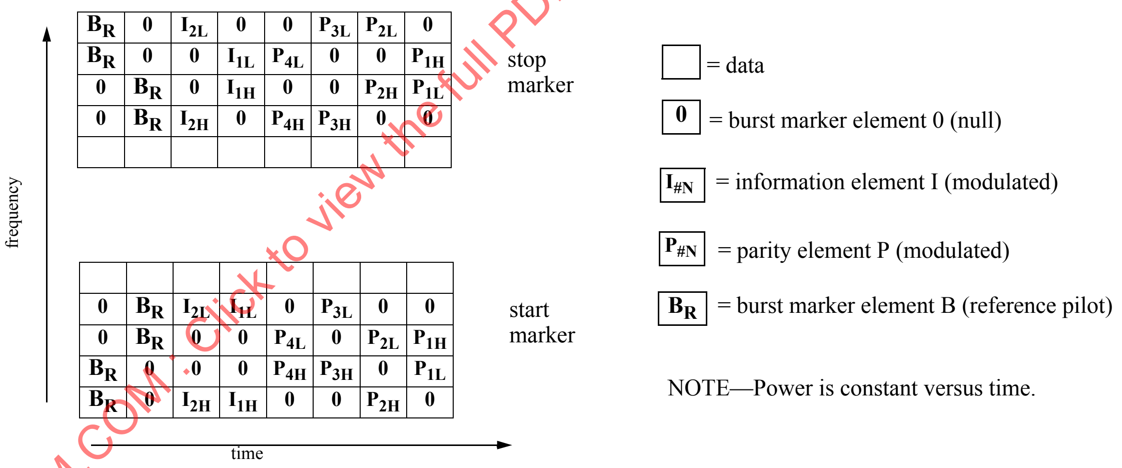
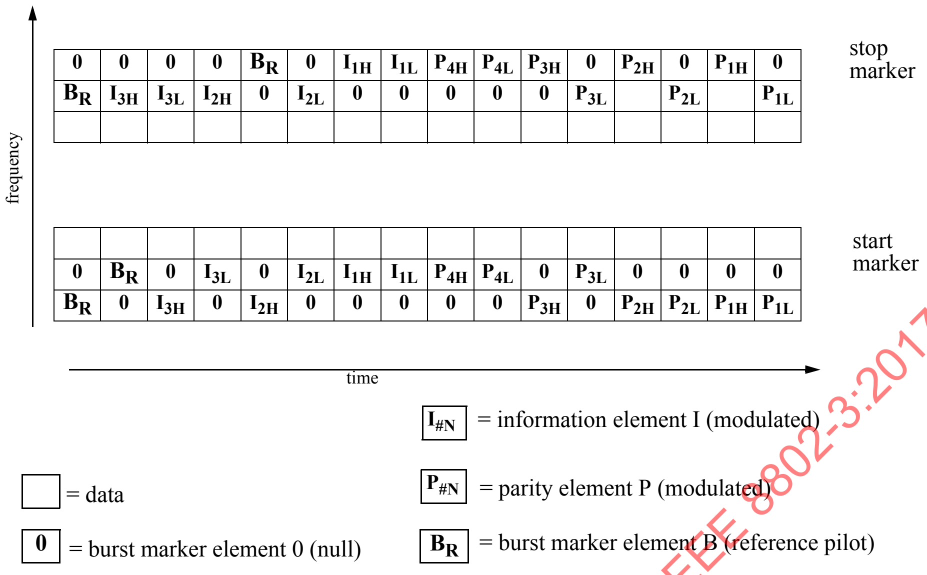


Figure 101–37—Burst marker encoding in 8 symbol Resource Block



NOTE—Power is constant versus time.

Figure 101–38—Burst marker encoding in 16 symbol Resource Block

101.4.4.9 Pre-equalization and Inverse Discrete Fourier Transform (IDFT)

The CNU upstream IDFT uses the same definition as in the downstream. See 101.4.3.11.

101.4.4.9.1 Pre-equalization coefficients

Linear pre-equalization is performed in the digital domain before upstream IDFT processing. The CNU shall support a single complex coefficient (equalizer tap) per subcarrier that may be updated via the PHY Link. A CNU shall use a default value of 0 + j0 for all pre-equalizer coefficients. Changing a subcarrier from excluded to active or visa versa shall cause the pre-equalizer coefficients for that subcarrier to be automatically set to a value of 1 + j0 (for subcarriers set to active) or 0 + j0 (for subcarriers set to excluded).

On update, the PHY Link may either indicate a complex coefficient (initialization or reset) or may indicate a multiplication factor. Coefficients are updated only as part of a response to upstream probes received by the CLT. See 102.4.2.

Upon reception of a coefficient multiplication factor, the CNU processes the update per subcarrier as follows:

$$C(k) \Leftarrow C(k) \times A(k) \qquad (101\text{–}36)$$

where

C(k)	is the pre-equalizer coefficient of the k-th subcarrier as used in the last probe transmission
A(k)	is the coefficient updates in variables *EQ_CoefR(k)* and *EQ_CoefI(k)* (see 101.4.4.9.2), received via the PHY Link
The symbol “×”	indicates a complex multiplication

The CNU shall normalize the newly calculated coefficients by adjusting the mean of the absolute value of $(Ck)^2$ to be one. The summation is over all *k* active subcarriers. The CNU shall switch from the prior set of coefficients to the new set of coefficients between transmissions within 10 ms after receiving an update via a PHY Link message.

On transmissions, the CNU shall

1) Always pre-equalize all transmissions other than probe and PHY Discovery signals.
2) Transmit a probe signal with or without pre-equalization (all coefficients are reset to 1 + j0) as instructed by the CLT using the PHY Link probe instruction described in 102.4.2.

The CLT shall be able to calculate and distribute initial pre-equalizer coefficients to reduce the OFDMA channel amplitude variation, by 0.8 dB or more corresponding to a 3 dB increase in MER from 16 dB to 19 dB, given that the probe signal power into CLT burst receiver is +5.4 dBmV ± 1 dB and the upstream OFDMA channel has an encompassed spectrum of at least 22 MHz, where all subcarriers within the encompassed spectrum are active subcarriers.

Testing methodology for pre-equalizer can be found in 101.4.6.1.

101.4.4.9.2 PHY Link managed variables

EQ_CoefR(n)

TYPE: Q2.14 format signed fractional number
This set of variables determines the real and imaginary part of the pre-equalizer settings for the upstream transmitter. Each variable in the set controls one subcarrier of the 4096 subcarriers that are transmitted over the OFDMA channel, with *EQ_CoefR(0)* controlling the real number setting for subcarrier 0 and *EQ_CoefR(1)* controlling the real number setting for subcarrier 1 and so on. Thus *EQ_CoefR(4096)* controls the real settings for subcarrier 4095.

EQ_CoefI(n)

TYPE:Q2.14 format signed fractional number
This set of variables determines the real and imaginary part of the pre-equalizer settings for the upstream transmitter. Each variable in the set controls one subcarrier of the 4096 subcarriers that are transmitted over the OFDMA channel, with *EQ_CoefI(0)* controlling the imaginary number setting for subcarrier 0 and *EQ_CoefI(1)* controlling the imaginary number setting for subcarrier 1and so on. Thus *EQ_CoefI(4095)* controls the imaginary settings for subcarrier 4095.

101.4.4.10 Cyclic prefix and windowing

The CNU upstream cyclic prefix and windowing function uses the same definition as in the downstream. See 101.4.3.12. The CNU shall use one of the permissible values for *USNcp* and *USNrp* in the upstream direction given in Table 101–17 and Table 101–18, respectively. Cyclic prefix and windowing function sizes shall be selected such that the *USNrp* value is less than the *USNcp* value.

Table 101–17—Size of cyclic prefix (USNcp), upstream direction

USNcp[a]	[µs]
256	1.25
384	1.875
512	2.5

Table 101–17—Size of cyclic prefix (USNcp), upstream direction *(continued)*

640	3.125
768	3.75

[a]USNcp is in units of OFDM Clock periods (1/204.8 MHz).

Table 101–18—Size of OFDM window (USNrp), upstream direction

USNrp[a]	[µs]
0	0
64	0.3125
128	0.625
192	0.9375
256	1.25

[a]USNrp is in units of OFDM Clock periods (1/204.8 MHz).

101.4.4.10.1 PHY Link managed variables

USNcp

TYPE: 4-bit binary

This variable controls the size of the cyclic prefix in the upstream direction per the following enumeration:

bit 3 2 1 0
1 x x x = reserved
0 1 1 1 = 768 OFDM Clock periods (1/204.8 MHz)
0 1 1 0 = 640 OFDM Clock periods (1/204.8 MHz)
0 1 0 1 = reserved
0 1 0 0 = 512 OFDM Clock periods (1/204.8 MHz)
0 0 1 1 = reserved
0 0 1 0 = 384 OFDM Clock periods (1/204.8 MHz)
0 0 0 1 = reserved
0 0 0 0 = 256 OFDM Clock periods (1/204.8 MHz)

USNrp

TYPE: 3-bit binary

This variable controls the size of the windowing function in the upstream direction per the following enumeration:

2 1 0
1 1 1 = 256 OFDM Clock periods (1/204.8 MHz)
1 1 0 = 192 OFDM Clock periods (1/204.8 MHz)
1 0 1 = reserved
1 0 0 = 128 OFDM Clock periods (1/204.8 MHz)
0 1 1 = reserved
0 1 0 = 64 OFDM Clock periods (1/204.8 MHz)
0 0 1 = reserved
0 0 0 = 0 samples (windowing disabled)

101.4.5 Constellation structure and mapping

After LDPC encoding and scrambling for downstream and upstream transmissions, the output bit stream of the CLT and CNU Symbol Mapper shall be mapped to QAM symbols such that first bit is the least-significant bit of the first QAM subcarrier constellation m-tuple, see Figure 101–39.

time →

encoded bit stream X_0 X_1 ... X_{m-1} X_m X_{m+1} ... X_{2m-1} X_{2m} ...

	MSB			LSB
QAM m-tuple 1:	X_{m-1}	X_{m-2}	...	X_0
QAM m-tuple 2:	X_{2m-1}	X_{2m-2}	...	X_m
QAM m-tuple 3	X_{3m-1}	X_{3m-2}	...	X_{2m}

Figure 101–39—Bitstream to QAM m-tuple mapping

The m-tuples are modulated onto subcarriers using QAM constellation. As described in the following subclauses, the QAM constellation structure and mappings are defined inductively and use Gray mapping as their base.

101.4.5.1 One dimensional Gray mapping for m-tuple binary bits

1) When m=1, the Gray mapping is define to be $\text{Gray}_1(0) = 1$ and $\text{Gray}_1(1) = -1$
2) When m>1, the Gray mapping is defined inductively, i.e.,

$$\text{Gray}_m(x_{m-1} \cdot x_{m-2} \cdot \ldots \cdot x_0) = (1 - 2 \cdot x_0) \cdot \left(2^{m-1} + \text{Gray}_{m-1} \cdot (x_{m-1} \cdot x_{m-2} \cdot \ldots \cdot x_0)\right)$$

101.4.5.2 Constellation structure and mapping of BPSK

Let m = 1 and a binary bit is x. The BPSK mapping is as follows:

$$(I_1(x), Q_1(x)) = (\text{Gray}_1(x), 0) = \begin{cases} (1, 0) & (x = 0) \\ (-1, 0) & (x = 1) \end{cases}$$

Also, see Figure 101–40.

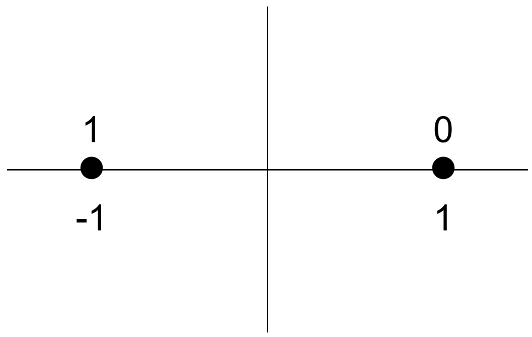


Figure 101–40—BPSK

101.4.5.3 Constellation structure and mapping of 2^{2n}–QAM

Let $m = 2 \cdot n$ and the m-tuple binary bits are $x_0, ..., x_{n-1}, x_n, ..., x_{2 \cdot n-1}$. The mapping from that m-tuple to a 2^m–QAM is defined by

$$(I_{2n}(x_{2n-1}, ..., x_n, x_{n-1}, ..., x_0), Q_{2n}(x_{2n-1}, ..., x_n, x_{n-1}, ..., x_0)) = (\mathrm{Gray}_n(x_{n-1}, ..., x_0), \mathrm{Gray}_n(x_{n-1}, ..., x_0)) \quad (101\text{–}37)$$

where the Gray mapping is defined in 101.4.5.1. Some of the examples are given in the following figures.

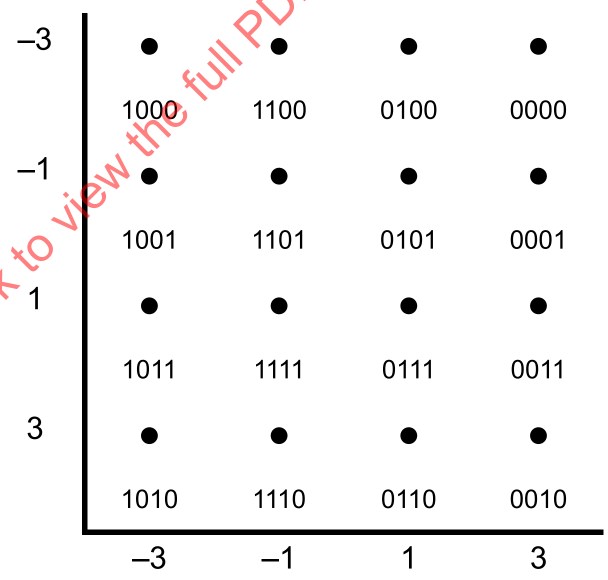


Figure 101–41—16-QAM

101.4.5.4 Constellation structure and mapping of 2^{2n+1}–QAM (n>0)

Let $m = 2n+1$ and the m-tuple binary bits are $x_0, \ldots, x_{n-1}, x_n, \ldots, x_{2n}$. Firstly, map this m-tuple to a rectangular constellation defined by

$$(I_{rct}(x_{2n}, \ldots, x_n, x_{n-1}, \ldots, x_0), Q_{rct}(x_{2n}, \ldots, x_n, x_{n-1}, \ldots, x_0)) = (\text{Gray}_{n+1}(x_{2n}x_{2n-1}\ldots x_n), \text{Gray}_n(x_{n-1}, x_{n-2}, \ldots, x_0)) \quad (101\text{–}38)$$

where the Gray mapping is defined in 101.4.5.1. Then the structures and mappings of cross-constellations are generated in the following subclauses.

101.4.5.4.1 Constellation structure and mapping of 8–QAM

Let the constellation signal and its mapping be denoted by $(I_3(x_2x_1x_0), Q_3(x_2x_1x_0))$ then

$$\begin{cases} \begin{cases} I_3(x_2x_1x_0) = I_{rct}(x_2x_1x_0) + 1 \\ Q_3(x_2x_1x_0) = Q_{rct}(x_2x_1x_0) \end{cases} & I_{rct}(x_2x_1x_0) < 3 \\ \begin{cases} I_3(x_2x_1x_0) = 3 - I_{rct}(x_2x_1x_0) \\ Q_3(x_2x_1x_0) = sign(Q_{rct}(x_2x_1x_0)) \times (|Q_{rct}(x_2x_1x_0)| + 2) \end{cases} & \text{otherwise} \end{cases}$$

where the sign function is defined by $sign(a) = \begin{cases} 1 & a \geq 0 \\ -1 & a < 0 \end{cases}$

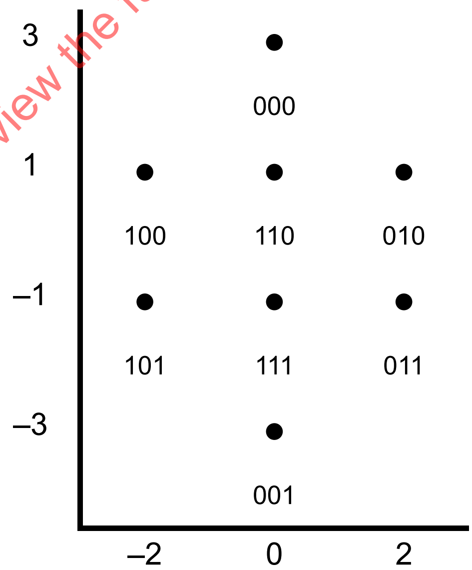


Figure 101–42—8-QAM

101.4.5.4.2 Constellation structure and mapping of 2^{2n+1}–QAM with $n > 1$

Let the mapping be denoted by $(I_{2n+1}(x_{2n}x_{2n-1}\ldots x_0), Q_{2n+1}(x_{2n}x_{2n-1}\ldots x_0))$ and let $s = 2^{n-1}$.

Then, when $|I_{rct}(x_{2n}x_{2n-1}\ldots x_0)| < 3s$

$$\begin{cases} I_{2n+1}(x_{2n}x_{2n-1}\ldots x_0) = I_{rct}(x_{2n}x_{2n-1}\ldots x_0) \\ Q_{2n+1}(x_{2n}x_{2n-1}\ldots x_0) = Q_{rct}(x_{2n}x_{2n-1}\ldots x_0) \end{cases}$$

and when $|I_{rct}(x_{2n}x_{2n-1}\ldots x_0)| \geq 3s$

$$\begin{cases} \begin{cases} I_{2n+1}(x_{2n}x_{2n-1}\ldots x_0) = sign(I_{rec}(x_{2n}x_{2n-1}\ldots x_0)) \times (|I_{rct}(x_{2n}x_{2n-1}\ldots x_0)| - 2s) \\ Q_{2n+1}(x_{2n}x_{2n-1}\ldots x_0) = sign(Q_{rct}(x_{2n}x_{2n-1}\ldots x_0)) \times (4s - |Q_{rct}(x_{2n}x_{2n-1}\ldots x_0)|) \end{cases} & \text{if } |Q_{rct}(x_{2n}x_{2n-1}\ldots x_0)| > s \\ \begin{cases} I_{2n+1}(x_{2n}x_{2n-1}\ldots x_0) = sign(I_{rec}(x_{2n}x_{2n-1}\ldots x_0)) \times (4s - |I_{rct}(x_{2n}x_{2n-1}\ldots x_0)|) \\ Q_{2n+1}(x_{2n}x_{2n-1}\ldots x_0) = sign(Q_{rct}(x_{2n}x_{2n-1}\ldots x_0)) \times (|Q_{rct}(x_{2n}x_{2n-1}\ldots x_0)| + 2s) \end{cases} & \text{if } |Q_{rct}(x_{2n}x_{2n-1}\ldots x_0)| \leq s \end{cases}$$

Figure 101–43 presents the 32-QAM structure and mapping.

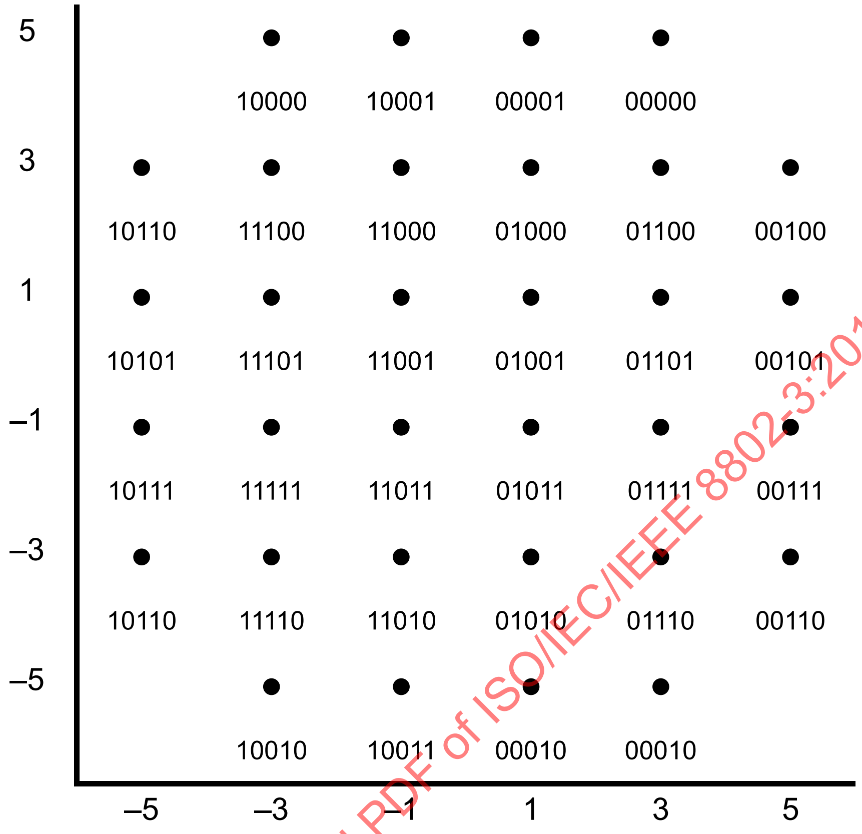


Figure 101–43—32-QAM

101.4.5.5 QAM constellation scaling

Both real and imaginary axis of a QAM constellation shall be scaled by the CLT or CNU transmitter using the scaling factors given in Table 101–19. These scaling factors ensure that the mean square value of all QAM constellations are equal to one.

Table 101–19—QAM constellation scaling factors

QAM constellation	*m* number of bits	Scaling factor
BPSK	1	1
QPSK	2	$1/(\sqrt{2})$
8-QAM	3	$1/(\sqrt{5})$
16-QAM	4	$1/(\sqrt{10})$
32-QAM	5	$1/(\sqrt{20})$
64-QAM	6	$1/(\sqrt{42})$

Table 101–19—QAM constellation scaling factors *(continued)*

QAM constellation	*m* number of bits	Scaling factor
128-QAM	7	$1/(\sqrt{82})$
256-QAM	8	$1/(\sqrt{170})$
512-QAM	9	$1/(\sqrt{330})$
1024-QAM	10	$1/(\sqrt{682})$
2048-QAM	11	$1/(\sqrt{1322})$
4096-QAM	12	$1/(\sqrt{2730})$
8192-QAM	13	$1/(\sqrt{5290})$
16384-QAM	14	$1/(\sqrt{10922})$

101.4.6 PMA testing

101.4.6.1 Pre-equalization testing

Pre-equalization operation is verified using the following method:

1) A test modulator generates the first transmission using a compliant probe. This transmission is input into a spectrum analyzer, with an initial "flat" test channel, achieving 0.3 dB peak-to-peak amplitude variation or less after calibration of the spectrum analyzer (corresponding to a residual MER of 35 dB).
2) A micro-reflection is added into the test channel with an amplitude of –16 dB ± 0.5 dB and a delay of 312.5 ± 0.5 ns compared to main path.
3) Verify the channel (except for the echo) changes by no more than 0.3 dB peak-to-peak, in addition to the 2.78 dB peak-to-peak signal amplitude variation induced by the micro-reflection (the 0.3 dB tolerance allows the maximum amplitude variation to increase to 3.08 dB peak-to-peak corresponding to total MER of 15.3 dB or a residual MER of 35 dB).
4) The test modulator generates a second transmission using a compliant probe sent to both the spectrum analyzer and the CLT receiver (unit under test) with a CNR > 35 dB.
5) Measure and record the amplitude variation over the spectrum of subcarriers (this is the "reference amplitude variation measurement" of the test) using the spectrum analyzer.
6) The CLT OFDMA receiver develops pre-equalizer coefficients.
7) The CLT formats and transmits compliant commands for the pre-equalizer coefficients.
8) The downstream test receiver validates reception of pre-equalization coefficients.
9) The received pre-equalization coefficients are implemented by the test modulator and used to generate a third transmission.
10) Measure and record the amplitude variation over the spectrum of subcarriers for this third transmission, pre-equalized, from the test modulator.
11) Compare the amplitude variation measurement taken in step 10) to the reference amplitude variation measurement. The difference observed should be less than the required minimum reduction in amplitude variation.

101.4.6.2 OFDM channel frequency accuracy test

The measurements of the frequency of the upstream Subcarrier Clock, and the subcarrier frequencies, are averaged over the duration of a single upstream burst. A constant temperature is maintained during the measurements within a range of 20 ºC ± 2 ºC. A minimum warm up time of 30 min occurs before the CNU frequency measurements are made.

NOTE—As an example, upstream Subcarrier Clock frequency is linked with upstream FFT duration (and subcarrier spacing in the frequency domain), and is at least one component in developing each upstream subcarrier frequency. Other components may also contribute to upstream subcarrier frequency, for example, an up conversion process from complex baseband or low intermediate frequency may contribute. All such components are locked to the derived 10.24 MHz Master Clock at the CNU. The accuracy requirements for the Subcarrier Clock frequency and for each individual subcarrier frequency necessary to support 4K-QAM upstream are not necessarily the same.

101.5 Applicability of Clause 90 and IEEE Std 802.1AS, Clause 13 for EPoC time transport

This subclause describes how the time synchronization functionality for EPON included in IEEE Std 802.1AS can also be used for EPoC time synchronization with minor adjustments to compensate for CLT and CNU PHY time delays described in Clause 90. CLTs and CNUs should use the methods described in 101.5.1 and 101.5.2.

101.5.1 CLT PHY asymmetry correction of future time transmitted by the CLT to CNU_i

In IEEE Std 802.1AS-2011 13.1.4, instead of sending a future time $ToD_{X,i}$ at a future MPCP frame X, for EPoC the following future time at the future MPCP frame is substituted for $ToD_{X,i}$:

$$ToD\_EPOC\_CLT_{X,i} = ToD_{X,i} + T\_CORR\_CLT \tag{101–39}$$

(i.e., future time sent by CLT to CNU_i = 802.1AS future time + CLT correction factor)

where

$ToD\_EPOC\_CLT_{X,i}$	is the time of day at the future MPCP counter value X being sent from the CLT to CNU_i, corrected for the EPoC CLT PHY time delay asymmetry
$ToD_{X,i}$	is the future time for CNU_i at future MPCP counter value X as defined in IEEE Std 802.1AS, 13.1.4
T_CORR_CLT	is 1/2 of the CLTs differential delay as defined in Equation (101–40)

$$T\_CORR\_CLT = (MaxTxDly - MaxRxDly + MinTxDly - MinRxDly)/2 \tag{101–40}$$

where

$MaxTxDly$	is the management variable equivalent to Clause 45 registers 1.1801 and 1.1802.
$MaxRxDly$	is the management variable equivalent to Clause 45 registers 1.1803 and 1.1804.
$MinRxDly$	is the management variable equivalent to Clause 45 registers 1.1805 and 1.1806.
$MinRxDly$	is the management variable equivalent to Clause 45 registers 1.1807 and 1.1808.

101.5.2 CNU PHY asymmetry correction of future time received by CNU_i

Instead of using the $ToD\_EPOC\_CLT_{X,i}$ future time for CNU_i directly, each CNU_i is to correct the future time value received from the CLT for its own CNU PHY time delay asymmetry as follows:

$$ToD\_EPOC\_CNU_{X,i} = ToD\_EPOC\_CLT_{X,i} + T\_CORR\_CNU_i \tag{101–41}$$

(i.e., CNU time = CNU_i future time sent by CLT + CNU_i correction factor) where

$ToD\_EPOC\_CNU_{X,i}$	is the future time to be loaded in the time of day counter of CNU_i at the future MPCP counter value X
$ToD\_EPOC\_CLT_{X,i}$	is defined above in Equation (101–39)
$T\_CORR\_CNU_i$	is 1/2 of the CNUs differential delay as given in Equation (101–42)

$$T\_CORR\_CNU = (MaxTxDly - MaxRxDly + MinTxDly - MinRxDly)/2 \quad (101\text{–}42)$$

101.6 Protocol implementation conformance statement (PICS) proforma for Clause 101, Reconciliation Sublayer, Physical Coding Sublayer, and Physical Media Attachment for EPoC[5]

101.6.1 Introduction

The supplier of a protocol implementation that is claimed to conform to Clause 101, Reconciliation Sublayer, Physical Coding Sublayer, and Physical Media Attachment for EPoC, shall complete the following protocol implementation conformance statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in Clause 21.

101.6.2 Identification

101.6.2.1 Implementation identification

Supplier[1]	
Contact point for inquiries about the PICS[1]	
Implementation Name(s) and Version(s)[1,3]	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)[2]	
NOTE 1—Required for all implementations. NOTE 2—May be completed as appropriate in meeting the requirements for the identification. NOTE 3—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

101.6.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3bn-2016, Clause 101, Reconciliation Sublayer, Physical Coding Sublayer, and Physical Media Attachment for EPoC
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See Clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3bn-2016.)	

Date of Statement	

[5]*Copyright release for PICS proformas:* Users of this standard may freely reproduce the PICS proforma in this subclause so that it can be used for its intended purpose and may further publish the completed PICS.

101.6.3 Major capabilities/options

Item	Feature	Subclause	Value/Comment	Status	Support
CLT	CLT Functionality	101.3	Device supports the functionality required for CLT	O	Yes [ ] No [ ] N/A [ ]
CNU	CNU Functionality	101.3	Device supports the functionality required for NCU	O	Yes [ ] No [ ] N/A [ ]

101.6.4 PICS proforma tables for Reconciliation Sublayer, Physical Coding Sublayer, and Physical Media Attachment for EPoC

101.6.4.1 General specifications

Item	Feature	Subclause	Value/Comment	Status	Support
G1	Unidirectional mode	76.2.3	Device operates in unidirectional transmission mode	CLT: M	Yes [ ] No [ ] N/A [ ]
G2	Delay variation	101.1.2	Combined delay variation through RS, PCS, and PMA sublayers is limited to 1 time_quantum	M	Yes [ ] No [ ]
G3	PMA to PCS transfer function	101.3.3.1.8	Meets the requirements of Figure 101–15	CLT: M	Yes [ ] No [ ] N/A [ ]
G4	PMA service interface	101.4.2	Support for PMA_UNITDATA.request() and PMA_UNITDATA.indication()	M	Yes [ ] No [ ]
G5	OFDM channel number	101.4.3.1	PHY declares number of downstream OFDM channels supported	M	Yes [ ] No [ ]
G6	OFDM Modulations	101.4.3.4	PHY declares optional modulations supported	M	Yes [ ] No [ ]
G7	IDFT subcarrier index range	101.4.3.11	$148 \leq k \leq 3947$	M	Yes [ ] No [ ]
G8	Time synchronization support	101.5	Methods described in 101.5.1 and 101.5.2 supported	O	Yes [ ] No [ ]

101.6.4.2 Transmission functions

Item	Feature	Subclause	Value/Comment	Status	Support
TX1	DS Excluded Subcarriers	101.4.3.4.4	No transmissions in excluded subcarriers	CLT:M	Yes [ ] No [ ] N/A [ ]
TX2	DS Subcarriers	101.4.3.11	Comply with Equation (101–30)	CLT:M	Yes [ ] No [ ] N/A [ ]
TX3	US Excluded Subcarriers	101.4.4.4.3	No transmissions in excluded subcarriers	CNU: M	Yes [ ] No [ ] N/A [ ]
TX4	Burst Start	101.4.4.3.2	CNU Burst begins with start burst marker	CNU: M	Yes [ ] No [ ] N/A [ ]
TX5	Burst End	101.4.4.3.4	Burst ends with start end marker	CNU: M	Yes [ ] No [ ] N/A [ ]

101.6.4.3 OFDM Configuration functions

Item	Feature	Subclause	Value/Comment	Status	Support
OC1	OFDM channel 1	101.4.3.1	OFDM channel 1 always enabled	M	Yes [ ] No [ ]
OC2	DS frame timing	101.4.4.3.6	Meets the requirements of Figure 101–31	CNU: M	Yes [ ] No [ ] N/A [ ]
OC3	DS Subcarrier configuration	101.4.3.4	Meets the requirements of Table 101–8	M	Yes [ ] No [ ]
OC4	DS CP values	101.4.3.12	As shown in Table 101–10	CLT: M	Yes [ ] No [ ] N/A [ ]
OC5	DS Windowing values	101.4.3.12	As shown in Table 101–11 and less than CP value	CLT: M	Yes [ ] No [ ] N/A [ ]
OC6	DS Profile changes ignored	101.4.2	When DS_CpyInP is a one writes to all downstream profile variables shall be ignored and switching between profiles is prohibited	CNU: M	Yes [ ] No [ ] N/A [ ]
OC7	US Superframe	101.4.4.3.1	Six symbol Probe Period followed by 256 symbols	CNU: M	Yes [ ] No [ ] N/A [ ]
OC8	US subcarrier configuration	101.4.4.4	Meets the requirements of Table 101–13	CNU: M	Yes [ ] No [ ] N/A [ ]

Item	Feature	Subclause	Value/Comment	Status	Support
OC9	US CP size	101.4.4.10	Per Table 101–17	CNU: M	Yes [ ] No [ ] N/A [ ]
OC10	US Windowing size	101.4.4.10	Per Table 101–18	CNU: M	Yes [ ] No [ ] N/A [ ]
OC11	US Profile changes ignored	101.4.2	When US_CpyInP is a one writes to all upstream profile variables shall be ignored and switching between profiles is prohibited	CNU: M	Yes [ ] No [ ] N/A [ ]
OC12	Activation of OFDMA timing adjustments	101.4.4.2.2	OFDMA timing adjustment accurate to within ± 10 ns	CNU:M	Yes [ ] No [ ] N/A [ ]
OC13	Bit stream to constellation mapping	101.4.5	Per Figure 101–39	M	Yes [ ] No [ ]
OC14	QAM constellation scaling	101.4.5.5	Per Table 101–19	M	Yes [ ] No [ ]

101.6.4.4 OFDM Timing

Item	Feature	Subclause	Value/Comment	Status	Support
OT1	Downstream Synchronization	101.4.3.2	CLT transmitters and CNU receivers meet the requirements of Table 101–7	M	Yes [ ] No [ ]
OT2	DS OFDM Channels	101.4.3.13	Conform to requirements of Table 101–12	CLT: M	Yes [ ] No [ ] N/A [ ]
OT3	CLT synchronization	101.4.3.2	CLT OFDM Clock and RF transmissions locked to 10.24 MHz Master Clock	CLT: M	Yes [ ] No [ ] N/A [ ]
OT4	CLT Subcarrier Clock source	101.4.3.3	Synchronous with the 10.24 MHz Master Clock	CLT: M	Yes [ ] No [ ] N/A [ ]
OT5	CLT Subcarrier Clock frequency	101.4.3.3	Meets the requirements of Equation (101–6)	CLT: M	Yes [ ] No [ ] N/A [ ]
OT6	CLT phase noise	101.4.3.2	CLT meets the more stringent requirements from Table 100–4 (Phase noise) and Table 101–7 (clock jitter)	CLT: M	Yes [ ] No [ ] N/A [ ]
OT7	CNU synchronization	101.4.3.2	CNU synchronizes its 10.24 MHz Master Clock to the PHY Link frame	CNU: M	Yes [ ] No [ ] N/A [ ]
OT8	CNU Subcarrier Clock synchronization	101.4.4.2.1	CNU Subcarrier Clock and 50 kHz subcarrier frequency locked to 10.24 MHz Master Clock	CNU:M	Yes [ ] No [ ] N/A [ ]

Item	Feature	Subclause	Value/Comment	Status	Support
OT9	CNU Subcarrier Clock frequency accuracy	101.4.4.2.1	CNU Subcarrier Clock accurate to within 0.4 ppm	CNU:M	Yes [ ] No [ ] N/A [ ]
OT10	CNU OFDM Clock timing error	101.4.4.2.3	CNU OFDM Clock timing error relative to the CLT 10.24 MHz Master Clock as measured at the CLT within ± 10 ns in each burst measured within 35 s measurement duration	CNU:M	Yes [ ] No [ ] N/A [ ]
OT11	CNU SC frequency accuracy	101.4.4.2.1	CNU subcarrier frequency accurate to within 30 Hz	CNU:M	Yes [ ] No [ ] N/A [ ]
OT12	FCP Update	101.4.3.8.4	FPC value passed with sufficient time for insertion in PHY Link frame	CLT: M	Yes [ ] No [ ] N/A [ ]

101.6.4.5 Data Detector functions

Item	Feature	Subclause	Value/Comment	Status	Support
DD1	Data Detector input process	101.3.2.5.8	Meets the requirements of Figure 101–11	M	Yes [ ] No [ ]
DD2	CLT Data Detector output process	101.3.2.5.8	Meets the requirements of Figure 101–12	CLT: M	Yes [ ] No [ ] N/A [ ]
DD3	CNU Data Detector output process	101.3.2.5.8	Meets the requirements of Figure 101–13	CNU: M	Yes [ ] No [ ] N/A [ ]

101.6.4.6 IDLE insertion and deletion functions

Item	Feature	Subclause	Value/Comment	Status	Support
IDI1	CLT Idle Deletion function implementation	101.3.2.1.5	Meets the requirements of Figure 101–6	CLT: M	Yes [ ] No [ ] N/A [ ]
IDI2	CNU Idle Deletion function implementation	101.3.2.5.8	Meets the requirements of Figure 101–7	CNU: M	Yes [ ] No [ ] N/A [ ]
IDI3	Idle Insertion	101.3.2.5.8	Meets the requirements of Figure 101–18	M	Yes [ ] No [ ]

101.6.4.7 FEC functions

Item	Feature	Subclause	Value/Comment	Status	Support
FE1	CLT FEC Encoder	101.3.2.4	LDPC (16200, 14400)	CLT: M	Yes [ ] No [ ] N/A [ ]
FE2	CNU FEC Decoder	101.3.3	LDPC (16200, 14400)	CNU: M	Yes [ ] No [ ] N/A [ ]
FE3	CNU FEC input/output	101.3.3.1.8	CNU FEC input process meets the requirements of Figure 101–16 and CNU FEC output process meets the requirements of Figure 101–17	CNU: M	Yes [ ] No [ ] N/A [ ]
FE4	CNU FEC Encoder	101.3.2.4	LDPC (16200, 14400), LDPC (5940, 5040) and LDPC (1120, 840)	CNU: M	Yes [ ] No [ ] N/A [ ]
FE5	CLT FEC Decoder	101.3.3	LDPC (16200, 14400), LDPC (5940, 5040) and LDPC (1120, 840)	CLT: M	Yes [ ] No [ ] N/A [ ]
FE6	CRC40 Calculation	101.3.2.3	Meets the requirements of Figure 101–8	M	Yes [ ] No [ ]
FE7	CRC40 Initialization	101.3.2.3	CRC40 calculation initialized to 0x00 at the beginning of each FEC codeword	M	Yes [ ] No [ ]
FE8	Uncorrectable FEC code-word indication	101.3.3.1.4	Uncorrectable FEC codewords marker under user configura-tion per Table 101–6	M	Yes [ ] No [ ]

101.6.4.8 Encoding functions

Item	Feature	Subclause	Value/Comment	Status	Support
EN1	CLT Scrambler	101.4.3.7	Downstream data scrambler meets the requirement of Figure 101–21	CLT: M	Yes [ ] No [ ] N/A [ ]
EN2	CLT scrambler initialization	101.4.3.7	at the first codeword of the downstream frame	CLT:M	Yes [ ] No [ ] N/A [ ]
EN3	CNU scrambler initialization	101.4.3.7	at the beginning of each grant	CNU:M	Yes [ ] No [ ] N/A [ ]
EN4	CLT Symbol Mapping	101.4.3.8.3	Symbol mapper processes all active subcarriers	CLT: M	Yes [ ] No [ ] N/A [ ]
EN5	CLT Time Interleaving	101.4.3.9.2	Time interleaving as described in 101.4.3.9.2	CLT: M	Yes [ ] No [ ] N/A [ ]

Item	Feature	Subclause	Value/Comment	Status	Support
EN6	CLT Time Interleaving depth	101.4.3.9.2	Between 1 and 32 inclusive	CLT: M	Yes [ ] No [ ] N/A [ ]
EN7	CLT Frequency Interleaving	101.4.3.9.3	Frequency interleaving meets the requirements of 101.4.3.9.3	CLT: M	Yes [ ] No [ ] N/A [ ]
EN8	CNU Symbol mapper Idle function	101.4.4.5.3	Meets the requirements of Figure 101–32	CNU: M	Yes [ ] No [ ] N/A [ ]
EN9	CNU Symbol mapper fill function	101.4.4.5.3	Meets the requirements of Figure 101–33	CNU: M	Yes [ ] No [ ] N/A [ ]

101.6.4.9 Pilots

Item	Feature	Subclause	Value/Comment	Status	Support
PI1	Scattered pilot definition	101.4.3.6.1	Defined per101.4.3.6	CLT: M	Yes [ ] No [ ] N/A [ ]
PI2	Continuous Pilot placement	101.4.3.6.4	Meets the Equation (101–9) and the eight steps given in 101.4.3.6.4	CLT: M	Yes [ ] No [ ] N/A [ ]
PI3	PHY Link Continous Pilots	101.4.3.6.3	Four pairs placed symmetrically about the PHY Link as in Figure 102–7 and Table 101–9	CLT: M	Yes [ ] No [ ] N/A [ ]
PI4	Pilot modulation	101.4.3.10	BPSK using pseudo-random generator shown in Figure 101–28	CLT: M	Yes [ ] No [ ] N/A [ ]
PI5	Pilot boosting	101.4.3.10.1	Amplitude of pilots is 2 times the RMS value of the amplitude of other subcarriers	CLT: M	Yes [ ] No [ ] N/A [ ]
PI6	US Pilot Insertion	101.4.4.7.2	Meets the requirements of 101.4.4.7.2	CNU: M	Yes [ ] No [ ] N/A [ ]

101.6.4.10 Equalization

Item	Feature	Subclause	Value/Comment	Status	Support
EQ1	Equalized subcarriers	101.4.4.9.1	All data transmissions except Probe and PHY Discovery Response. Probe equalization under control of PHY Link	CNU: M	Yes [ ] No [ ] N/A [ ]
EQ2	US Subcarrier equalization	101.4.4.9.1	Single complex coefficient per subcarrier updated by the PHY Link	CNU: M	Yes [ ] No [ ] N/A [ ]
EQ3	US Subcarrier equalization default	101.4.4.9.1	Default value of 1+j0	CNU: M	Yes [ ] No [ ] N/A [ ]
EQ4	Equalizer coefficient normalization	101.4.4.9.1	Adjusting the mean of (abs $(Ck)^2$) to be 1	CNU: M	Yes [ ] No [ ] N/A [ ]
EQ5	Equalizer coefficient activation time	101.4.4.9.1	Within 10 ms of receipt at the beginning of a transmission	CNU: M	Yes [ ] No [ ] N/A [ ]

102. EPoC PHY Link

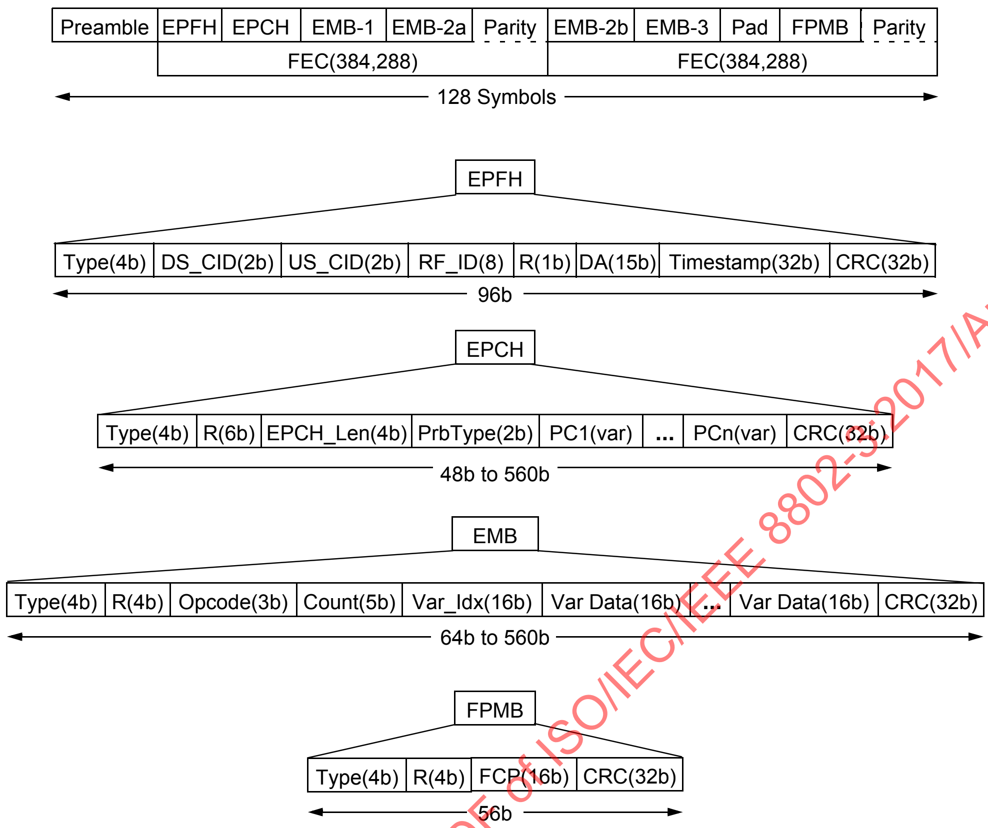
102.1 PHY Link overview and architecture

The PHY Link is a low level communications link used between the CLT PHY and its subordinated CNU PHYs. It is used to communicate PHY OFDM channel parameters and to negotiate initialization of CNUs that wish to join the EPoC network. A small amount of RF spectrum is dedicated to the PHY Link at network setup time for both the upstream (US) and the downstream (DS) directions (see 102.2.1 and 102.3.1). In a multi-OFDM channel PHY, only OFDM channel one has a PHY Link (see Figure 102–1 and Figure 102–3). The PHY Link uses a straightforward query response protocol with broadcast capability to transfer information in variables between the CLT and its subordinated CNUs and vice versa. Both the upstream and the downstream PHY Link include a frame structure. Each PHY Link frame is composed of message blocks containing timing, control information, status information, PHY Instructions, or PHY Responses. The frame is padded to achieve a fixed bit length and encoded in multiple FEC codewords.

The upstream superframe (see 101.4.4.3.1) begins with the Probe Period. CNU PHY Discovery Responses and probing are performed during the Probe Period. The PHY Discovery Response is used for initial CNU bring up and is fully described in 102.4.1.4. Probing is used to perform fine ranging and periodic link maintenance tasks and is described in 102.4.2.

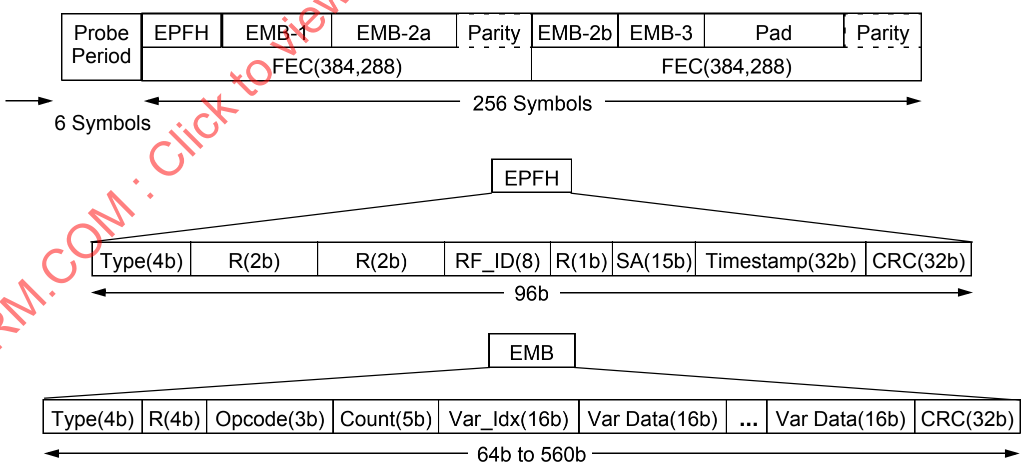
102.1.1 PHY Link frame structure and protocol

The PHY Link frame is illustrated in Figure 102–1 and Figure 102–2.



NOTE—The notation "(#b)" indicates the number of bits in the field.

Figure 102–1—Downstream PHY Link frame



NOTE—The notation "(#b)" indicates the number of bits in the field.

Figure 102–2—Upstream PHY Link frame

The PHY Link protocol is a query and response protocol where the CLT transmits one or more instructions enclosed in EPoC Message Blocks to a CNU or group of CNUs. Each instruction can perform a read, write or write/verify operation. Read and write/verify instructions cannot be addressed to a group of CNUs. The PHY Link frame length shall be fixed; the downstream length is 128 OFDM symbols long and the upstream length is 262 OFDM symbols long.

The CLT and the CNU shall support both an upstream and a downstream PHY Link channel.

102.1.2 PHY Link block diagram

The architecture of the PHY Link data path is illustrated in Figure 102–3 and Figure 102–4. The relationship between the PHY Link functional blocks and the rest of the 10GPASS-XR PHY is illustrated in Figure 101–1 and Figure 101–2.

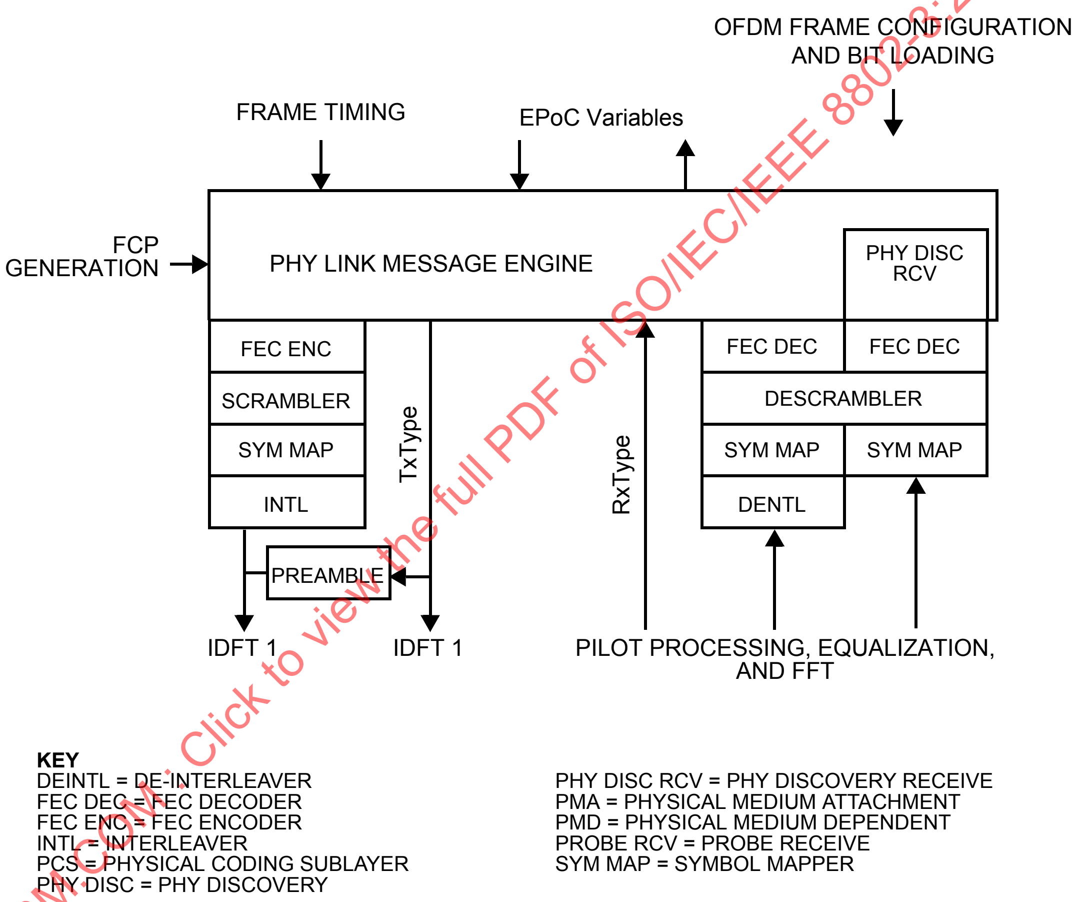


Figure 102–3—PHY Link CLT architecture

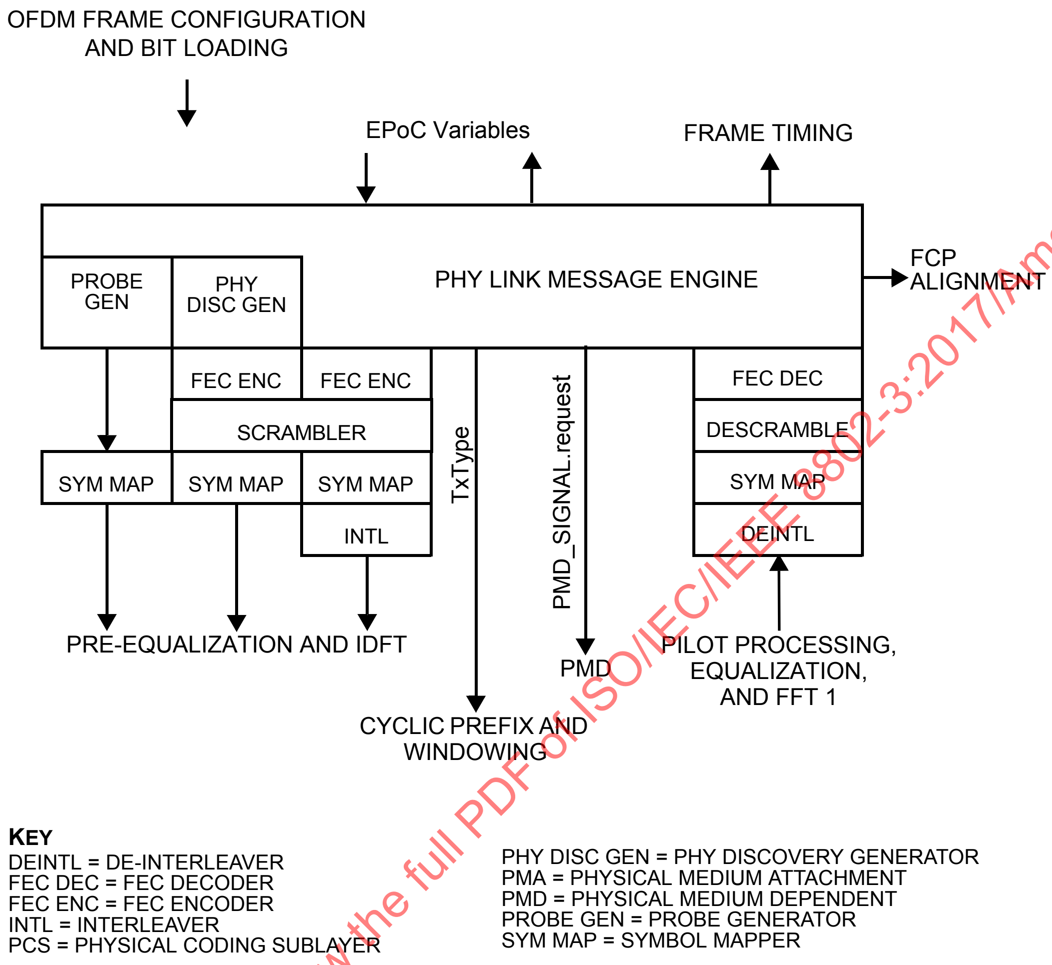


Figure 102–4—PHY Link CNU architecture

102.1.3 PHY Link Message Engine

The PHY Link Message Engine block is responsible for the origination and termination of all messages passed over the PHY Link, as well as PHY to PHY signaling. In the downstream direction there are four message blocks—the EPoC PHY Frame Header (EPFH), the EPoC Probe Control Header (EPCH), the EPoC message block, and the FEC Parity message block. The upstream PHY Link Message Engine also has the two additional PHY to PHY signaling types—PHY Discovery Response and Probing.

The content of each message block is detailed in the following subclauses as is the characteristic of the two additional PHY signaling types. The details of the PHY Message Engine behavior is described in 102.2.3 and 102.3.2.

Once a PHY Link message block has been created the stream of bytes is converted into a stream of bits, MSB first.

102.1.4 PHY Link FEC encoder

The PHY Link uses several LDPC FEC encoders. These encoders are derived from mother encoders using either puncturing only or both shortening and puncturing. A general description of LDPC codes is given in 101.3.2.4.

102.1.4.1 LDPC (480, 288) mother code

The base matrix of a parity check matrix for the (480,288) mother code is listed in Table 102–1, where the submatrix size (lifting factor) is $L = 48$ (see 101.3.2.4 for the general definition of a base matrix).

Table 102–1—Base matrix of (480,288) LDPC code parity check matrix

Columns	Rows									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	16	1	28	9	40	38	16	—	—	—
2	28	42	36	11	39	9	8	38	—	—
3	5	2	18	16	25	47	—	2	19	—
4	18	18	40	18	0	34	—	—	7	32

102.1.4.2 LDPC (160, 80) mother code

The base matrix of a parity check matrix for the (160,80) mother code is listed in Table 102–2, where the submatrix size (lifting factor) is $L = 16$ (see 101.3.2.4 for the general definition of a base matrix).

Table 102–2—Base matrix for (160, 80) DPC code parity check matrix

Columns	Rows									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	1	11	10	12	7	9	—	—	—	—
2	2	1	14	15	14	14	12	—	—	—
3	0	9	3	2	—	—	11	7	—	—
4	6	8	—	10	3	—	—	10	4	—
5	12	13	11	—	0	—	—	—	5	2

102.1.4.3 Shortening and puncturing encoders

Shortening encoder operationally includes the following three steps:

a) Pad zero bits to the payload bits to fit for the codeword size of the mother code, the entire bits are called mother code information bits and the coordinates corresponded to the padded zeros are called shortening coordinates.
b) Encode the information bits obtained in step a) using mother code encoder.
c) Delete the shortening coordinates: i.e., all the padded zero bits in step a).

Puncturing encoder operationally includes the following two steps:

1) Encode the payload (with or without padding) bits using mother encoder.
2) Delete the puncturing coordinates of encoded codeword of step 1), where the puncturing coordinates are given coordinates of the mother code codeword.

102.1.4.3.1 LDPC (384, 288) puncturing encoder

The LDPC (384, 288) encoder is operated on the (480, 288) LDPC mother code encoder with the puncturing.

The mother code is defined in 102.1.4.1. The puncturing operation is as follows (also see Figure 102–5):

1) Denote the information bits sent to the mother code encoder by (a_0, … , a_{287})
2) Let the encoding output be (a_0, … , a_{287}, b_{288}, … , b_{479}), where (b_{288}, … , b_{479}) are parity-check bits. The coordinates to be deleted by the puncturing step are as follows:
   — Period 1: 48 consecutive coordinates a_{48}, … , a_{95}
   — Period 2: 48 consecutive coordinates b_{384}, … , b_{431}

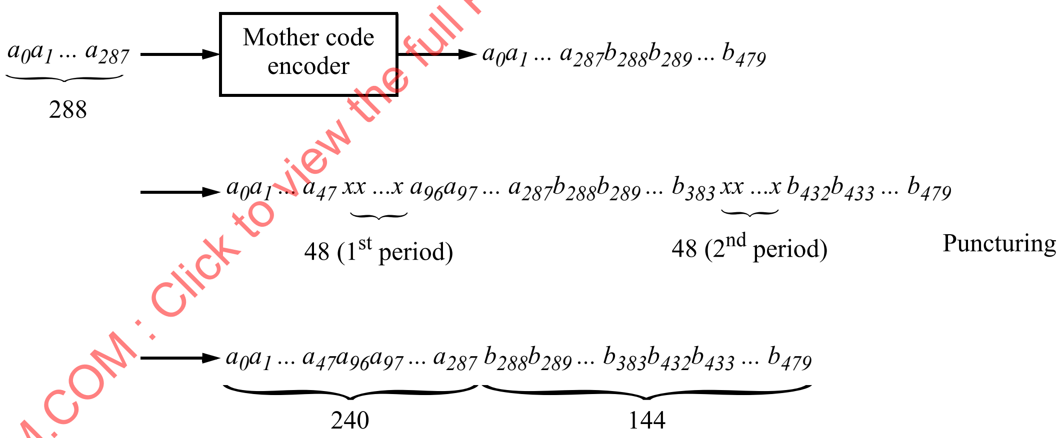


Figure 102–5—Puncturing encoder for LDPC (384,288) FEC

102.1.4.3.2 LDPC (128, 80) puncturing encoder

The LDPC (128, 80) encoder is operated on the (160, 80) LDPC mother code encoder with the puncturing.

The mother code is defined in 102.1.4.2.

The puncturing operation is as follows (also see Figure 102–6):

Denote the information bits sent to the mother code encoder by (a_0, ... , a_{79}) and let the encoding output be (a_0, ... , a_{79}, b_{80}, ... , b_{159}), where (b_{80}, ... , b_{159}) are parity-check bits. Then do puncturing on the puncturing coordinates given by the following:

— Period 1: 16 consecutive coordinates a_0, ... , a_{15}
— Period 2: 16 consecutive coordinates b_{144}, ... , b_{159}

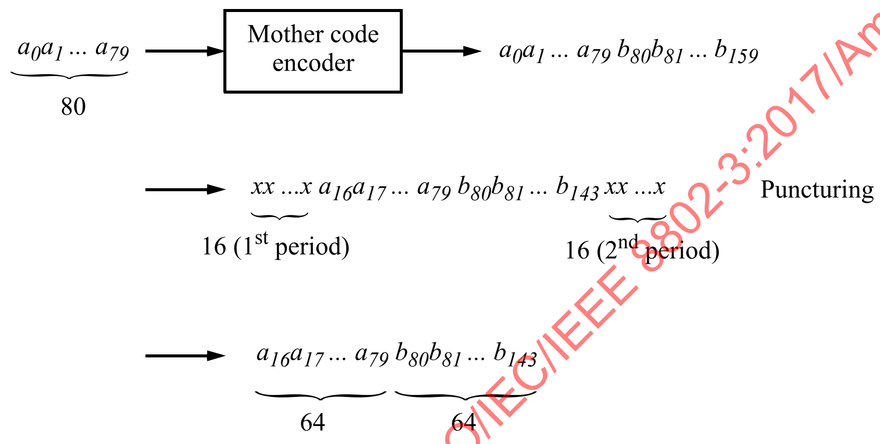


Figure 102–6—Puncturing encoder for the LDPC (128, 80) FEC

102.1.5 PHY Link scrambler

The CLT and CNU shall scramble the output of the PHY Link FEC encoding process using a linear feedback shift register mechanism as illustrated in Figure 101–21.

The scrambler is defined by the following polynomial:

$$x^{23} + x^{18} + 1$$

The scrambler is initialized to the hexadecimal value of 0x4732BA. The CLT shall initialize the scrambler with the hexadecimal value at the beginning of the first OFDM symbol following the PHY Link preamble in the downstream direction. In the upstream direction, the CNU shall initialize the scrambler at the beginning of an upstream PHY Link transmission.

The PHY shall not scramble the PHY Link preamble.

102.1.6 PHY Link symbol map and constellation mapping

The PHY maps the scrambled bit stream of normal PHY Link data into a complex number using the assigned modulation order. In the downstream direction, the assigned modulation order shall be 16-QAM and uses the mapping shown in 101.4.5. The upstream PHY Link shall be 16-QAM or a higher order modulation (see 101.4.5 for mapping structure). The PHY multiplies the real and imaginary parts by the appropriate factor in Table 101–19 to ensure that mean-square value of the QAM constellation is unity.

102.1.7 Interleaving

Data in the PHY Link channel is time interleaved. For the downstream direction this time interleaving is described in 102.2.1.3.

Transmissions in the upstream direction for PHY Discovery Response are not time interleaved.

Control for the interleaving process is conveyed using the TxType in the CNU (see Figure 102–4) and RxType in the CLT (see Figure 102–3).

102.1.8 Mapping of PHY Link variables

The optional MDIO capability described in Clause 45 defines several variables that may provide control and status information for and about the PHY Link or are communicated between CLT and CNU via the PHY Link. Mapping of MDIO control and status variables to PHY Link variables is shown in Table 102–3. The least significant bit in each variable is mapped to the lowest numbered bit in the lowest numbered register for Clause 45 registers. These variables are used by the PHY Link for PHY management.

NOTE—Most of the variables transferred via the PHY Link are reflected in Clause 45. The EPoC Index and bits are determined from Clause 45 register designations using the following rules:
If 1.1900 ≤ RegAdd ≤1.1999, then Index = (RegAdd – 1.1900) × 1000 (i.e., 0 to 99).
If 12.0000 ≤ RegAdd, then Index = (RegAdd – 12.0000) × 1000 + 1000 (i.e., 1000 +).
If variable is not in Clause 45, indexes between 500 and 999 are used and are given in the variable definition.

Table 102–3—MDIO register to PHY variable mapping

MDIO parameter name	MDIO register name	Register / bit number	PHY variable		
			Name	Index	Bit(s)
Link up ready	10GPASS-XR control and status	1.1900:10	*LinkUpRdy*	0	10
PHY Discovery complete	10GPASS-XR control and status	1.1900.1	*PhyDiscCmplt*	0	1
PHY Discovery enable	10GPASS-XR control and status	1.1900.0	*PD_Enable*	0	0
DS windowing	DS OFDM control	1.1901.6:4	*DSNrp*	1	6:4
DS cyclic prefix	DS OFDM control	1.1901.3:0	*DSNcp*	1	3:0
DS OFDM freq ch 1	DS OFDM channel frequency control 1	1.1902.15:0	*DS_FreqCh(1)*	2	15:0
DS OFDM freq ch 2	DS OFDM channel frequency control 1	1.1903.15:0	*DS_FreqCh(2)*	3	15:0
DS OFDM freq ch 3	DS OFDM channel frequency control 3	1.1904.15:0	*DS_FreqCh(3)*	4	15:0
DS OFDM freq ch 4	DS OFDM channel frequency control 4	1.1905.15:0	*DS_FreqCh(4)*	5	15:0
DS OFDM freq ch 5	DS OFDM channel frequency control 5	1.1906.15:0	*DS_FreqCh(5)*	6	15:0
Random seed	US OFDM control	1.1907.15:8	*Rnd*	7	15:8
Resource Block size	US OFDM control	1.1907.7	*RBsize*	7	7

Table 102–3—MDIO register to PHY variable mapping *(continued)*

MDIO parameter name	MDIO register name	Register / bit number	PHY variable		
			Name	Index	Bit(s)
US windowing	US OFDM control	1.1907.6:4	*USNrp*	7	6:4
US cyclic prefix	US OFDM control	1.1907.3:0	*USNcp*	7	3:0
US OFDM freq	US OFDM channel frequency control	1.1908.15:0	*US_FreqCh1*	8	15:0
US copy in process	Profile control	1.1910.11	US_CpyInP	10	11
US profile copy	Profile control	1.1910.10	US_PrflCpy	10	10
US configuration ID	Profile control	1.1910.9:8	US_CID	10	9:8
DS copy channel ID	Profile control	1.1910.6:4	DS_CpyCh	10	6:4
DS copy in process	Profile control	1.1910.3	DS_CpyInP	10	3
DS profile copy	Profile control	1.1910.2	DS_PrflCpy	10	2
DS configuration ID	Profile control	1.1910.1:0	*DS_CID*	10	1:0
DS PHY Link start	DS PHY Link control	1.1911.11:0	*DS_PhyLinkStrt*	11	11:0
US PHY Link modulation	US PHY Link control	1.1912.15:12	US_PhyLinkMod	12	15:12
US PHY Link start	US PHY Link control	1.1912.11:0	*US_PhyLinkStrt*	12	11:0
PHY Discovery start lower	PHY Discovery control	1.1913.15:0	*DiscStrt*(15:0)	13	15:0
PHY Discovery start upper	PHY Discovery control	1.1914.15:0	*DiscStrt*(31:16)	14	15:0
Assigned CNU_ID flag	New CNU control	1.1915.15	*AssgndCNU_ID*	15	15
Allowed CNU_ID	New CNU control	1.1915.14:0	*AllwdCNU_ID*	15	14:0
New CNU range	New CNU info	1.1916.15:0	*NewCNU_Rng*	16	15:0
New CNU MAC 0	New CNU info	1.1917.15:0	*New_MAC* (15:0)	17	15:0
New CNU MAC 1	New CNU info	1.1918.15:0	*New_MAC* (31:16)	18	15:0
New CNU MAC 2	New CNU info	1.1919.15:0	*New_MAC* (47:32)	19	15:0
PHY timing offset lower	PHY timing offset	1.1922.15:0	*PhyTimingOffset* (15:0)	22	15:0
PHY timing offset upper	PHY timing offset	1.1923.15:0	*PhyTimingOffset* (31:16)	23	15:0
PHY power offset	PHY power offset	1.1924.7:0	*PHYPowerOffset*	24	7:0
PHY ranging offset lower	PHY ranging offset	1.1925.15:0	*PhyRngOffset* (15:0)	25	15:0
PHY ranging offset upper	PHY ranging offset	1.1926.15:0	*PhyRngOffset* (31:16)	26	15:0
DS PHY data rate lower	DS PHY data rate	1.1927.15:3	*DS_DataRate (15:3)*	27	15:3

Table 102–3—MDIO register to PHY variable mapping *(continued)*

MDIO parameter name	MDIO register name	Register / bit number	PHY variable		
			Name	Index	Bit(s)
DS PHY data rate fractional	DS PHY data rate	1.1927.2:0	*DS_DataRate (2:0)*	27	2:0
DS PHY data rate mid	DS PHY data rate	1.1928.15:0	*DS_DataRate (31:16)*	28	15:0
DS PHY data rate upper	DS PHY data rate	1.1929.4:0	*DS_DataRate (36:32)*	29	4:0
US PHY data rate lower	US PHY data rate	1.1930.15:3	*US_DataRate (15:3)*	30	15:3
US PHY data rate fractional	US PHY data rate	1.1930.2:0	*US_DataRate (2:0)*	30	2:0
US PHY data rate mid	US PHY data rate	1.1930.15:0	*US_DataRate (31:16)*	31	15:0
US PHY data rate upper	US PHY data rate	1.1931.4:0	*US_DataRate (36:32)*	32	4:0
PHY Link EPFH counter	PHY Link EPFH counter	1.1939.15:0	*EPFHcnt*	39	15:0
PHY Link EPFH error counter	PHY Link EPFH error counter	1.1940.15:0	*EPCHcnt*	40	15:0
PHY Link EPCH counter	PHY Link EPCH counter	1.1941.15:0	*EMBcnt*	41	15:0
PHY Link EPCH error counter	PHY Link EPCH error counter	1.1942.15:0	*FPMBcnt*	42	15:0
PHY Link EMB counter	PHY Link EMB counter	1.1943.15:0	*EPFHerr*	43	15:0
PHY Link EMB error counter	PHY Link EMB error counter	1.1944.15:0	*EPCHerr*	44	15:0
PHY Link FPMB counter	PHY Link FPMB counter	1.1945.15:0	*EMBerr*	45	15:0
PHY Link FPMB error counter	PHY Link FPMB error counter	1.1946.15:0	*FPMBerr*	46	15:0
US PHY Link response time	US PHY Link response time	1.1947.15:0	*PhyLinkRspTm*	47	15:0
PHY Discovery Response power step	PHY Discovery Response power control	1949.15:8	*PdRespPwrStep*	51	15:8
PHY Discover Response initial power	PHY Discovery Response power control	1949.7:0	*PdRespInitPwr*	51	7:0
DS OFDM channel ID	DS OFDM channel ID	12.0.2:0	*DS_OFDM_ID*	1000	2:0
DS modulation type SC7	10GPASS-XR DS profile descriptor control 1	12.1.15:12	*DS_ModTypeSC(7)*	1001	15:12

Table 102–3—MDIO register to PHY variable mapping *(continued)*

MDIO parameter name	MDIO register name	Register / bit number	PHY variable		
			Name	Index	Bit(s)
DS modulation type SC6	10GPASS-XR DS profile descriptor control 1	12.1.11:8	*DS_ModTypeSC(6)*	1001	11:8
DS modulation type SC5	10GPASS-XR DS profile descriptor control 1	12.1.7:4	*DS_ModTypeSC(5)*	1001	7:4
DS modulation type SC4	10GPASS-XR DS profile descriptor control 1	12.1.3:0	*DS_ModTypeSC(4)*	1001	3:0
DS modulation type SC8 through DS modulation type SC4095	10GPASS-XR DS profile descriptor control 2 through 10GPASS-XR DS profile descriptor control 1023	12.2 through 12.1023	*DS_ModTypeSC(8)* through *DS_ModTypeSC(4095)*	1002 through 2023	as in index 1001
US modulation type SC0	10GPASS-XR US profile descriptor control 0	12.1024.3:0	*US_ModTypeSC(0)*	2024	3:0
US modulation type SC1	10GPASS-XR US profile descriptor control 0	12.1024.7:4	*US_ModTypeSC(1)*	2024	7:4
US modulation type SC2	10GPASS-XR US profile descriptor control 0	12.1024.11:8	*US_ModTypeSC(2)*	2024	11:8
US modulation type SC3	10GPASS-XR US profile descriptor control 0	12.1024.15:12	*US_ModTypeSC(3)*	2024	15:12
US modulation type SC4 through US modulation type SC4095	10GPASS-XR US profile descriptor control 1 through 10GPASS-XR US profile descriptor control 1023	12.1025 through 12.2047	*US_ModTypeSC(4)* through *US_ModTypeSC(4095)*	2025 to 3047	
Real pre-equalizer coefficient SC0	10GPASS-XR US pre-equalizer coefficients 0	12.2048.15:0	*EQ_CoefR(0)*	3048	15:0
Imaginary pre-equalizer coefficient SC0	10GPASS-XR US pre-equalizer coefficients 0	12.2049.15:0	*EQ_CoefI(0)*	3049	15:0
Real pre-equalizer coefficient SC1 through Real pre-equalizer coefficient SC4095	10GPASS-XR US pre-equalizer coefficients 1 through 10GPASS-XR US pre-equalizer coefficients 4095	12.2050 12.2052 ... 12.10238	*EQ_CoefR(1)* through *EQ_CoefR(4095)*	3050 3052 ... 11238	15:0
Imaginary pre-equalizer coefficient SC1 through Imaginary pre-equalizer coefficient SC4095	10GPASS-XR US pre-equalizer coefficients 1 through 10GPASS-XR US pre-equalizer coefficients 4095	12.2051 12.2053 ... 12.10239	*EQ_CoefI(1)* through *EQ_CoefI(4095)*	3051 3053 ... 11239	15:0

102.2 Downstream PHY Link

102.2.1 Downstream PHY Link Physical Layer

102.2.1.1 Resource allocation

During network setup the downstream PHY Link shall be allocated 400 kHz of spectrum. The allocated spectrum for the downstream PHY Link shall reside anywhere within a 24 MHz contiguous OFDM channel spectrum (i.e., 24 MHz with no internal exclusion bands) and have at least 3 MHz of contiguous spectrum above and below it for a total band of 6 MHz. This PHY Link band also includes eight pilot tone subcarriers placed symmetrically above and below the information subcarriers as illustrated in Figure 102–7; see 101.4.3.6.3 for exact placement of pilots. No additional continuous pilots are allowed within this 6 MHz band (see 101.4.3.6). However, scattered pilots are allowed in this spectrum in subcarriers that normally carry MAC data. The downstream PHY Link is located per the *DS_PhyLinkStrt* variable (see 102.2.7.3) that determines the lowest frequency subcarrier of the PHY Link. The downstream PHY Link shall use the same OFDM Symbol definition (cyclic prefix duration and windowing size) as the downstream MAC data OFDM channel.

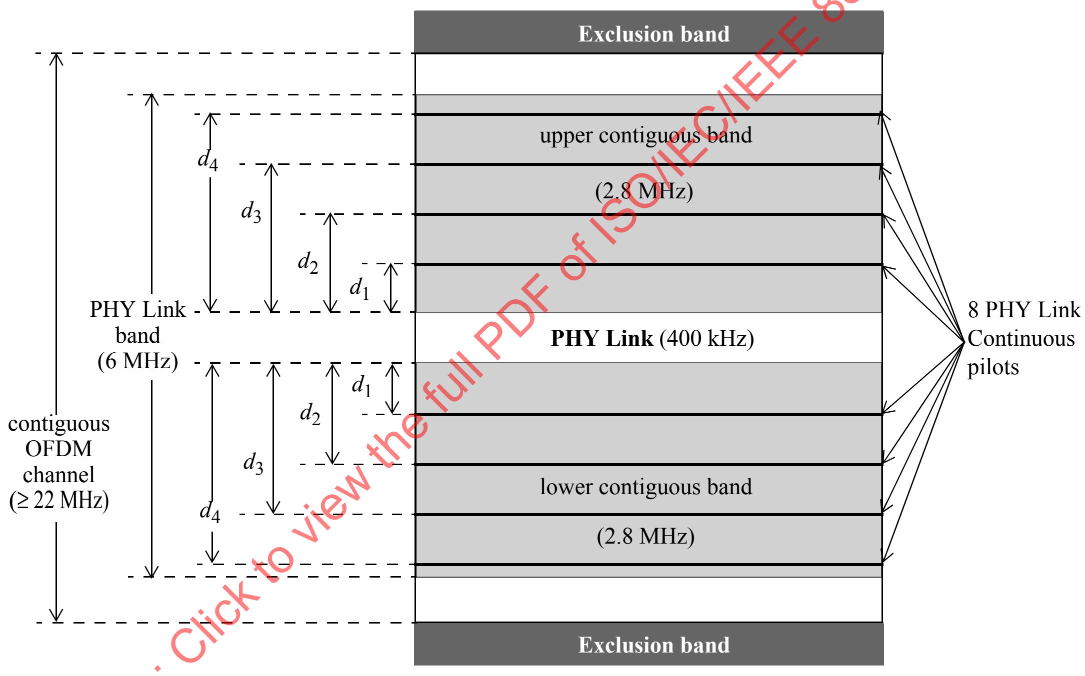


Figure 102–7—Downstream PHY Link spectrum placement

102.2.1.2 Downstream PHY Link modulation

The downstream PHY Link uses a 16-QAM constellation for all information subcarriers as specified under PHY Link CLT Tx/CNU Rx in Table 100–2.

102.2.1.3 Downstream PHY Link subcarrier block interleaving

Figure 102–5 shows 288 data bits entering the LDPC Encoder and 384 encoded bits exiting it. This sequence is in effect time-reverse ordered. The time-ordered sequence takes the form shown in Figure 102–8. The PHY shall map the 384 FEC encoded data bits, as processed by the scrambler, to 96 4-bit nibbles $\{u_i, i=0, 1, \dots, 95\}$ as shown in Figure 102–8.

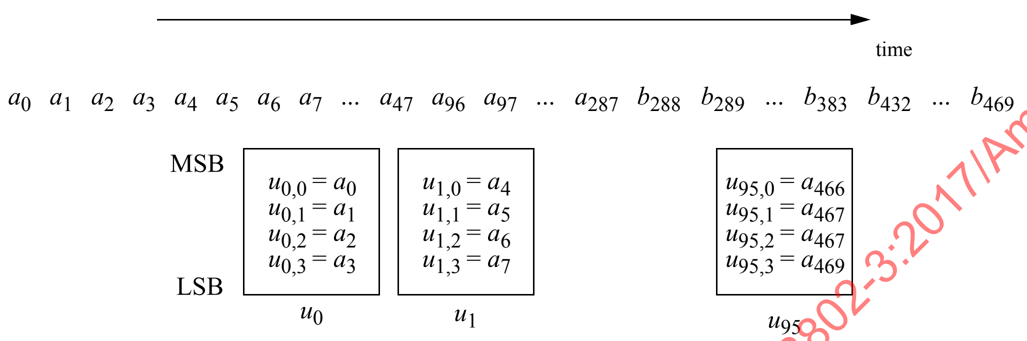


Figure 102–8—Downstream PHY Link mapping of FEC output to stream nibbles

The resulting 4-bit nibbles from this mapping operation are then time-interleaved. The PHY shall interleave the 96-nibble sequence $\{u_0\ u_1\ u_2 \dots\ u_{95}\}$ as illustrated in Figure 102–9.

Conceptually, the PHY uses an 8×2 array to perform interleaving. The PHY writes the values u_i along the rows of this two-dimensional array, as shown in Figure 102–9. The PHY reads this two-dimensional array along vertical columns to form the two-dimensional sequence $\{v_{t,f},\ t = 0,1,\dots,11$ and $f = 0,1,\dots,7\}$. This operation is mathematically represented as follows:

$$v_{t,f} = u_{t+12f} \qquad (102\text{–}1)$$

The PHY maps each of the 8-point sequences given in Equation (102–2) to the eight successive PHY Link subcarriers of an OFDM symbol after scrambling as described in the 102.1.5.

$$V_t = \{v_{t,f}, f = 0,1,\dots,7\} \text{ for 12 successive OFDM symbols t} = 0, 1, \dots, 11 \qquad (102\text{–}2)$$

Therefore, each FEC codeword will occupy the PHY Link segment of twelve successive OFDM symbols. There will be ten such codewords in a 128-symbol PHY Link frame, including the 8-symbol preamble.

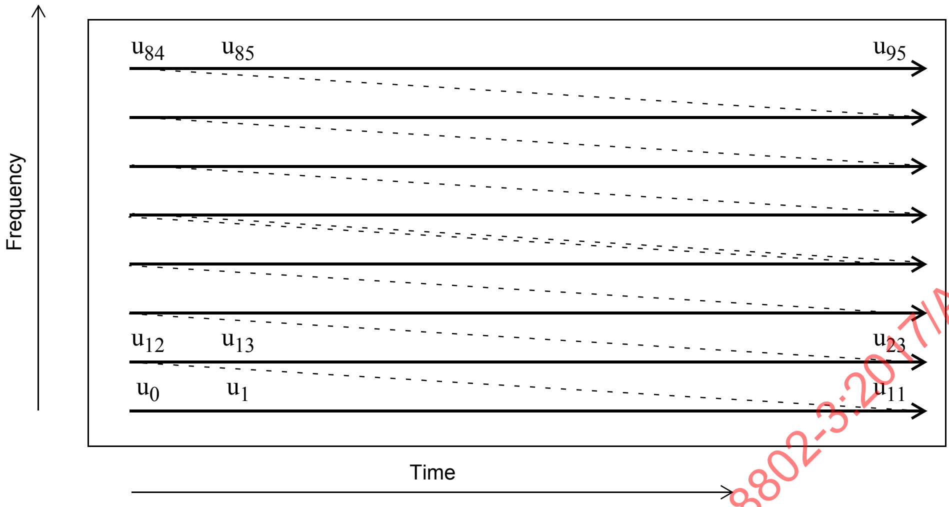


Figure 102–9—Downstream PHY Link subcarrier block interleaving

The PHY Link is time interleaved separately from the MAC data OFDM channel. The PHY Link preamble is not time interleaved.

102.2.2 Downstream preamble

The downstream Preamble shall be a fixed pattern of 64 bits as illustrated in Table 102–4, modulated using binary phase-shift keying (BPSK), that fill the first eight symbols of the PHY Link frame. The pattern is selected to enable the CNU to easily ascertain the PHY Link subcarriers without prior knowledge of the PHY Link's precise location in the RF spectrum range of an EPoC network. Detection of the PHY Link is the first action a CNU takes to join an EPoC network.

The CLT maps each of the binary bits shown in Table 102–4 to a BPSK constellation point in the complex plane using the following transformation:

$0 \rightarrow (1 + j0)$
$1 \rightarrow (-1 + j0)$

Table 102–5 is provided for information purposes and illustrates the receiver processing of the PHY Link preamble.

Table 102–4—Downstream PHY Link 2D preamble

Subcarrier	Symbol							
	1	2	3	4	5	6	7	8
8	1	0	1	0	0	0	1	1
7	1	0	1	0	0	0	1	1

Table 102–4—Downstream PHY Link 2D preamble *(continued)*

Subcarrier	Symbol							
	1	2	3	4	5	6	7	8
6	1	0	1	0	0	0	1	1
5	0	0	0	0	1	0	0	1
4	1	0	1	0	0	0	1	1
3	0	0	0	0	1	0	0	1
2	0	0	0	0	1	0	0	1
1	1	0	1	0	0	0	1	1

Table 102–5—Downstream PHY Link differential demodulation sequence

Subcarrier	Symbol							
	1	2	3	4	5	6	7	8
8	X	1	1	1	0	0	1	0
7	X	1	1	1	0	0	1	0
6	X	1	1	1	0	0	1	0
5	X	0	0	0	1	1	0	1
4	X	1	1	1	0	0	1	0
3	X	0	0	0	1	1	0	1
2	X	0	0	0	1	1	0	1
1	X	1	1	1	0	0	1	0

102.2.3 Downstream frame

The downstream PHY Link uses a frame format, illustrated in Figure 102–1, to which the 128 symbol staggered pilot pattern is aligned with as described in 101.4.3.6. The 128 symbol downstream PHY Link frame is composed of a Preamble (see 102.2.2), one 96-bit EPoC PHY Frame Header (EPFH), one variable length EPoC Probe Control Header (EPCH), some number of variable length EPoC message blocks (EMB), one 56-bit FEC Parity message block (FPMB), and padding. The message blocks within the frame are protected with a FEC mechanism. Each message block and its included fields is described next. The number of optional EPoC message blocks contained within the frame is limited only by the frame size.

Each message block contains a Type field used to identify the contents of the block. CLTs shall use the appropriate message Type fields listed in Table 102–6 in each message block. The contents of the each message block is protected by a CRC32. See 3.2.9 for a description of how this field is calculated. The CNU shall calculate a CRC32 on the data fields within each message block received and, if the calculated CRC32 does not match the received CRC32 discard the message and take no action based on it.

Table 102–6—PHY Link message block Type values

Type value	Message block
0x00 to 0x08	reserved
0x09	EPoC PHY Frame Header
0x0A	EPoC Probe Control Header
0x0B	EPoC message block
0x0C	FEC Parity message block
0x0D to 0x0F	Reserved

102.2.3.1 Downstream EPoC PHY Frame Header

The downstream EPoC PHY Frame Header includes a Type field, the Configuration ID fields (*DS_CID* and *US_CID*), the Return Frame ID field (*RF_ID*), the PHY Link DA field, the PHY Timestamp field, and a CRC32 as illustrated in Figure 102–1.

102.2.3.1.1 Configuration ID and profile activation

The Configuration ID fields are 2-bit fields used to inform a CNU to switch from one modulation profile to another. There is one field for control of the downstream profile (*DS_CID*) and one field for the upstream profile (*US_CID*). Each CNU contains two profiles in each direction, copy “A” and copy “B”; only one of which is active at any given time. The CLT shall set an identical inactive profile in all CNUs prior to its activation. The CLT updates the unused profile then, using the PHY Configuration ID field, switches the CNU to the updated profile. Once the CLT begins the switchover, as indicated by Configuration ID field values 0b01 or 0b10 it shall complete the switchover. During a switchover the value of the Configuration ID field is either incremented or decremented by one in each successive frame. The switchover is completed and the CNU activates the new profile when the Configuration ID field reaches a value of 0b00 or 0b11; thus a switchover takes three PHY Link frame times. Table 102–7 summarizes the use and meaning of the PHY Configuration ID bits and their operation is illustrated in Figure 102–10.

102.2.3.1.2 Response Frame ID

In the downstream direction, the new profile is activated at the first symbol (i.e., the symbol containing the PHY Link Preamble) in the next PHY Link frame. In the upstream direction, the new profile is activated in the first symbol of the Probe Period following the frame identified by the Return Frame ID field.

Table 102–7—Configuration ID bits

PHY Configuration ID		Meaning
bit 1	bit 0	
0	0	Copy "A" in use
0	1	Prepare for switchover
1	0	Prepare for switchover
1	1	Copy "B" in use

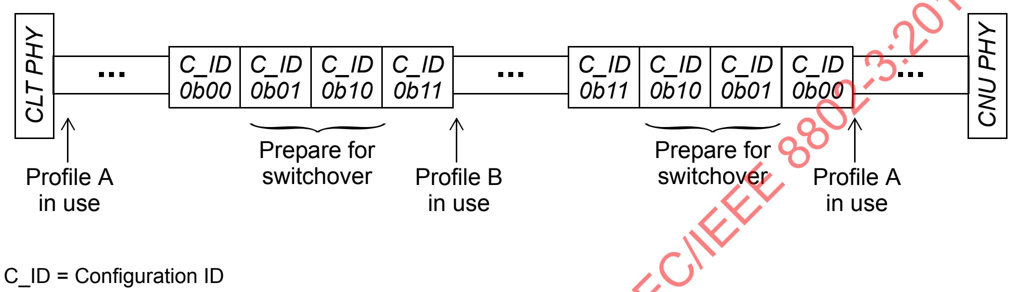


Figure 102–10—Configuration ID bit usage

The Response Frame ID field is an 8-bit field that indicates to the receiving CNU which RB Frame to use for the response message to this frame. The CLT shall ensure that all CNUs have sufficient time (as determined by the variable PhyLnkRspTm) to respond to the downstream PHY Link frame.

102.2.3.1.3 PHY Link DA

The PHY Link DA is an address field that identifies the CNU for which any EPoC message blocks in that PHY frame are targeted. This field is 15 bits and may be a unicast address or a broadcast address (see Table 102–8). In the CNU if the DA does not match the assigned address (*CNU_ID*) or the broadcast address, then the EMBs in the frame are discarded and no response is made. The CLT shall only transmit the valid values of the PHY DA field as given in Table 102–8.

Table 102–8—PHY DA field values

Field Values	Use
0x7F00 .. 0x7FF0	Broadcast addresses
0x7EFF ..0x0001	Unicast CNU addresses
0x0000	CLT PHY DA address

102.2.3.1.4 PHY Timestamp

The PHY Timestamp is a 32-bit field that the EPoC PHY uses to synchronize the upstream PHY Link frame and OFDMA symbols. The *LocalTS*, from which this field is set, is clocked from the 204.8 MHz OFDM Clock. When a CNU PHY that has *PD_Enable* equal to FALSE receives a PHY Frame addressed to it or to the broadcast address, it shall reset its *LocalTS* to the value in the Timestamp. The reference point for the Timestamp shall be the first sample of the PHY Link symbol immediately following the Preamble (Figure 102–11). For additional information on the use of the Timestamp, see 101.3.3.1.3.

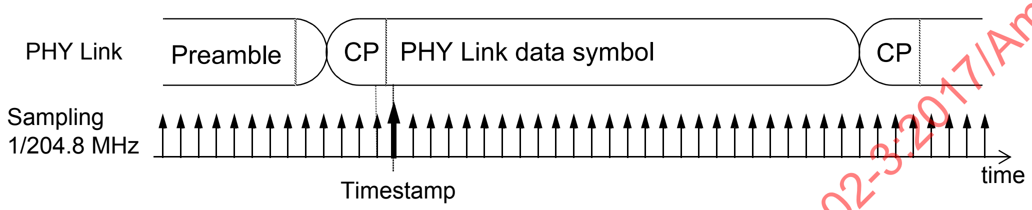


Figure 102–11—PHY Link Timestamp reference point

The CNU PHY Link receiver maintains counts of EPoC PHY Frame Headers received and those received that have CRC32 errors using the variables *EPFHcnt* and *EPFHerr*, respectively.

102.2.3.2 EPoC Probe Control Header message block

The EPoC Probe Control Header includes a Type field, the EPCH_Len field, the PrbType field, some number of Probe Control (PCn) fields, and a CRC32 as illustrated in Figure 102–1.

The EPCH_Len field is a 4-bit number that conveys the number of Probe Control fields contained in the message block. Each EPoC Probe Control Header may contain 0 to 15 Probe Control fields.

The PrbType field is a 2-bit field that conveys the type of Probe Control fields contained in the message block. There are three types of Probe Control fields; a Probe Scheduling type, a broadcast PHY Discovery type and a Unicast PHY Discovery type as shown in Table 102–9.

Table 102–9—PrbType values

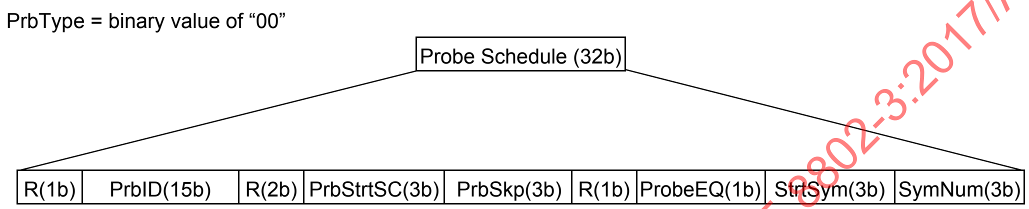
PrbType value	Probe Control field	Probe Control length
0x00b	Probe Scheduling	32 bits
0x01b	Broadcast PHY Discovery	16 bits
0x10b	Unicast PHY Discovery	64 bits
0x11b	Reserved	n/a

The CNU PHY Link receiver maintains counts of EPoC Probe Control Headers received and those received that have CRC32 errors using the variables *EPCHcnt* and *EPCHerr,* respectively.

The CNU shall decode and be capable of acting on EPoC Probe Control Header instructions included in a downstream PHY Link frame within 2.5 ms after reception.

102.2.3.2.1 Probe Scheduling type Probe Control fields

The Probe Scheduling type Probe Control fields each enable one CNU to participate in the first Probe Period of the upstream PHY Link frame following the Response Frame ID. Each Probe Scheduling field contains a PrbID, PrbStrtSC, PrbSkip, PrbEQ, StrtSym, SymNum, and several reserved (R) subfields as illustrated in Figure 102–12. To enable a CNU to participate in a Probe Period the *CNU_ID* of the participating CNU is placed in PrbID subfield of the Probe Control. The remaining subfields set the corresponding variables in the designated CNU. A Probe Control field set to all zeros or any broadcast *CNU_ID* is ignored and does not enable any CNU. For additional information on use of the Probe Control fields, see 102.4.2.3.

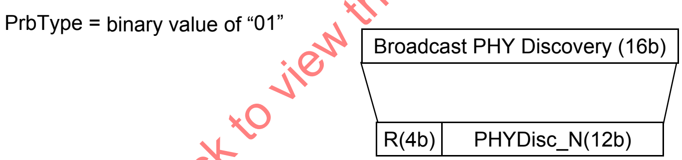


NOTE—The notation "(#b)" indicates the number of bits in the field.

Figure 102–12—Probe Scheduling type Probe Control field

102.2.3.2.2 Broadcast PHY Discovery type Probe Control fields

The Broadcast PHY Discovery type Probe Control fields each enable one PHY Discovery window within the Probe Period of the upstream PHY Link frame following the Response Frame ID. Each Broadcast PHY Discovery field contains a PHY Discovery window descriptor (PHYDisc_N), which designates the starting subcarrier of the PHY Discovery window as illustrated in Figure 102–13. For additional information on use of the Broadcast PHY Discovery type Probe Control fields, see 102.4.1.3.

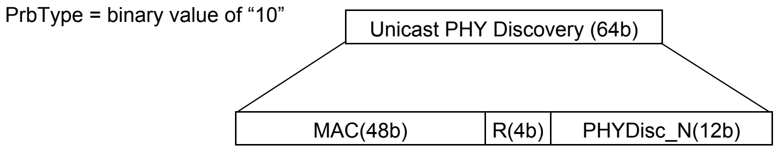


NOTE—The notation "(#b)" indicates the number of bits in the field.

Figure 102–13—Broadcast PHY Discovery type Probe Control field

102.2.3.2.3 Unicast PHY Discovery type Probe Control fields

The Unicast PHY Discovery type Probe Control fields each enable a single CNU, as designated by a MAC address, to use a unique PHY Discovery window within the Probe Period of the upstream PHY Link frame following the Response Frame ID. Each Unicast PHY Discovery field contains a MAC address and a PHY Discovery window descriptor (PHYDisc_N), which designates the starting subcarrier of the PHY Discovery window as illustrated in Figure 102–13. For additional information on use of the Broadcast PHY Discovery type Probe Control fields, see 102.4.1.3.



NOTE—The notation "(#b)" indicates the number of bits in the field.

Figure 102–14—Unicast PHY Discovery type Probe Control field

102.2.3.2.4 PHY Link managed variables

DiscStrt

TYPE: 32-bit unsigned integer
This variable indicates when the next PHY Discovery window is open relative to the downstream Timestamp. Setting the PHY Discovery start parameter to zero disables the PHY Discovery window.

102.2.3.3 Downstream EPoC message block

The downstream EPoC message block contains a Type field (see Table 102–6) a PHY Instruction and a CRC32.

The CLT can perform read and write operations on the EPoC variables of subordinated CNUs via PHY Instructions. Each instruction contains an OPCODE, a Variable Group Count, a Variable Index, and up to 31 Variable Group Data fields.

The PHY Link OPCODE is a 3-bit field that conveys the operation of the PHY Instruction in which it resides. The CLT shall only transmit the valid OPCODE field values as given in Table 102–10.

Table 102–10—Valid OPCODE values

Value	Operation	Description
b000	NOP	No operation, the CNU acknowledges this instruction only
b001	Read	The CNU responds with the contents of variables starting at the index specified by the Variable Group Index field and subsequent variables as specified by the Variable Group Count field
b010	Write	The CNU stores the values given in the data field starting at the variable given in the Variable Group Index field and subsequent variables as specified by the Variable Group Count field
b011	Write/Verify	The CNU first writes the variables as specified by Variable Group Index and Variable Group Count field and then responds with the values contained in those same variables
b1xx	Reserved	No operation, the CNU ignores these instructions

The Variable Group Count field specifies the number of 16-bit EPoC Variable groups contained in a write or write/verify PHY Instruction or the number of 16-bit EPoC Variable groups that are to be returned in a read or write/verify PHY Instruction. The Variable Group Count field has a value of 0 to 31. The Variable Group Count field in a NOP instruction always has a value of 0. Whereas, for a read, write, or write/verify instruction, the Variable Group Count always has a value between 1 and 31.

The 16-bit EPoC Variable Index field specifies the variable group at which the CNU is to begin the read, write, or write/verify operation. The NOP instruction does not include an Index field.

The 16-bit Variable Group Data fields contain the data values to be written in consecutive variable groups starting with the group indicated by the Variable Index field and continuing for the number of groups indicated by Variable Group Count of the target CNU. The Variable Group Data fields are valid only for a write or write/verify PHY Instructions; or in the response to a read or write/verify PHY Instruction. In the event there is a discrepancy between the Variable Group Count field and the number of 16-bit Variable Group Data fields, the CNU shall write no data to its variables and returns a Nack indication (see 102.3.2.2).

The CNU PHY Link receiver maintains counts of EPoC message blocks received and those received that have CRC32 errors using the variables *EMBcnt* and *EMBerr,* respectively.

102.2.3.4 Downstream padding

The Pad field is used to fill the PHY frame in the event there are unused bits after the message blocks and FEC fields have been populated. The Pad field consists of all zeros and is ignored upon receipt.

102.2.3.5 Downstream FEC Parity message block

The FEC Parity message block includes a Type field, the FEC Codeword pointer (*FCP*), and a CRC32. The *FCP* is a 16-bit field used to identify the start of the first FEC codeword in the next PHY Link frame.

The CNU PHY Link receiver maintains counts of FEC Parity message blocks received and those received that have CRC32 errors using the variables *FPMEcnt* and *FPMEerr,* respectively.

102.2.4 Downstream PHY Link FEC

The downstream PHY Link shall use a binary punctured LDPC (384,288) code described in 102.1.4.1 and 102.1.4.3.1.

102.2.5 Downstream PHY Link response time.

The CNU shall decode and be capable of acting on EPoC message block instructions included in a downstream PHY Link frame within 4.8 ms. The CNU may indicate it is capable of a shorter response time to a downstream EPoC message block by setting the *PhyLinkRspTm* to a value of less than 61440 (4.8 ms).

102.2.6 PHY Link managed variables

DS_PhyLinkStrt

TYPE: 12-bit unsigned integer

This variable sets the starting subcarrier in OFDM Channel 1 of the downstream PHY Link. It specifies the lowest frequency subcarrier of the downstream PHY Link used to carry PHY Link information bits.

102.2.7 Downstream state diagrams

102.2.7.1 Constants

EMB
TYPE: 4-bit unsigned integer
This constant represents the PHY Link message type for the EPoC message blocks.
VALUE: 0x0B

EPCHtp
TYPE: 4-bit unsigned integer
This constant represents the PHY Link message type for the EPoC Probe Control Header message block.
VALUE: 0x0A

EPFHtp
TYPE: 4-bit unsigned integer
This constant represents the PHY Link message type for the EPoC PHY Frame Header message block.
VALUE: 0x09

FPMBtp
TYPE: 4-bit unsigned integer
This value represents the PHY Link message type for the FEC Parity message block.
VALUE: 0x0C

MaxMBlen
TYPE: unsigned integer
This constant represents the maximum number of bits in the downstream PHY Link frame minus the length of the one CRC 32 and the FEC Pointer message block and excluding FEC Parity.
VALUE: 2824

102.2.7.2 Counters

EMBcnt
TYPE: 16-bit unsigned integer
This variable counts the number of EPoC message blocks received. The variable is cleared when read and does not roll over at maximum count.

EMBerr
TYPE: 16-bit unsigned integer
This variable counts the number of EPoC message blocks received with CRC32 errors. The variable is cleared when read and does not roll over at maximum count.

EPCHcnt
TYPE: 16-bit unsigned integer
This variable counts the number of EPoC Probe Control Headers received. The variable is cleared when read and does not roll over at maximum count.

EPCHerr
TYPE: 16-bit unsigned integer
This variable counts the number of EPoC Probe Control Headers received with CRC32 errors. The variable is cleared when read and does not roll over at maximum count.

EPFHcnt
TYPE: 16-bit unsigned integer

This variable counts the number of EPoC PHY Frame Headers received. The variable is cleared when read and does not roll over at maximum count.

EPFHerr

TYPE: 16-bit unsigned integer
This variable counts the number of EPoC PHY Frame Headers received with CRC32 errors. The variable is cleared when read and does not roll over at maximum count.

FPMEcnt

TYPE: 16-bit unsigned integer
This variable counts the number of FEC Parity message blocks received. The variable is cleared when read and does not roll over at maximum count.

FPMEerr

TYPE: 16-bit unsigned integer
This variable counts the number of FEC Parity message blocks received with CRC32 errors. The variable is cleared when read and does not roll over at maximum count.

LocalTS

TYPE: 32-bit unsigned integer
This counter holds the value of the local Timestamp. The counter is advanced by the OFDM Clock and rolls over to zero from 0xFF-FF-FF-FF. At the CLT the counter shall track the transmit clock, while at the CNU the counter shall track the receive clock. For accuracy of receive clock, see 101.4.4.2.

102.2.7.3 Variables

BEGIN

TYPE: Boolean
This variable is used when initiating operation of the functional block state diagram. It is set to TRUE following initialization and every reset.

DS_CID

TYPE: 2-bit unsigned integer
This variable represents the downstream Configuration ID value as described in 102.2.3.1.

FCP

TYPE: unsigned integer
This variable represents the beginning of the first MAC data FEC codeword in the current downstream PHY Link frame as described in 102.2.3.5.

FmLen

TYPE: unsigned integer
This variable represents the total number of bits transmitted in the current PHY Link frame.

PC_Fifo

TYPE: bit array
This variable holds the Probe Scheduling, Broadcast PHY Discovery, or Unicast PHY Discovery variables to be transmitted in the next EPCH message block.

PhyDA

TYPE: 15-bit unsigned integer
This variable represents the *CNU_ID* of the intended recipient of the PHY Link frame.

PhyDA_Fifo

TYPE: bit array
This variable holds the CNU_IDs to which the PHY Link frame and each PHY Link Instruction is to be sent. For any single PHY Link Frame there is one entry for the frame and one entry for each instruction.

PhyLinkRspTm
TYPE: 16-bit unsigned integer
This read only variable indicates the PHYs minimum response time to a downstream PHY Link instruction in units of 16/204.8 MHz. The maximum value for this variable is 61440 (4.8 ms), which is also the default value for this variable.

PhyTD
TYPE: bit array
This variable represents a bit array corresponding to data to be sent over the PHY Link.This variable is used to accumulate payload of outgoing PHY Link message blocks, for example to set the Timestamp Message Block.

PhyTxFifo
TYPE: bit array
This variable holds a series of PHY Instructions to be transmitted in the next PHY frame. Each entry in the fifo includes Opcode, Count, Variable Group Index, and Data fields for each instruction.

RF_ID
TYPE: 8-bit unsigned integer
This variable represents the Response Frame ID as described in 102.2.3.1.

RT
TYPE: Boolean
This variable represents the Response Type as described in 102.2.3.1.

PhyLnkRspTm
TYPE: 16-bit unsigned integer
The value of this variable defines the minimum time, in units of 78.125 ns (16 × 1/204.8 MHz), after receiving the last bit of the FEC, needed by the CNU to decode and prepare the response to a PHY Link Instruction.

PrbCtrl
TYPE: 32-bit binary
These variables represent the eight Probe control fields as described in 102.2.3.2.

StrtOfFm
TYPE: Boolean
When this variable transitions from FALSE to TRUE it indicates the beginning of an OFDM frame.

tmpDA
TYPE: 15-bit unsigned integer
This variable represents the *CNU_ID* of the intended recipient of the EPoC message blocks included in the PHY Link frame.

PD_Enable
TYPE: Boolean
This variable enables the device to respond to a PHY Discovery window and transmit onto the media when TRUE. It is set to FALSE following initialization and every reset. In the CNU it is set to TRUE after all elements required for PHY Discovery listed in Table 102–13 have been written by the CLT. In the CLT this variable, when set to FALSE, prevents transmissions from the CLT until it is fully configured and when TRUE permits transmissions.

TxPre
TYPE: Boolean
When TRUE, this variable indicates the PHY Link should be sending the preamble pattern as defined in 102.2.2.

US_CID

TYPE: 2-bit binary
This variable represents the upstream Configuration ID value as described in 102.3.2.1.

102.2.7.4 Functions

CRC32(x)

This function returns a 32-bit CRC of the bit array *x* (see 3.2.9).

LEN(x)

This function returns the length of variable *x*.

PCnxt(x)

This function removes and returns the next *x* bits from the *PC_Fifo* bit array.

POP()

This function removes one record from the *PhyTxFifo*.

PUSH()

This function returns one record from the *PhyTxFifo*.

Send(x)

This function transfers the contents of variable *x* to the PHY Link FEC Encoder block. When the transfer is complete, the variable length is zero.

102.2.7.5 State diagrams

The CLT PHY Link transmit process shall conform to the state diagram shown in Figure 102–15.

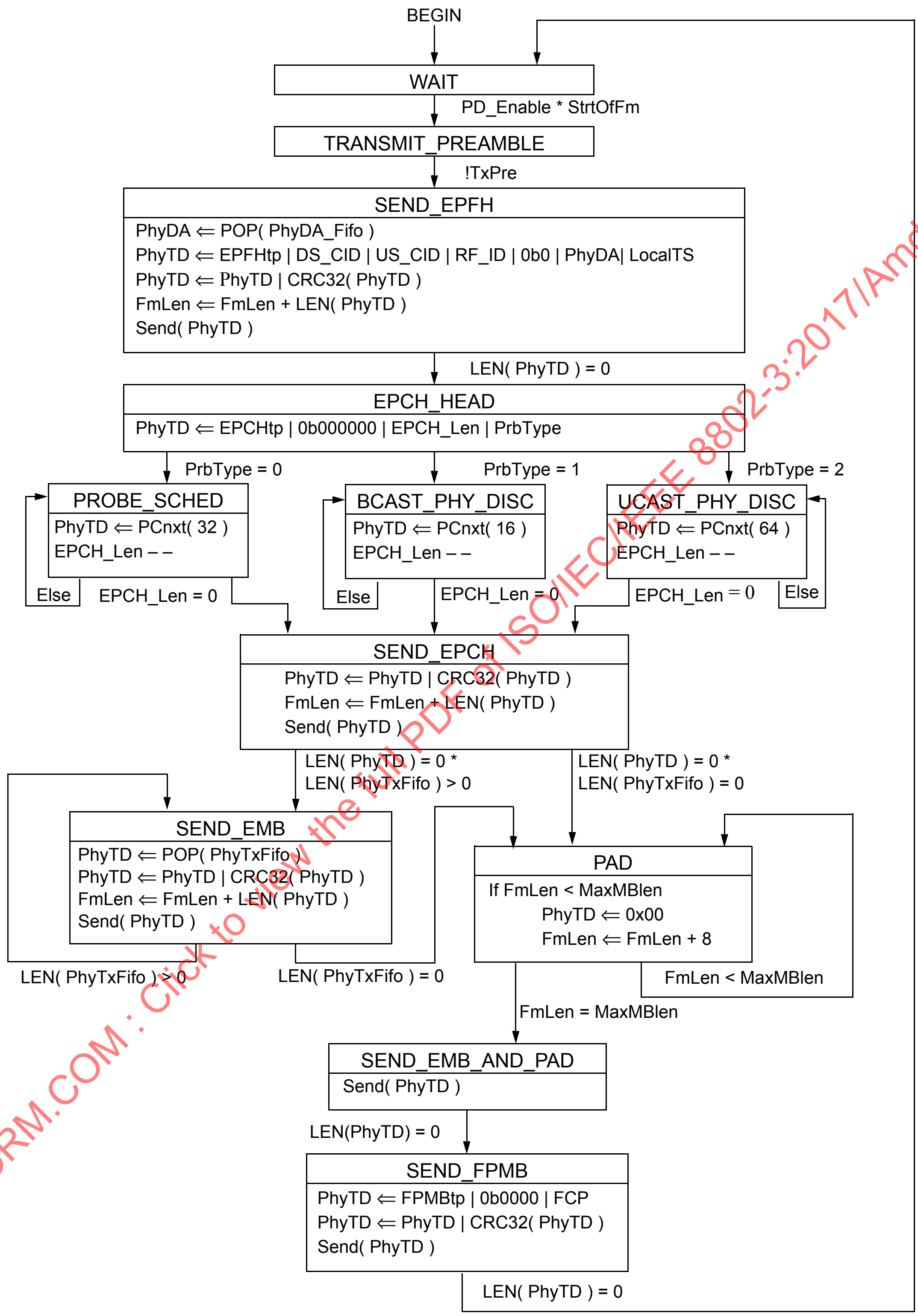


Figure 102–15—CLT PHY Link transmit process state diagram

102.3 Upstream PHY Link

102.3.1 Upstream PHY Link Physical Layer

102.3.1.1 Upstream resource allocation

During network setup the upstream PHY Link shall be allocated 400 kHz of spectrum. The upstream PHY Link is located per the *US_PhyLinkStrt* variable (see 102.3.5.3) that determines the lowest frequency subcarrier of the PHY Link. The upstream PHY Link shall use the same cyclic prefix duration and window size as the upstream MAC data OFDM channel.

102.3.1.2 Upstream PHY Link modulation

The upstream PHY Link shall use any of the modulation formats listed under PHY Link CNU Tx/CLT Rx in Table 100–2 and is set using the *US_PhyLinkMod* variable.

102.3.1.3 Upstream PHY Link transmission

CNU only operation: upon initialization of the CNU, the PMD_SIGNAL.request(*Tx_enable*) primitive is set to the value OFF in the PHY Link. When the first bit of a PHY Link message arrives at the PHY Link symbol mapper, the CNU sets the PMD_SIGNAL.request(*Tx_enable*) primitive to the value ON, which instructs the PMD sublayer to start the process of turning the RF power amplifier ON (see Figure 101–2 and 100.3.4.6). When the last bit of a PHY Link message arrives at the PHY Link symbol mapper, the CNU sets the PMD_SIGNAL.request(*Tx_enable*) primitive to the value OFF, which instructs the PMD sublayer to start the process of turning the RF power amplifier off.

102.3.2 Upstream PHY Link frame

The upstream PHY Link frame is composed of the EPoC PHY Frame Header, optional EPoC message blocks, and a FEC. These messages are described in the paragraphs that follow.

Each message block contains a Type field used to identify the contents of the block. CNUs shall use the appropriate message Type fields listed in Table 102–6 in each message block.

The contents of the each message block is protected by a CRC32. See 3.2.9 for a description of how this field is calculated. The CLT shall calculate a CRC32 on the data fields within each message block received and, if the calculated CRC32 does not match the received CRC32, discard the message and take no action based on it. The CLT PHY Link receiver maintains count of EPoC PHY Frame Headers received and those received that have CRC32 error using the variables *EPFHcnt* and *EPFHerr*, respectively.

102.3.2.1 Upstream EPoC PHY Frame Header

The upstream EPoC PHY Frame Header includes a Type field, the Return Frame ID field, the PHY SA, the PHY Timestamp field, and a CRC32 as illustrated in Figure 102–2. The Type field and Return Frame ID field are echoes of the same fields in the downstream message to which the CNU is responding. The PHY SA is an address field that identifies the CNU from which the PHY frame is transmitted. This field is 15 bits and is always the unicast address (*CNU_ID*) associated with the CNU transmitting in the PHY Link (see Table 102–8). The CNU SA is assigned during the PHY Discovery process (see 102.4.1). The PHY Timestamp is a 32-bit field set from the *LocalTS*.

102.3.2.2 Upstream EPoC message block

The EPoC message block contains a Type field (see Table 102–6), the PHY Response and a CRC32.

If the downstream PHY Link EPoC PHY Frame Header contains the unicast *CNU_ID* for the CNU, the addressed CNU shall respond to PHY Link instructions using the PHY Response. Each Response contains an OPCODE, a Variable Group Count, an Variable Group Index, and up to 31 Variable Group Data fields.There is a one-to-one correspondence between PHY Instructions in the downstream PHY Link and PHY Responses in the upstream PHY Link.

The PHY Response OPCODE is a 3-bit value that conveys the acknowledge type for the PHY Instruction to which the CNU is responding and the success or failure of the PHY Instruction command. CNUs shall use the valid values of the acknowledgment type given in Table 102–11.

Table 102–11—OPCODE Acknowledgement values

Value	Operation	Description
b000	NOP ACK	NOP Instruction acknowledge returned in response to a successfully received NOP Instruction
b001	Read ACK	Read Instruction acknowledge returned in response to a successfully received and executed read Instruction along with the requested variables as specified in the Variable Group Index and Variable Group Count fields of the PHY Instruction
b010	Write ACK[a]	Write Instruction acknowledge returned in response to a successfully received and executed Write Instruction
b011	Write/Verify ACK[a]	Write/Verify Instruction acknowledge returned in response to a successfully received and executed Write/Verify Instruction along with the requested variables as specified in the Variable Group Index and Variable Group Count fields of the PHY Instruction
b100	NOP NACK	NOP Instruction negative acknowledge returned in response to a unsuccessfully received NOP Instruction {might just want to keep this as a reserved value}
b101	Read NACK	Read Instruction negative acknowledge returned in response to an unsuccessfully received or executed Read Instruction
b110	Write NACK	Write Instruction negative acknowledge returned in response to an unsuccessfully received or executed Write Instruction
b111	Write/Verify NACK	Write/Verify Instruction negative acknowledge returned in response to an un successfully received or executed Write/Verify Instruction

[a]A write or write/verify PHY Instruction to an index that contains read-only bits is considered successful when all read/write bits in the index are written.

The Variable Group Count field specifies the number of 16-bit variable groups that are being returned in response to a read or write/verify PHY Instruction. In the event the CNU is returning a Nack response (Acknowledgment values 0b100 through 0b0111) the Variable Group Count field shall be set to zero and is ignored at the CLT.

The 16-bit Variable Group Index field specifies the first index for which the CNU is returning data due to a read or write/verify operation or the first index of the corresponding write Instruction.

The 16-bit Variable Group Data fields contain the data values read from the variables due to a read or write/verify PHY Instruction. In the event the CNU is responding to a write instruction this field is omitted. The Variable Group Data field should be omitted in Nack Responses (Acknowledgment values 0b100 to 0b111) and, if included, shall be ignored at the CLT.

The CLT PHY Link receiver maintains count of EPoC message blocks received and those received that have CRC32 error using the variables *EMBcnt* and *EMBerr,* respectively.

102.3.2.2.1 Padding

The Pad field is used to fill the PHY frame in the event there are unused bits after the message blocks and FEC fields have been accounted for.

102.3.3 Upstream PHY Link FEC

The upstream PHY Link shall use a (384,288) binary punctured LDPC code described in 102.1.4.1 and 102.1.4.3.1.

102.3.4 Upstream PHY Link pilot pattern

The upstream PHY Link utilizes a pilot pattern to assist the CLT receiver in capturing the bursting PHY Link transmissions. The PHY Link pilot pattern is illustrated in Figure 102–16. PHY Link pilots are BPSK encoded. The two edge subcarriers of the upstream PHY Link are Type 2 pilots; whereas, the six internal subcarriers are Type 1 Pilots.

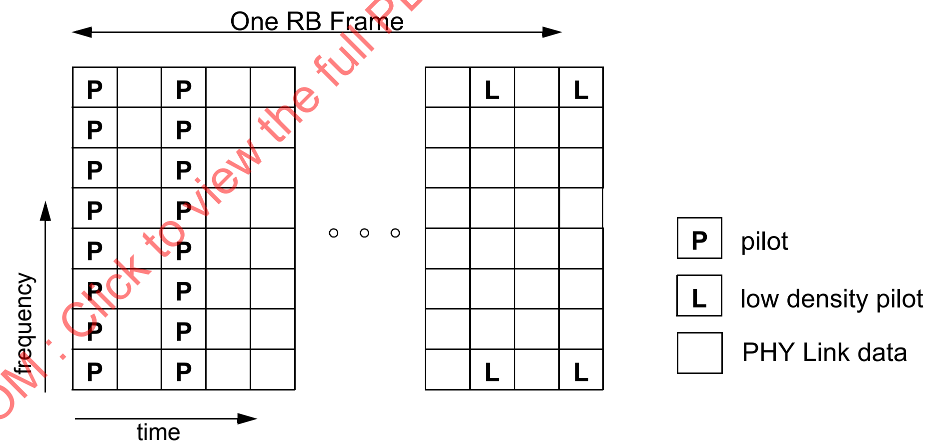


Figure 102–16—Upstream PHY Link pilot pattern

102.3.5 Upstream state diagrams

102.3.5.1 Constants

EPFHtp

See 102.2.7.1.

USPLfec
TYPE: Integer
This constant represents the upstream PHY Link FEC data length.
Value: 288

102.3.5.2 Counters

EMBcnt
See 102.2.7.2.

EMBerr
See 102.2.7.2.

EPFHcnt
See 102.2.7.2.

EPFHerr
See 102.2.7.2.

US_FmCnt
TYPE: 9-bit unsigned
This modulo 262 counter tracks the OFDMA symbols within the upstream superframe. Symbol zero is the first symbol in the Probe Period.

102.3.5.3 Variables

CNU_ID
TYPE: 15-bit integer that carries the value of the CNU_ID assigned by the CLT to the CNU during PHY Discovery process (see 102.4.1.6).

PhyDA
See 102.2.7.3.

PhyTD
See 102.2.7.3.

PhyTxFifo
See 102.2.7.3.

RF_ID
See 102.2.7.3.

RT
See 102.2.7.3.

PD_Enable
See 102.2.7.3.

PdCmplt
TYPE: Boolean
When TRUE this variable indicates the CNU has completed the PHY Discovery process and is allowed to transmit in the OFDMA MAC and PHY Link data paths.

US_PhyLinkMod
TYPE: 4-bit binary
This variable sets the type of modulation used for the upstream PHY Link. The assignment of bits to each modulation type is shown below.
bit 3 2 1 0
1 x x x = reserved
0 1 1 1 = 128-QAM

0 1 1 0 = 64-QAM
0 1 0 1 = 32-QAM
0 1 0 0 = 16-QAM
0 0 1 x = reserved
0 0 0 1 = BPSK

US_PhyLinkStrt
TYPE: 12-bit unsigned integer
This variable indicates the starting subcarrier of the upstream 10GPASS-XR PHY Link. It specifies the lowest frequency subcarrier of the upstream PHY Link used to carry PHY Link information bits.

102.3.5.4 Functions

CRC32()
See 102.2.7.4.

LEN()
See102.2.7.4.

Mod(x,y)
This function returns the remainder of *x/y*.

POP()
See 102.2.7.4.

Send()
See 102.2.7.4.

102.3.5.5 State diagrams

The CNU PHY Link transmit process shall conform to the state diagram shown in Figure 102–17.

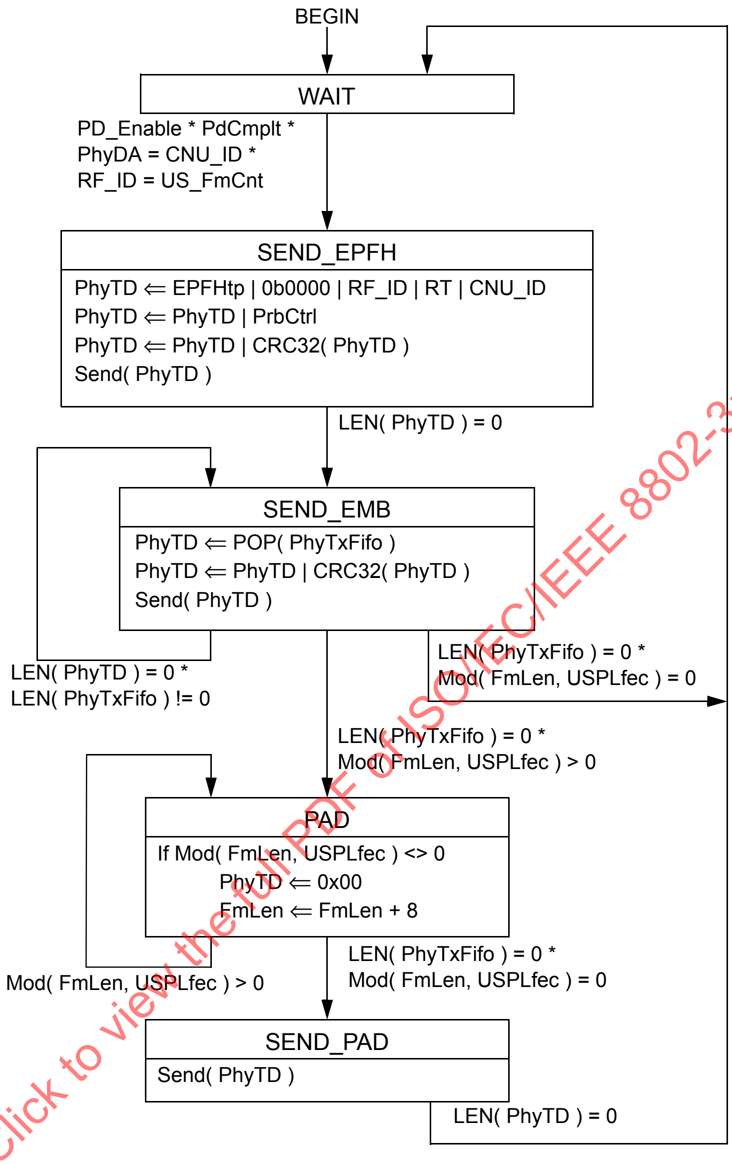


Figure 102–17—CNU PHY Link transmission control state diagram

102.4 PHY Link applications

When a CNU first joins the EPoC network it has no prior knowledge of the upstream RB Superframe configuration and timing necessary to produce transmissions that are orthogonal to the rest of the EPoC network when viewed from the perspective of the CLT receiver. PHY Discovery is the process whereby newly connected or off-line CNUs are provided timing and operating parameters necessary to function properly in the EPoC network.

While an EPoC network is in operation, periodic verification of the CNUs OFDMA timing, transmission power, and pre-equalizer coefficients is needed to ensure orthogonality and proper reception. This is accomplished using Wideband Probing. Wideband Probing may also used during the PHY Discovery process to fine tune the timing of CNUs joining the network.

102.4.1 PHY Discovery

102.4.1.1 Overview of PHY Discovery

The PHY Discovery process is composed of PHY Link acquisition, PHY Discovery window opening, PHY Discovery Response, CNU_ID Allocation, and Wideband Probing. Each of these steps is described in detail in the following subclauses. The PHY Discovery message exchange is illustrated in Figure 102–18.

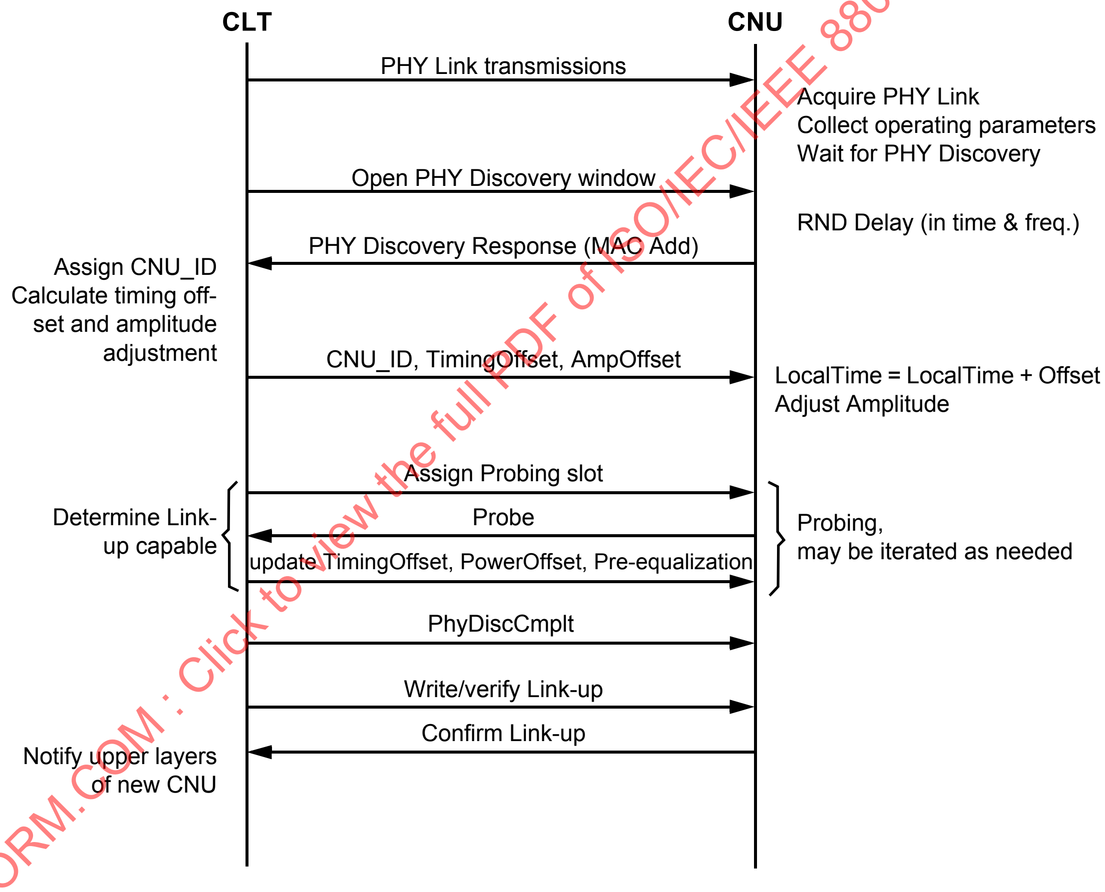


Figure 102–18—PHY Discovery message exchange

102.4.1.2 PHY Link acquisition

When a CNU joins an EPoC network it first locates the downstream PHY Link. This is typically done via a vendor specific correlation algorithm. Prior to any transmission in an EPoC network the CNU shall locate the downstream PHY Link, gather the required PHY Discovery operating parameters listed in Table 102–13 and synchronize its 10.24 MHz Master Clock to the downstream OFDM Clock. Once the CNU has completed the prerequisites for transmission it waits for the CLT to issue a PHY Discovery window.

102.4.1.3 PHY Discovery window opening

The CLT periodically makes available PHY Discovery windows during which off-line CNUs are given the opportunity to make themselves known to the CLT. The periodicity of these windows is unspecified. The CLT signifies that a PHY Discovery period is occurring by transmitting either a Broadcast PHY Discovery type or Unicast PHY Discovery type Probe Control message block.

The PHY Discovery window is coincident with the Probe symbols (see 101.4.3.10) but is only four symbols in duration to allow for timing ambiguity in the PHY Discovery Response.

102.4.1.4 PHY Link Discovery Response

Off-line CNUs, upon being notified of a PHY Discovery window, wait for the beginning of the PHY Discovery window and then transmit a PHY Discovery Response to the CLT. The CNU initially transmits a PHY Discovery Response using the power level indicated by *PdRespInitPwr*. If there is no acknowledgment from the CLT to the initial PHY Discovery Response the CNU increases the PHY Discovery Response transmit power by the value indicated by *PdRespPwrStep*. The CNU continues to increases the PHY Discovery Response transmit power by the value indicated by *PdRespPwrStep* until an acknowledgment is received from the CLT. If the CNU has transmitted four PHY Discovery Responses at maximum power without acknowledgment from the CLT it reverts to the power level indicated by *PdRespInitPwr* and begins incrementing its output power as described previously.

PHY Discovery windows are unique in that they are the only times when multiple CNUs can access the coax cable distribution network using the same RF spectrum simultaneously, and transmission overlap can occur in both time and frequency. In order to reduce transmission overlaps, a contention algorithm is used by all off-line CNUs. Measures are taken to reduce the probability for overlaps by artificially introducing a random distribution in the PHY Discovery window used by each CNU. Each CNU selects a random number of PHY Discovery windows it waits before transmitting the PHY Discovery Response. Multiple valid PHY Discovery Responses that overlap in time, but not frequency, may be received by the CLT during a single PHY Discovery window depending on the modulated spectrum of the upstream OFDM channel.

Included in the PHY Discovery Response is a preamble (see 102.4.1.5), the CNU's MAC address and a 32-bit CRC. See 3.2.9 for a description of how the 32-bit CRC is calculated. The data in the PHY Discovery Response shall be encoded using a (128,80) binary punctured LDPC code described in 102.1.4.3.2.

The PHY Discovery Response is composed of 128 subcarriers with a duration of four symbols and may include exclusions between these 128 subcarriers (see Figure 102–19). In a single Probe Period there may be up to 16 PHY Discovery windows. For the purposes of PHY Discovery Response contention mitigation, the broadcast PHY Discovery windows are numbered consecutively from lower starting frequency to higher starting frequency and increasing as time progresses as illustrated in Figure 102–20. Unicast PHY Discovery windows are not numbered for contention mitigation purposes.

In the event there is an analog fiber segment between the CLT and CNU, the CLT can delay the PHY Discovery Response by the amount of time specified in *PhyRngOffset*.

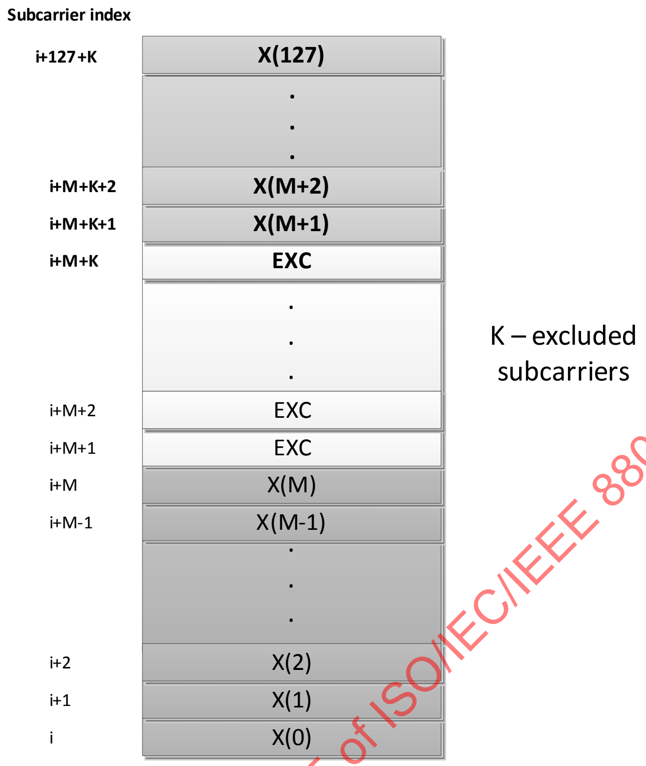


Figure 102–19—PHY Discovery Response sequence with exclusions

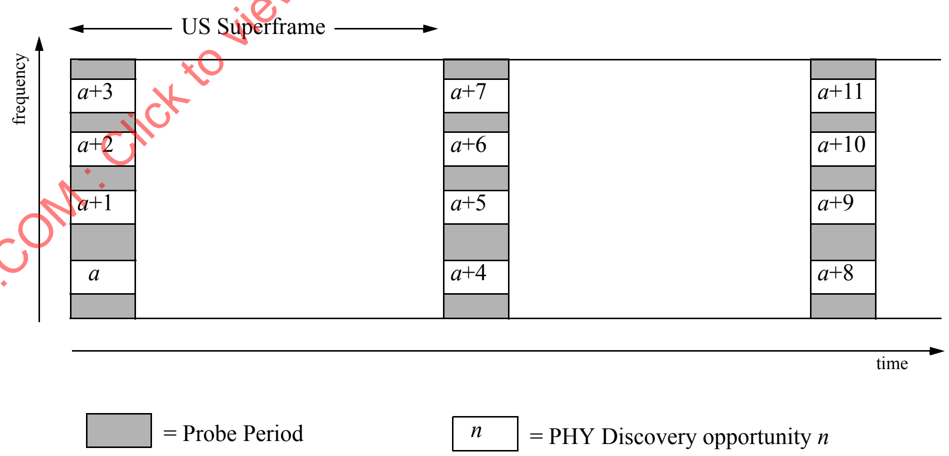


Figure 102–20—PHY Discovery opportunity numbering

The CNU PHY Discovery Response is only allowed after a CNU has completed the PHY Discovery prerequisites (Table 102–13). In the PHY Discovery Response message, the preamble used is the special PHY Discovery Preamble (see 102.4.1.5) and the only data included is the CNU MAC address protected by a CRC32. The PHY duplicates symbols of the upstream PHY Discovery Response transmission. This duplication is accomplished by duplicating the time domain samples at the output of the iFFT in the upstream data path for these signals, and adding cyclic prefix and windowing (per variables *USNcp* and *USNrp*, respectively) as illustrated in Figure 102–21. Control for the duplication process is conveyed using the TxType in the CNU (see Figure 102–4).

The CLT calculates the range of the CNU based on the PHY Link Response and uses this to report the NewCNU_Rng when declaring the CNU link-up (see 102.4.3).

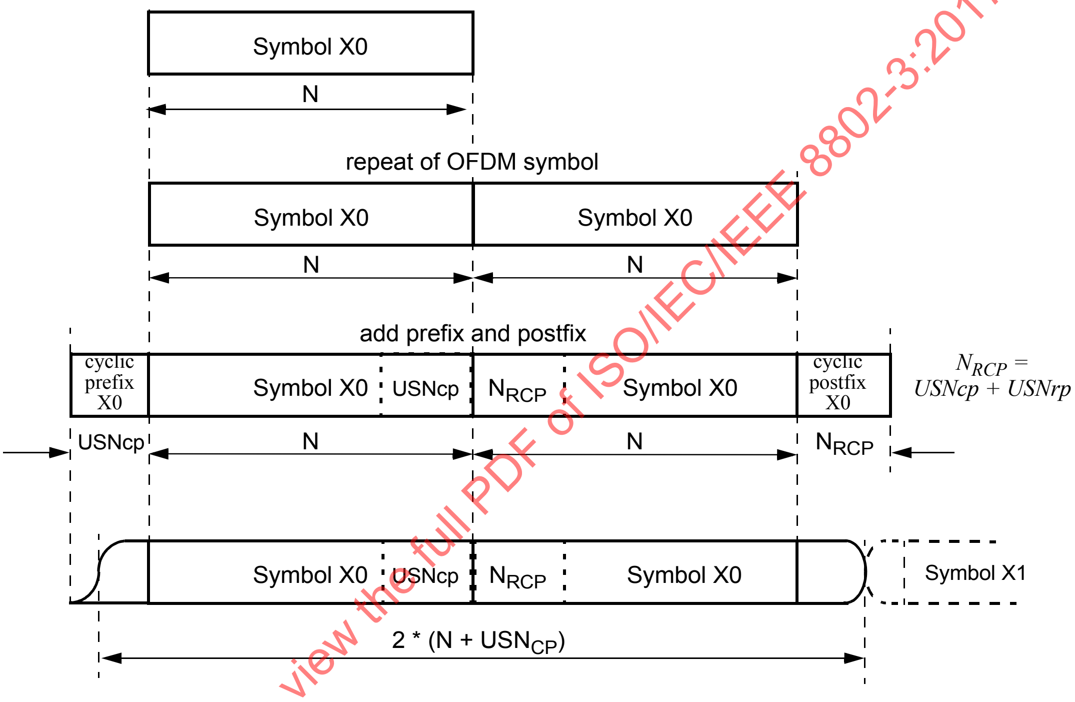


Figure 102–21—Symbol duplication, cyclic prefix, and windowing algorithm for PHY Discovery Response

102.4.1.5 PHY Discovery preamble

The PHY Discovery preamble is transmitted in the first two symbols of the PHY Discovery Response. The first symbol of the preamble shall be populated with a BPSK mapped 128-bit sequence generated by a pseudo-random sequence generator defined by the polynomial $x^7 + x^1 + 1$ seeded with a fixed bit pattern of 0x55 (see Figure 102–22) at the beginning of the PHY Discovery Response (see Figure 102–23). The output of the sequence generator is mapped using BPSK modulation (see 101.4.5.2) where a bit value of 0 is mapped to a BPSK value of plus 1 and a bit value of 1 is mapped to a BPSK value of minus 1. The second symbol of the PHY Discovery preamble shall be a duplicate copy of the first symbol as illustrated in Figure 102–21.

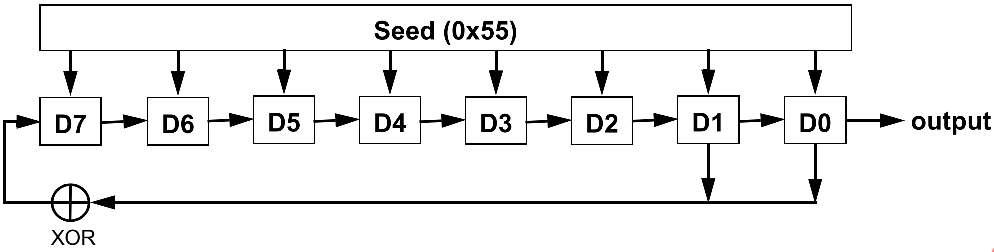


Figure 102–22—PHY Discovery Preamble generator

102.4.1.6 CNU_ID allocation

Upon receipt of a valid PHY Discovery Response, the CLT updates the CNU by allocating and assigning a new port identity (*CNU_ID*) using the *AssgndCNU_ID* and *AllwdCNU_ID* variables. To allocate the *CNU_ID* the CLT shall use the CNU_ID Allocation instruction as defined in Table 102–12. This instruction uses a broadcast DA.

The CLT calculates an OFDMA timing and power offsets and adjusts the CNU using the *PHYTimingOffset* and *PHYPowerOffset* variables, respectively. These parameters are transmitted to the CNU via the CNU_ID Allocation instruction. The first EMB of the CNU_ID Allocation instruction is a write of the *New_MACn* variables (note that this variable is read only so the actual variable value in the CNU will not change). The value written is the CNU MAC address received in the PHY Discovery Response.

The second EMB writes *AllwdCNU_ID* and sets *AssgndCNU_ID* to TRUE in the CNU. This causes the value of *AllwdCNU_ID* to be assigned in the CNU. Thereafter the CLT cannot use the same value of *AllwdCNU_ID* for another newly discovered CNU. See 102.4.3 for additional information on use of *AllwdCNU_ID* and *AssgndCNU_ID*.

Subsequent EMBs are used to write the CNU *PHYTimingOffset* and *PHYPowerOffset* variables.

Table 102–12—Special Instruction sequences

Special Instruction	EMB order	Read/Write	Variable
CNU_ID Allocation	1	Write	*New_MAC0* through *New_MAC2*
	2	Write	*AllwdCNU_ID*
	3	Write	*PHYTimingOffset* *PHYPowerOffset*

When the CNU receives the *PhyTimingOffset* variable, it shall add the new value of *PhyTimingOffset* to the *LocalTS* affecting the CNU transmit timing accordingly. When the CNU receives the *PhyPowerOffset* variable, it shall add the new value of *PhyPowerOffset* to the *PHYPowerOut* affecting the CNU transmit power accordingly.

102.4.1.7 PHY Discovery completion

When the CLT determines [via Wideband Probing (see 102.4.2), updates to *PhyTimingOffset,* and updates to *PhyPowerOffset*] that the new CNU has successfully tuned its transmitter to be orthogonal to the rest of the CNUs on the coax cable distribution network, it sets *PhyDiscCmplt* TRUE. This signifies that the CNU has completed the process of PHY Discovery.

102.4.1.8 PHY Link managed variables

AllwdCNU_ID
TYPE: 15-bit unsigned integer
This variable is used to indicate to the 10GPASS-XR PHY a valid *CNU_ID* value. The value may be assigned to a new CNU when the associated *CNU_ID* assigned flag (*AssgndCNU_ID*) is set to zero, when the flag is set to one it is an indication that this value has already been assigned to a CNU and it should not be use for another CNU.

AssgndCNU_ID
TYPE: Boolean
The value of this variable is used to indicate if the associated *AllwdCNU_ID* value has been assigned to a CNU by the PHY. When the flag is set to TRUE the associated *AllwdCNU_ID* has been assigned to a new CNU whereas when the flag is set to FALSE the associated *AllwdCNU_ID* has not been assigned.

DS_OFDM_ID
See 101.4.3.4.5.

LinkUpRdy
TYPE: Boolean
This Boolean variable is set to TRUE by the CLT when it has verified all of the variables required for Link-Up state in Table 102–13. The variable is set to FALSE on reset or as describe in 102.4.4.

NewCNU_Rng
TYPE: 16-bit unsigned integer
This variable indicates the range of the CNU corresponding to Allowed CNU_ID in units of OFDM Clock periods (1/204.8 MHz).

PhyDiscCmplt
TYPE: Boolean
When TRUE, this variable indicates that the CNU has completed PHY Discovery (see 102.4.1) on the coaxial cable distribution network. When FALSE, the variable indicates that the PHY has not completed PHY Discovery on the coaxial cable distribution network. This variable is defined in 10GPASS-XR-U PMA/PMD only. The variable is set to FALSE on any reset.

PdRespInitPwr
TYPE: 8-bit unsigned integer
This variable is used to set the initial transmit level, in units of 0.25 dBmV/1.6 MHz, for a CNUs PHY Discovery Response message. The range of this variable is from 0 to 64 dBmV/1.6 MHz.

PdRespPwrStep
TYPE: 8-bit unsigned integer
This variable is used to increase the transmit level, in units of 0.25 dB, for a CNUs PHY Discovery Response message in the event a PHY Discovery Response sent by the CNU is not acknowledged by the CLT.

PdRndDly
TYPE: unsigned integer

This variable indicates the random delay, in PHY Discovery windows, selected by the PHY to avoid contention during PHY Discovery.

PhyPowerOffset
TYPE: signed 8-bit integer
This variable is used to set the CNU upstream transmitter power by specifying the relative change in transmission power level the CNU is to make, in units of 0.25 dB, in order that transmissions arrive at the CLT at the desired power level. Changing the value of this variable while running using Management is highly undesirable and is unspecified.

PhyRngOffset
TYPE: 32-bit unsigned integer
This variable may be used to provision a delay in the ranging response, in units of 1/204.8 MHz, in the event there is an analog optical segment between the CLT and the CNUs as described in 102.4.1.4. This variable defaults to a value of 0 on reset.

PhyTimingOffset
TYPE: signed 32-bit integer
This variable is used to align the CNU to the upstream OFDM timing in units of 1/204.8 MHz. A negative value causes the timing of the CNU transmissions to be delayed. Changing the value of this variable while running using Management is highly undesirable and is unspecified.

102.4.1.9 PHY Discovery state diagrams

102.4.1.9.1 Constants

Pad96
TYPE: 96 bit binary
This constant holds 96 bits of padding.
Value: 0

102.4.1.9.2 Variables

New_MAC
TYPE: 48-bit hex
This vairable holds the MAC address of the CNU.

NxtWin
TYPE: unsigned integer
This variable holds the subcarrier index for the next PHY Discovery window.

PdData
TYPE: bit array
This variable holds the data to be transmitted in the PHY Discovery window.

PdWinFifo
TYPE: bit array
This fifo holds the list of 12-bit subcarrier indexes for each PHY Discover window from the most recent EPoC Probe 64B/65B sync header bit message block.

PdWinTp
TYPE: Boolean
This variable indicates if the list PHY Discover windows in *PdWinFifo* are unicast or broadcast windows. *PdWinTp* has the value of Ucast when the PHY Discovery window is unicast and Bcast when the window is broadcast.

Rnd

TYPE: 8-bit unsigned integer
This variable is used as a seed in the back-off algorithm for the PHY Discovery Response.

SoSF

TYPE: Boolean
This variable indicates the beginning of the upstream superframe and is set to TRUE for one OFDM Clock period at the beginning of the superframe.

PD_Enable

See 102.2.7.3.

102.4.1.9.3 Counters

SC_Cnt

TYPE: 12-bit
This counter tracks the subcarriers within each symbol and increments once for every subcarrier. Subcarrier zero is the first subcarrier while subcarrier 4095 is the last. The counter is reset at the beginning of every symbol.

102.4.1.9.4 Functions

CRC32()

See 102.2.7.4.

Len(x)

See 102.2.7.4.

PD_Pre

This function returns the PHY Discovery preamble as described in 102.4.1.5.

POP(x)

See 102.2.7.4.

rnd(r)

This function returns a random integer number uniformly distributed between 1 and *r*.

102.4.1.9.5 State diagrams

The CNU PHY Discovery Response transmission control shall conform to the state diagram shown in Figure 102–23.

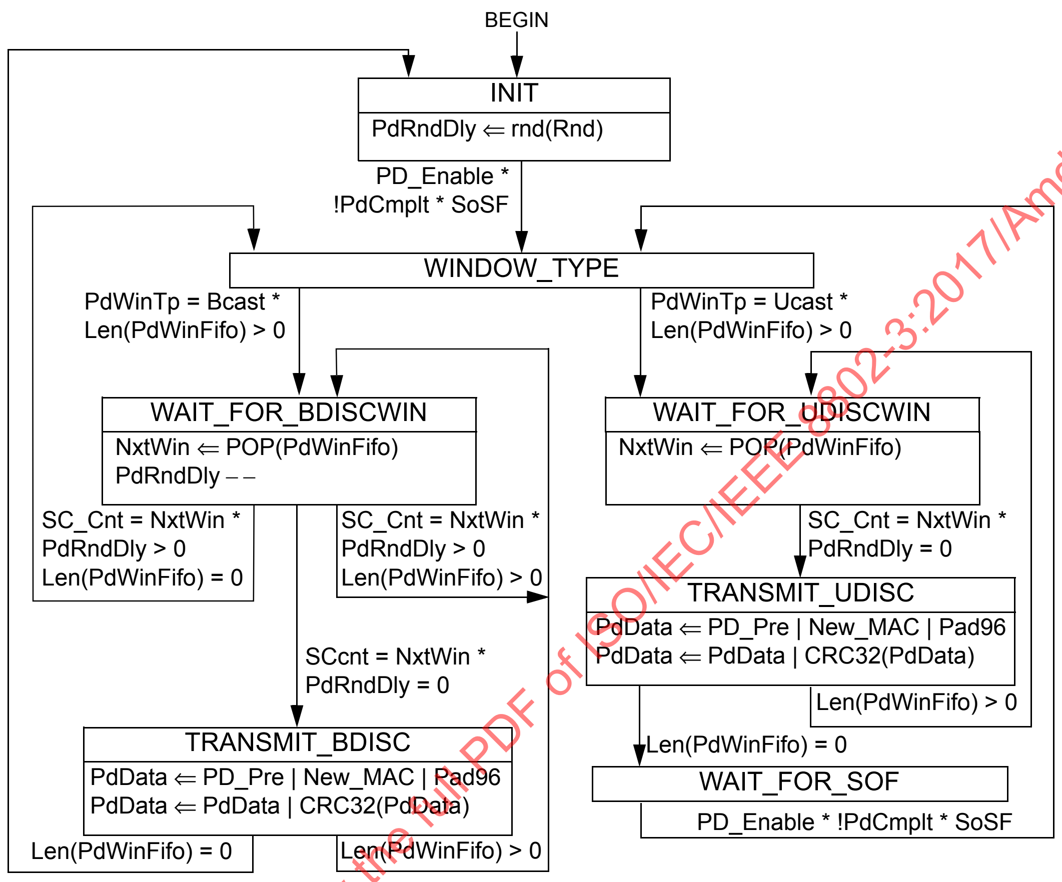


Figure 102–23—CNU PHY Discovery Response transmission control state diagram

102.4.2 Upstream Wideband Probing

102.4.2.1 Introduction

In upstream Wideband Probing a CNU transmits pilots spanning all active subcarriers. The CNU transmits one pilot per subcarrier. Each pilot is a predefined BPSK symbol. Each upstream superframe begins with six symbols, called the Probe Period, designated for probing and PHY Discovery. Each symbol within the Probe Period is referred to as a probing symbol. The CLT may use the received probing symbol for the following:

a) Upstream OFDM channel estimation. The CLT computes the coefficients of the upstream pre-equalizer for each CNU and sends them back to that CNU.
b) Upstream SNR measurement. The CLT measures the SNR per subcarrier and computes the upstream bit loading tables.
c) Upstream timing adjustment. During CNU bring up the CLT may use Wideband Probing to adjust the timing of the new CNU to the upstream RB Frame and superframe.

102.4.2.2 Probing symbol pilots

Probing symbol pilots are BPSK symbols.

Probing symbol pilot i is always associated with the i-th subcarrier of the symbol, where:

$i = 0, 1, \ldots , 4095$

NOTE—Subcarriers are numbered in ascending order of frequency starting from 0.

102.4.2.3 Probing symbol scheduling

The CLT may allocate a one or more probing symbols to a CNU within the Probe Period and instruct the CNU to transmit the probing sequence in that symbol. CLT specifies the probing symbol within the Probe Period via the EPoC Probe Control Header message block in the downstream PHY Link frame. The CLT assigns a CNU either all the pilots of the assigned probing symbol, or a subset of (scattered) pilots of the assigned probing symbol.

The CLT allocates subcarriers within a probing symbol by sending five variables to the CNU: *PrbStrtSC*, *PrbSkp*, *PrbEQ*, *StrtSym,* and *SymNum* (see 102.4.2.6.2). Figure 102–24 and Figure 102–25 illustrate the use of *PrbStrtSC* and *PrbSkp*. The CNU uses the *PrbStrtSC* and *PrbSkp* variables to determine which subcarriers are to be used for probing transmission, as follows:

— The *PrbStrtSC* variable is the starting subcarrier number.
— The *PrbSkp* variable is the number of subcarriers to be skipped between successive pilots. *PrbSkp* = 0 implies no skipping of subcarriers (i.e., all subcarriers are used for probing).

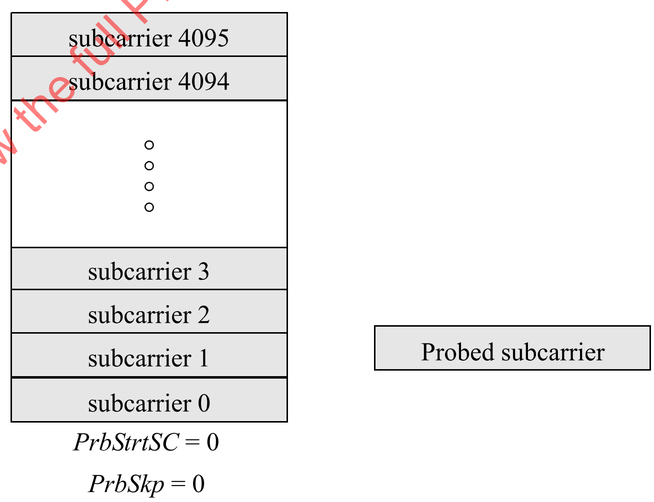


Figure 102–24—Example, all subcarriers used for probing, no skipping

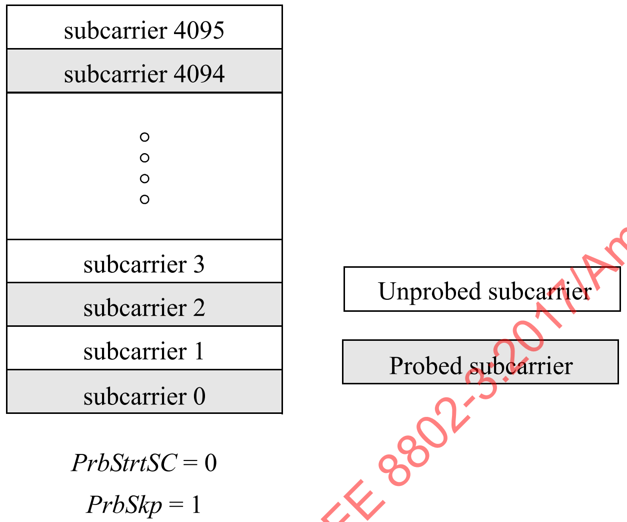


Figure 102–25—Example, alternate subcarriers used for probing

To schedule a single CNU in a probing symbol without skipping subcarriers, the CLT does the following:

— Allocate a specific probing symbol to a single CNU using *StrtSym* and *SymNum*.
— Set *PrbSkp* to zero.
— Set *PrbStrtSC* to the number of the first subcarrier.

To schedule a single CNU in a probing symbol with skipping subcarriers to create nulls (as illustrated in Figure 102–25), the CLT does the following:

— Allocate a specific probing symbol to a single CNU using *StrtSym* and *SymNum*.
— Set *PrbSkp* to a non-zero positive integer value.
— Set *PrbStrtSC* to the number of the first subcarrier.

To schedule multiple CNUs in a probing symbol (as illustrated in Figure 102–26), the CLT does the following:

— Allocate the same probing symbol at any given time to more than one CNU using *StrtSym* and *SymNum*.
— Assign a different *PrbStrtSC* number to each CNU.
— Assign the same *PrbSkp* value to every CNU within the probing symbol.

This method can be used with or without skipping subcarriers to create nulls. To create nulls, specify a *PrbSkp* value equal to, or greater than, the number of CNUs in the pattern.

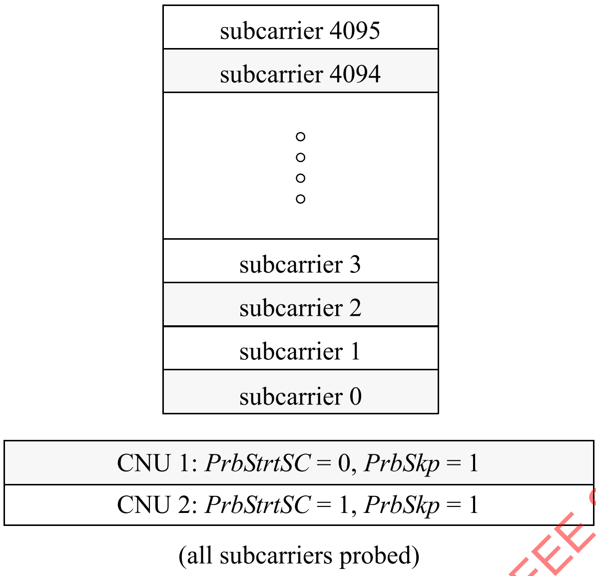


Figure 102–26—Scheduling two CNUs in the same probing symbol

The *PrbEQ* variable determines if the pilots transmitted are to be equalized (*PrbEQ* TRUE) or unequalized (*PrbEQ* FALSE).

StrtSym and *SymNum* variables determine which symbols within the Probe Period are to be used by the CNU. The value of *StrtSym* determines the first symbol within the Probe Period to begin probe transmissions and *SymNum* determines the number of adjacent symbols in which to send probe pilots. The CLT is responsible for properly setting the Probe Control fields so that the probe pilots are defined within the Probe Period. The CNU shall not transmit probe pilots in response to settings which define transmission outside the configured Probe Period. For example if *StrtSym* equals 4 and *SymNum* equals 3 the CNU does not transmit any probe pilots. The CNU is not responsible for crosschecking Probe Control settings to ensure that two CNUs are not assigned the same subcarriers for probing. Should the CLT make such an assignment it will receive a garbled response.

102.4.2.4 Probing sequence

The Probe symbol shall be populated with a BPSK mapped bit sequence generated by a pseudo-random sequence generator defined by the polynomial shown in Equation (102–3) seeded with a fixed bit pattern of 0xBFF at the beginning of each upstream superframe (illustrated in Figure 102–27). The output of the sequence generator is mapped using BPSK modulation (see 101.4.5.2) where a bit value of 0 is mapped to a BPSK value of plus 1 and a bit value of 1 is mapped to a BPSK value of minus 1.

$$x^{12} + x^9 + x^8 + x^5 + 1 \qquad (102\text{–}3)$$

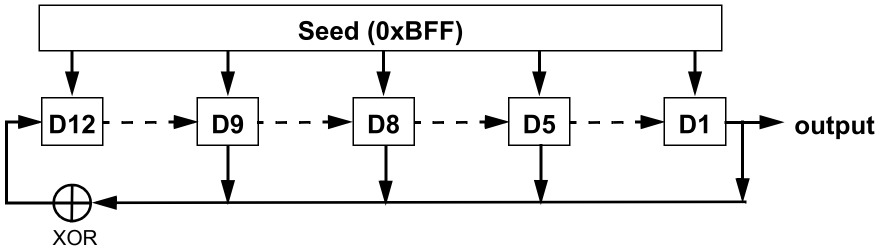


Figure 102–27—Probe sequence generator

102.4.2.5 Probe symbol repetition

Probes use all active subcarriers of a symbol. The first symbol in a Probe is generated as described in 102.4.2.4. The second symbol is a direct copy of the first symbol.

102.4.2.6 Wide Band Probing state diagrams

102.4.2.6.1 Constants

Exclude
: This constant informs the PMA that the subcarrier with which it is associated is not to be used for transmission.

102.4.2.6.2 Variables

ActPrbID
: TYPE: set of 15-bit Integers
When the *CNU_ID* of the CNU is contained in this set of variables the CNU is allowed to transmit a Probe Signal per the Probe Control variable *PrbEQ*, *PrbSkp*, *PrbStrtSC*, *StrtSym,* and *SymNum*. This set of variables is updated with each downstream PHY Link frame when *RF_ID* = *US_FmCnt* (see Figure 102–29). Each element in this set is one of the *PrbIDs* received in the most recent EPoC Probe Control Header.

CNU_ID
: See 102.3.5.3.

PhyDisc_N (N = 1, 2, ... 16)
: TYPE: 12-bit Integers
Each of these variables designates the starting subcarrier of a PHY Discovery window within the Probe Period.

PrbEQ
: TYPE: Boolean
When this provisioned variable is TRUE, the CNU transmits the probe symbol with equalization applied. When this variable is FALSE, the CNU transmits the probe symbol without equalization applied.

PrbSkp
: TYPE: unsigned integer
The value of this provisioned variable determines the number of subcarriers to be skipped in the probe symbol. The range of *PrbSkp* is from zero to seven.

PrbStrtSC

TYPE: unsigned integer
The value of this provisioned variable determines the starting subcarrier to be used in the probe symbol. The range of *PrbStrtSC* is from zero to seven.

RcvPrbID

TYPE: set of 15-bit Integers
This set of provisioned variables contains the received set of *PrbID* variables from the most recent downstream PHY Link frame, *PrbID*. When *US_FrmCnt* = *RF_ID* the values in this set replaces the values in the *ActPrbID* set (see Figure 102–2).

PrbData

TYPE: bit array
This variable holds the probe sequence bits to be transmitted during the Probe Period.

SC_clk

TYPE: Boolean
This clear on read variable goes TRUE at the beginning of each subcarrier.

StrtSym

TYPE: unsigned integer
The value of this variable determines the starting symbol within the Probe Period in which to begin transmitting probe pilots. The range of this variable is from one to six. The sum of *StrtSym* and *SymNum* is less than or equal to six.

SymNum

TYPE: unsigned integer
The value of this variable determines the number of consecutive symbols in which to transmit probe pilots. The range of this variable is from one to six. The sum of *StrtSym* and *SymNum* is less than or equal to six.

US_ModTypeSC(n)

See 101.4.4.4.4 for the definition of these variables.

102.4.2.7 Counters

SC_Cnt

See 102.4.1.9.3.

US_FmCnt

See 102.3.5.2.

102.4.2.8 Functions

Mod(x,y)

This function returns the remainder of *x* divided by *y*.

PrbSeq

This function returns one bit worth of probe data using the sequence generator described in 102.4.2.4. The function is reset at the beginning of the Probe Period.

SndPrbData(x)

This function transfers one symbols worth of Probe data (*PrbData*) from the Probe Symbol Mapper function to the PMA. If *x* = TRUE then the probe data is to be sent with equalization, if *x* = FALSE then probe data is sent without equalization.

102.4.2.9 State diagrams

The CNU probe transmit process shall conform to the state diagram shown in Figure 102–28.

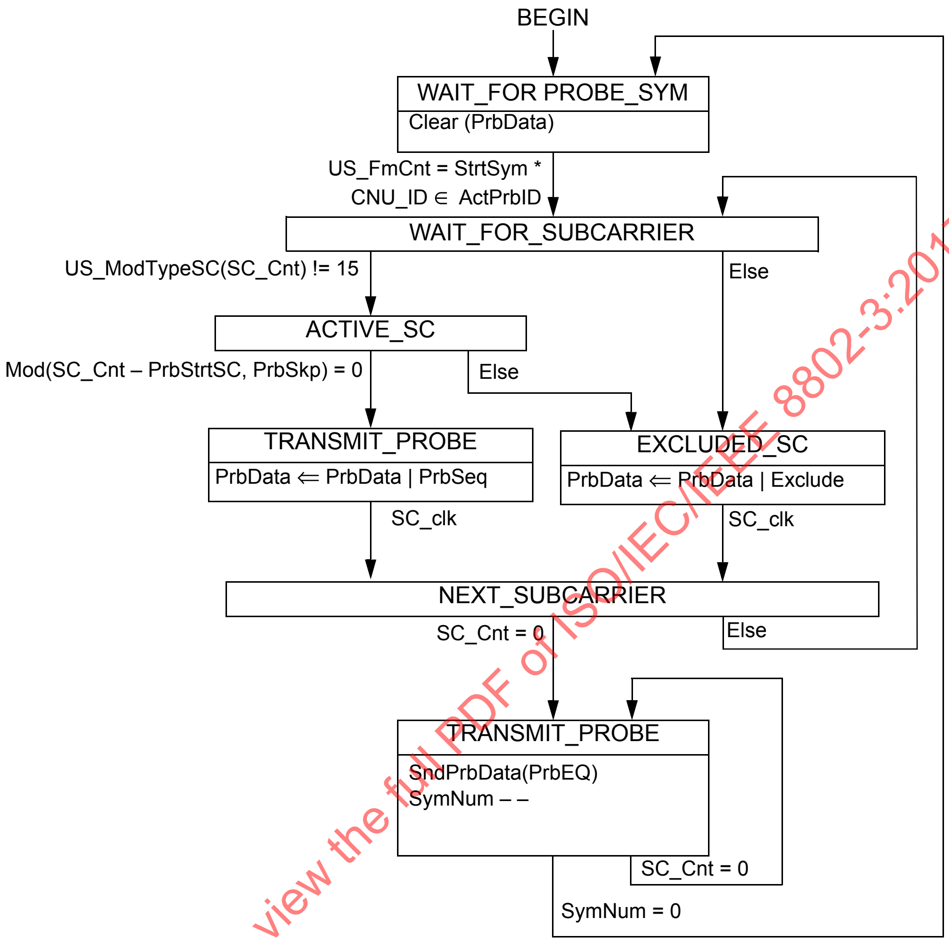


Figure 102–28—CNU Probe transmission control state diagram

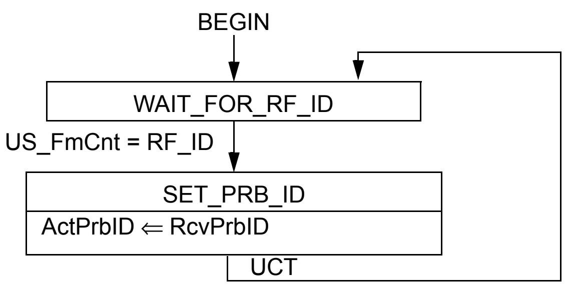


Figure 102–29—PrbID update state diagram

102.4.3 Link-up declaration

Before declaring a CNU is in the link-up state the CLT shall ensure that a CNU joining the EPoC network is properly aligned to the upstream OFDMA timing and is cognizant of all necessary provisioning parameters needed to properly operate in the OFDMA network without adverse impact to the EPoC network or other services operating in RF spectrum unused by the EPoC network. A list of required parameters is given in Table 102–13.

Once the CLT has verified the CNU is in the link-up status by reading the variables listed in the Link-Up column of Table 102–13 it shall set the *LinkUpRdy* variable to TRUE. Once the CLT has verified the CNU is in the link-up status by reading the *PD_Enable* variable as TRUE it may set the *AssgndCNU_ID* to TRUE to notify the upper layers that the associated CNU_ID has been assigned and a device has been added to the network (see 102.4.1.9.2).

There may exist situations when the CLT requires that a CNU go through the PHY Discovery sequence again. Similarly, there may be situations where a CNU needs to inform the CLT of its desire to leave the EPoC network. The CNU can then go through the PHY Discovery sequence again.

Table 102–13—Required variables for PHY Discovery Response and Link-Up

Variable/Variable Group	Reset on change[a]	Required for[b]	
		PHY Discovery	Link-Up
LinkUpRdy	N		T
PD_Enable	N	T	T
PhyDiscCmplt	N		T
DS_ChCnt	Y		Y
DS_TmIntrlv	Y		Y
DSNrp	Y		Y
DSNcp	Y		Y
DS_FreqCh(1) through *DS_FreqCh(5)* [a]	Y		Y
Rnd	N	Y	Y
RBsize	Y	Y	Y
USNrp	Y	Y	Y
USNcp	Y	Y	Y
US_FreqCh1	Y	Y	Y
Type2_Repeat	N		Y
Type2_Start	N		Y
Type1_Repeat	N		Y
Type1_Start	N		Y
DS_PhyLinkStrt	Y	Y	Y

Table 102–13—Required variables for PHY Discovery Response and Link-Up *(continued)*

Variable/Variable Group	Reset on change[a]	Required for[b]	
		PHY Discovery	Link-Up
US_PhyLinkStrt	Y	Y	Y
AllwdCNU_ID [c]	Y		Y
PhyTimingOffset	N		Y
PhyPowerOffset	N		Y
PhyRngOffset	Y	Y	Y
DS_DataRate	N	Y	Y
US_DataRate	N	Y	Y
DS_ModAbility	N/A		Y
US_ModAbility	N/A		Y
DS_OFDM_ChAbility	N/A		Y
DS_OFDM_ID [d]	N		Y
PdRespInitPwr	N	Y	Y
PdRespPwrStep	N	Y	Y
DS_ModTypeSC(4) through *DS_ModTypeSC(4095)* [c]	N		Y
US_ModTypeSC(0) through *US_ModTypeSC(4095)*	N	Y	Y
EQ_CoefR(0) through *EQ_CoefR(4095)*	N		Y
EQ_CoefI(0) through EQ_*CoefI(4095)*	N		Y
OFDMA_ClkSync	Y [e]	T	T

[a]Y = a network reset is required before changing this variable, N = this variable can be changed without a network reset, N/A = not applicable.
[b]T = variable is TRUE, Y = variable has been written in the CNU via the PHY Link.
[c]*AllwdCNU_ID* is set using the CNU_ID Allocation special instruction (see 102.4.1.6).
[d]The downstream OFDM descriptor is written for each OFDM channel that contains active subcarriers.
[e]See Table 102–14.

In some instances the CNU may fail to achieve link-up status. This may happen for a number of reasons; for example the CNU may be unable to support the downstream or upstream Profile due to network conditions. In these circumstances the CLT may take mitigating action outside the scope of this standard and attempt to bring up the CNU at a later time.

102.4.4 Link-down declaration

There are three ways to declare a CNU in the Link-down state—CNU PHY self declared, CLT declared, CNU Upper layer declared. These are described in 102.4.4.1 through 102.4.4.3.